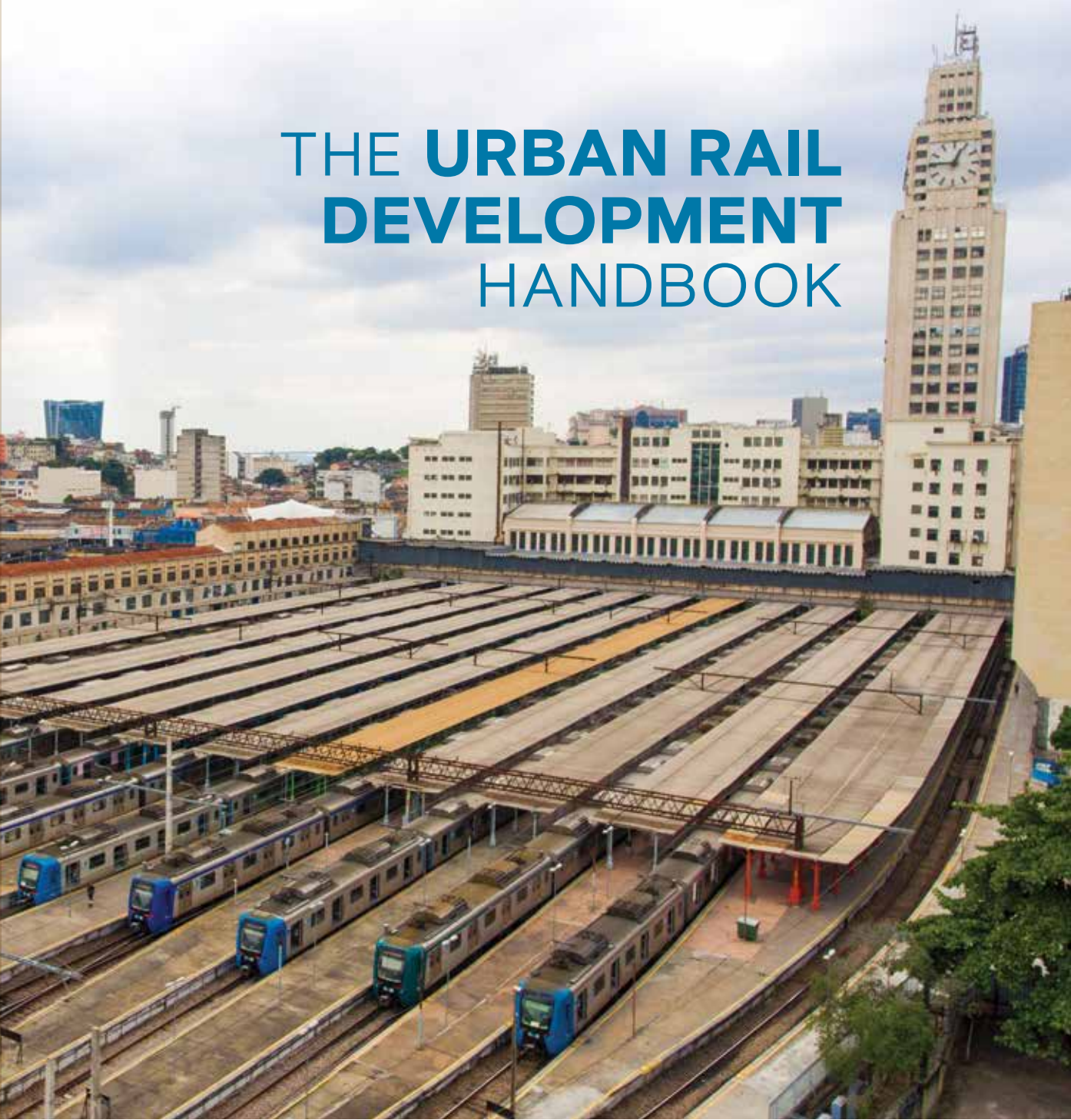


# THE URBAN RAIL DEVELOPMENT HANDBOOK



**Daniel Pulido**  
**Georges Darido**  
**Ramon Munoz-Raskin**  
**Joanna Moody**  
Editors



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Daniel Pulido  
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## FOREWORD

Urban transport is an important part of the World Bank Group’s investment, knowledge, and advisory portfolio. Economically, transport is the lifeblood of metropolitan regions, which represent large and increasing sources of economic growth in both high-income and low- and middle-income countries. Socially, urban transport provides access to jobs, health care, education, and social services that are essential to the welfare of all. Urban transport can contribute to poverty reduction, shared prosperity,<sup>1</sup> and social inclusion both through its impact on a city’s economy, and hence on economic growth, and through its direct impact on the daily needs of all (Gwilliam 2002). As high-capacity, high-speed modes of passenger public transport in urban areas, rapid transit systems on exclusive rights-of-way—including urban rail transit (metros and commuter rail), light rail transit, and bus rapid transit (BRT)—are critical for urban transport strategies. They need to be approached as an element of an integrated public transport network that is aligned with the city’s housing, land use, and economic development vision and objectives.

The World Bank Group has extensive experience supporting urban transport policies and planning, as well as financing project implementation in metropolitan regions around the world. This experience includes rapid transit projects, such as urban rail and BRT.<sup>2</sup> The World Bank Group is therefore positioned to provide a unique, mode-agnostic, independent, and honest perspective on what elements are needed to determine the right modal solution for a given city (which may or may not include urban rail). If a city decides that urban rail is the most appropriate mode for satisfying the mobility and accessibility needs of a given corridor,

then the World Bank Group can help the city to maximize the many long-term benefits of such a project. Urban rail projects may influence generations of city dwellers and have a large opportunity cost in terms of human and budgetary resources. As the number, variety, and complexity of urban rail projects are on the rise, it is relevant to understand how to approach the development of these projects to attain the greatest return on investment possible from social, environmental, and economic perspectives. Urban rail projects have the potential to reduce poverty and contribute to shared prosperity, but, if poorly planned or implemented, they could be regressive and have negative impacts. This *Urban Rail Development Handbook* shares lessons learned from globally selected past and ongoing projects (within and beyond the World Bank Group portfolio) and provides policy makers with practical recommendations to improve implementation in every step of the project development process and to obtain the most value from urban rail investments throughout their life.

### **The World Bank Group's Experience with Urban Rail**

The World Bank Group's experience with urban rail dates to the early stages of its lending to cities, during which time projects, such as those in Tunis (1973), Seoul (1975–80), Porto Alegre (1980), and Buenos Aires (1997), focused on the rehabilitation or extension of existing urban rail systems and the procurement of rolling stock. In the 1990s, projects in Bangkok (1990–95), Rio de Janeiro (1993), Busan (1994), Belo Horizonte (1995), Recife (1995), and others extended World Bank Group involvement to include financing and advisory consulting for institutional restructuring, project evaluation, and implementation of new urban rail lines (Mitrić 1997).

In the past decade, each of the institutions that make up the World Bank Group have continued to grow and diversify their involvement in urban rail projects (see maps F.1 and F.2). For example, the International Bank for Reconstruction and Development (IBRD) and the International Development Association have provided advisory or financial support for projects in cities throughout China (Kunming, Nanchang, and Zhengzhou), India (Mumbai), and Latin America (Bogotá, Colombia; Lima, Peru; Quito, Ecuador; Rio de Janeiro, Salvador, and São Paulo, Brazil; and Santiago, Chile). Within these projects, IBRD has offered advisory support throughout project development, as well as financing for preliminary studies, civil works, equipment, or rolling stock. Additionally, the International Finance Corporation (IFC) has helped to structure, finance, and mobilize private sector financing for urban rail projects in India (Chennai), the Philippines (Manila), and Turkey (Istanbul and Izmir). The Multilateral Investment



## MAP F.1. The World Bank Group's Experience with Urban Rail Projects in Latin America and the Caribbean, 2007–17



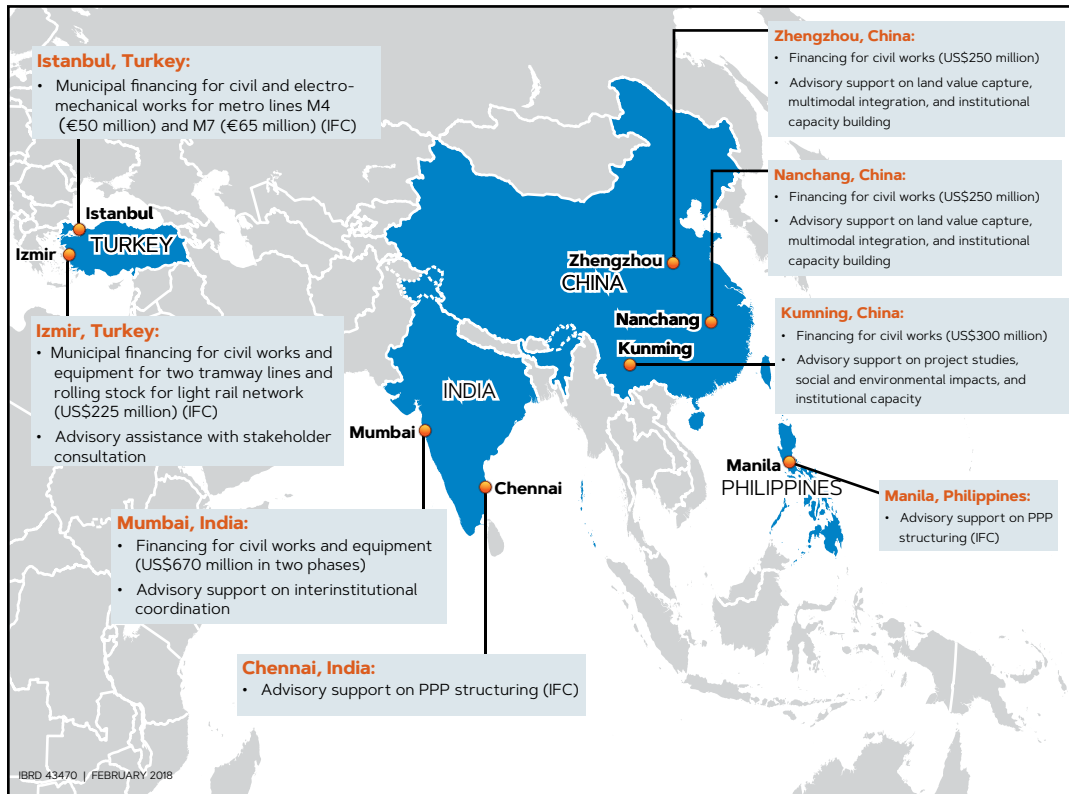
Note: MIGA = Multilateral Investment Guarantee Agency.

Guarantee Agency (MIGA) also has provided Non-Honoring of Sovereign Financial Obligations (NHSFO) guarantees for Panama City Metro's Line 1 and for urban rail projects in Istanbul and Izmir. The knowledge gained from these projects is synthesized in this handbook to inform decision makers considering urban rail development.

### The Role of the World Bank Group in Supporting Urban Rail

The World Bank Group is one of the world's largest sources of funding and knowledge for low- and middle-income countries. The rationale for Bank

## MAP F.2. The World Bank Group's Experience with Urban Rail Projects in Eastern Europe and Asia, 2007–17



Note: IFC = International Finance Corporation; PPP = public-private partnership.

involvement in urban rail projects is threefold: (1) technical, (2) financial, and (3) institutional. These roles complement one another, with most projects receiving advisory support on all three dimensions. This holistic perspective and experience of the World Bank Group are among the greatest assets that it brings to its partner governments.

### Technical Aspects

The World Bank Group can provide technical support for urban rail and other rapid transit projects throughout the project development process, from alternatives analysis and project evaluation through long-term operations. The planning and design of urban rail projects can be intensely political and can face technical difficulties due to the presence of pervasive externalities.

Financing, procuring, constructing, and operating such projects can be even more difficult given the relatively weak institutions and creditworthiness of most urban governments in low- and middle-income countries.

The World Bank Group can provide technical support for initiatives to improve existing urban rail systems or to develop new ones—such as how to integrate land use and transportation planning; how to plan, design, and procure the appropriate transit solution; how to assess and mitigate the many social and environmental, health, and safety impacts of urban rail projects; how to improve equity of access; how to improve operational efficiency, safety, and resilience; and how to conduct stakeholder consultations. This technical support can improve the quality, cost efficiency, effectiveness, and sustainability of these megaprojects. It also can help to achieve value for money and to deliver the expected economic benefits to society. The knowledge gained from these projects is synthesized in this handbook to inform new investments in urban rail development.

### **Financial Aspects**

The World Bank Group's financial involvement can include the provision of financing and guarantees, the mobilization of financing from others through syndication, and cofinancing arrangements. It also can include IFC advisory assistance for project structuring (including public-private partnership arrangements) and delivery processes to ensure bankability, risk-reward balance, and sustainability of these massive investments. The World Bank Group—particularly the IFC—can provide advisory assistance in evaluating whether or not to involve private participation in an urban rail project, how to incentivize interest from the private sector, and how to structure contracts with private partners. Through such advisory assistance, the World Bank Group can help to build the administrative capacity for internal staff to begin to structure and manage private participation projects on their own.

The use of public-private partnerships for new urban rail projects in the developing world is on the rise, but these experiences have had mixed results. These joint ventures come in a variety of forms, often combining the involvement of commercial banks, equipment manufacturers, operators, and local government contributions and guarantees. In the past five years, public-private partnerships totaling US\$30 billion have been established to construct a total of 283 kilometers of rail in five cities: Beijing, Hangzhou, Hyderabad, Lima, and São Paulo. The total rail length is nearly triple that of such projects in the preceding five years, and the average length per project, 40 kilometers, is nearly double, often involving extensive underground construction.

### **Institutional Aspects**

The World Bank Group can provide institutional advice to help partner governments to use these complex, multistakeholder projects as a catalyst for the development and adoption of sustainable transport strategies and urban land use policies. The World Bank Group can help partner governments to consider the governance structures, regulatory frameworks, specific enabling legislation, and other institutional reforms necessary to develop and implement urban rail projects that work for the metropolitan region and all of its inhabitants. It can also help to build internal capacity within existing or newly structured institutions and help nascent institutions to bring in the right external expertise to develop urban rail projects.

The best urban rail projects form an essential part of a broader integrated urban transportation strategy that is designed to meet the diverse accessibility needs of different users through a program of integrated and multimodal interventions. Only when implemented as part of such an integrated urban mobility strategy can urban rail projects yield their greatest benefit to their host city. As large-scale megaprojects with wide-ranging impacts, urban rail developments call for a strategic approach involving both policy and investment in infrastructure and equipment. Therefore, when viewed as development projects, urban rail systems provide an opportunity to catalyze institutional reform and policy changes to support broader urban development goals. The World Bank Group can help partner governments to catalyze broader policy agendas of sustainable economic growth and improved accessibility through the development of a holistic urban rail project.

**José Luis Irigoyen**

*Senior Director, Transport and Digital Development  
Global Practice, World Bank*

**Franz R. Drees-Gross**

*Director, Transport and Digital Development  
Global Practice, World Bank*

### **Notes**

1. In 2013, the World Bank Group adopted two new goals to guide its work: ending extreme poverty and boosting shared prosperity. More specifically, the goals are to reduce extreme poverty in the world to less than 3 percent by 2030 and to foster income growth of the bottom 40 percent of the population in each country (World Bank Group 2015).
2. The World Bank Group has supported BRT projects in cities in China, Colombia (including Bogotá), India, Mexico, Peru (Lima), Tanzania (Dar es Salaam), and Vietnam, among others.

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## ABOUT THE EDITORS AND AUTHORS

### About the Editors

**Daniel Pulido** is a senior infrastructure specialist at the World Bank. In this role, he has led the preparation and implementation of lending and advisory engagements focused on promoting private participation in urban mobility and logistics, primarily in Eastern Europe and Latin America. He has published research on public-private partnerships in transport and sustainable urban mobility. In 2018, he was selected to be part of the first cohort of the World Bank Presidential Fellows Program, an institutional initiative aimed at promoting innovative approaches to leveraging private sector solutions for sustainable development. Prior to joining the World Bank, he worked at Goldman Sachs and at European banks Dexia and Depfa, specializing in the financing of transport and energy infrastructure. His experience includes transaction structuring, financial analysis, and credit evaluation for public-private partnerships and project and municipal financings. He has also worked in transportation policy and development issues as part of previous positions at the World Bank and the Inter-American Development Bank. He is a graduate of the University of Pennsylvania, where he obtained a master's degree in business administration from the Wharton School and a master's degree in international studies from the School of Arts and Sciences. Daniel also holds a master's degree in economics from the American University in Washington, DC.

**Georges Darido** is a lead urban transport specialist for the World Bank, based in Washington, DC. He has more than 16 years of experience as a practitioner and team leader of urban mobility plans, public transport projects, and transport investments in several countries in Asia, Europe, Latin America, and North America. He has also led technical assistance and advisory activities for the public sector in transport planning and policy, sector reforms, and public-private partnerships. Prior to joining the World Bank in 2007, he was a management consultant for Booz Allen Hamilton, a senior research associate for the Center for Urban Transport Research at the University of South Florida, and a traffic engineer. He holds a master's degree in transportation systems from the Massachusetts Institute of Technology, a master's degree in economics and management from Scuola Enrico Mattei (Italy), and a bachelor's degree in civil engineering from University of Central Florida. He is a licensed professional engineer in the United States.

**Ramon Munoz-Raskin** is a senior transport specialist with the World Bank. He works with local and national governments leading transport reforms. He leads activities in the urban transport sector, including support for national urban transport programs, mass transit, urban mobility planning, and nonmotorized transport programs. He also leads work in the roads and intercity-freight rail sectors. Prior to joining the World Bank, he worked in the Americas and Europe, holding positions with the Inter-American Development Bank, the U.S. Department of Transportation (USDOT), academia, the private sector (construction and consulting), and the World Resources Institute. At the USDOT, he was a team leader for the Federal Transit Administration's New Starts program, which provides funding and technical assistance to urban mass transit projects, and later a regional manager for the Federal Railroad Administration's High Speed and Intercity Passenger Rail program. He has authored multiple peer-reviewed journal publications and blogs on transport planning, policy, and economics. He is a member of the Transportation Research Board's Committee for Transportation in the Developing Countries and a founder of the Lee Schipper Memorial Scholarship for Sustainable Transport and Energy Efficiency.

**Joanna Moody** is a consultant at the World Bank and a PhD candidate in transportation at the Massachusetts Institute of Technology, where she manages two research projects as part of the Energy Initiative Mobility of the Future consortium. Her doctoral research measures social status bias (car pride and bus shame) and how it relates to travel behavior and transportation planning. This research was awarded the Lee Schipper Memorial Scholarship in 2017. While completing her master's degree in transportation, she served as the senior

research assistant for a three-year research program with East Japan Railway Company that focused on understanding high-speed rail projects as sociotechnical systems. Her master's thesis was awarded the Council for University Transportation Centers' Charley V. Wootan Memorial Award for outstanding master's thesis in planning and policy in 2016. She also received a University Transportation Center Fellowship in 2014 and Eisenhower Graduate Fellowships in 2015 and 2016 from the U.S. Department of Transportation. She is a member of the Transportation Research Board's Committee for Transportation in the Developing Countries.

### About the Authors

**Edward R. Fleischman** is an engineering consultant providing oversight of major mass transport investments. He previously worked for 38 years at the U.S. Department of Transportation for the Federal Transit Administration and the Federal Highway Administration.

**Sofía Guerrero Gámez** is a senior transport specialist at the World Bank based in the country office in Lima, Peru. She has extensive experience in underground construction of transport megaprojects, including work on Madrid Metro Line 8, the M-30 ring road in Madrid, and Crossrail in London. She holds a master's degree in civil engineering and an MBA from the Instituto de Empresa.

**Wenyu Jia** is a senior urban transport specialist with the World Bank and chair of the Rail Transit Systems Committee with the Transportation Research Board. Prior to the World Bank, she was a planning manager at the Washington Metropolitan Area Transit Authority. She received a dual master's degree in transportation engineering and city planning from the University of California, Berkeley.

**(Xavier) Cleddan Mandri-Perrott** is head of Infrastructure Finance and Public-Private Partnerships at the World Bank in Singapore. He has experience in developing and implementing infrastructure project finance transactions valued cumulatively at more than US\$3 billion. Prior to joining the World Bank Group, he acted as transaction adviser to infrastructure projects, advising both governments and private clients. A graduate in civil engineering with honors, he also holds an MS in finance and an LLM in commercial and transaction law from the University of Dundee and a PhD in project finance from the University of Groningen.

**Slobodan Mitrić** was an urban transport specialist working as a consultant to the World Bank, where he had spent 25 years in active service prior to retiring in 2003. He held a diploma from the University of Belgrade, Serbia, as well as a master's degree and a doctorate from the University of California, Berkeley, all in transport engineering.

**Robert H. Montgomery** is a lead environmental specialist at the World Bank. He specializes in sustainable (environmental, social, health and safety, and labor aspects) risk management and opportunity development for public and private sector entities and financial institutions in a broad range of sectors—across 35 countries in Africa, Europe, the Middle East, and North and South America.

**Carlos T. Pérez-Brito** is a senior social development specialist at the World Bank with emphasis on social inclusion and sustainable infrastructure. Prior to the World Bank, he was a social specialist at the Inter-American Development Bank in Washington, DC, the U.S. Agency for International Development in Guatemala, and the United Nations Economic Commission for Latin America and the Caribbean in Mexico City. He holds a master's degree in Latin American studies, international development, and technology transfer from Tulane University.

**Ramiro Alberto Ríos** is a principal transport planner for the city of Alexandria, Virginia. He holds a master's degree in urban planning from the University of California, Los Angeles. He has worked in the development of urban transport projects in Latin America, the United States, and other countries around the world.

**Felipe Targa** is a senior urban transport specialist at the World Bank. Recently, he was Colombia's deputy transport minister and director of the university-based CityLab. An advocate of urban cycling, place making, and human-scale cities, he holds a master's degree in city and regional planning and advanced to PhD candidacy in transport systems.

**Jean Paul Vélez** is a senior transportation planner with King County Metro, Seattle, Washington, where he leads the agency's innovative mobility efforts. Previously, he worked at the World Bank on public transportation, urban development, and smart city initiatives. He holds master's degrees in city planning and international development from the University of California, Berkeley.

## ABBREVIATIONS

AC	alternating current
ATO	automatic train operation
ATP	automatic train protection
BART	Bay Area Rapid Transit
B/C	benefit-cost ratio
BCA	benefit-cost analysis
BNDES	Brazilian Development Bank
BIM	Building Information Modeling
BRT	bus rapid transit
BTS	Bangkok Mass Transit System
CAD	computer-aided design
CaDD	Climate Capacity Diagnosis and Development
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
CBTC	communications-based train control
CEPAC	certificate of additional construction potential
CMR	construction manager at risk
COFIDES	Spanish Development Finance Institution
CPI	consumer price index
CRRC	China Railway Rolling Stock Corporation
CTA	Chicago Transit Authority
DART	Dallas Area Rapid Transit
DB	design-build

DBB	design-bid-build
DBF	design-build-finance
DBFM	design-build-finance-maintain
DBFOM	design-build-finance-operate-maintain
DBOM	design-build-operate-maintain
DC	direct current
DFI	development finance institution
EBRD	European Bank for Reconstruction and Development
ECA	export credit agency
EHS	environment, health, and safety
EHSMS	environment, health, and safety management system
EIRR	economic internal rate of return
EIA	environmental impact assessment
EOT	equip-operate-transfer
EPB	earth pressure balance
EMU	electric multiple unit
EPC	engineering, procurement, and construction
EPCM	engineering, procurement, construction, and maintenance
ESIA	environmental and social impact assessment
ESMP	environmental and social management plan
ESMS	environmental and social management system
ESU	economic social unit
FAR	floor area ratio
FIDIC	International Federation of Consulting Engineers
FIRR	financial internal rate of return
FOB	foot-over-bridge
FTA	Federal Transit Administration
GBR	geotechnical baseline report
GDP	gross domestic product
GHG	greenhouse gas
GIS	geographic information system
GMP	guaranteed maximum price
GoA	grade of automation
GPS	Global Positioning System
GTFS	General Transit Feed Specification
HITS	hierarchically integrated transit system
HSU	household social unit
IBRD	International Bank for Reconstruction and Development
IFC	International Finance Corporation

ITDP	Institute for Transportation and Development Policy
INVEST	Infrastructure Voluntary Evaluation Sustainability Tool
ISO	International Organization for Standardization
KPESIC	Knowledge Platform on Environmentally Sustainable Infrastructure Construction
KPI	key performance indicator
LEED	Leadership in Energy and Environmental Design
LRT	light rail transit
LVC	land value capture
MAX	Metropolitan Area Express
MBTA	Massachusetts Bay Transportation Authority
MCA	multicriteria analysis
MDB	multilateral development bank
MIGA	Multilateral Investment Guarantee Agency
M/LRT	mass/light rail transit
MTA	Metropolitan Transportation Authority
MTRC	Mass Transit Railway Corporation
MWAA	Metropolitan Washington Airports Authority
NATM	New Austrian Tunneling Method
NHSFO	Non-Honoring of Sovereign Financial Obligations
NPV	net present value
OECD	Organisation for Economic Co-operation and Development
O&M	operation and maintenance
PATH	New York/New Jersey Port Authority Trans-Hudson
PED	platform edge protection
PIU	project implementation unit
PMOC	project management oversight consultant
PPP	public-private partnership
PPSD	Project Procurement Strategy for Development
PSD	platform screen door
PSHA	probabilistic seismic hazard assessment
PSIA	Poverty and Social Impact Assessment
QA	quality assurance
QC	quality control
RFF	Réseau Ferré de France
RFP	request for proposals
RFQ	request for qualifications
ROA	real options analysis
RPI-CAO	<i>retribución por inversiones-certificado de avances de obras</i>

RSSB	Rail Safety and Standards Board
SIA	social impact assessment
SNCF	National Society of French Railways
SPT	Strathclyde Partnership for Transport
TAD	transit-adjacent development
TBM	tunnel boring machine
TCMS	Train Control and Monitoring System
TIFIA	Transportation Infrastructure Finance and Innovation Act
TOD	transit-oriented development
TOEI	Tokyo Metropolitan Bureau of Transportation
TRaCCA	Tomorrow's Railway and Climate Change Adaptation
TUCA	Tunneling and Underground Construction Academy
UITP	International Association of Public Transport
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UTO	unattended train operation
V/C	volume-to-capacity
VE	value engineering
VfM	value for money
VGF	viability gap funding
WMATA	Washington Metropolitan Area Transit Authority







# 1

## INTRODUCTION

Joanna Moody, Georges Darido, Ramon Munoz-Raskin,  
and Daniel Pulido

As metropolitan regions in both high- and low- and middle-income countries continue to urbanize and motorize, governments are considering ways to expand public transport networks to fulfill the mobility and accessibility needs of their growing populations (World Bank 2002). Many of these cities have high-activity corridors that demand a combination of passenger volume and service quality that may be most sustainably served by urban rail systems with dedicated infrastructure. Thus, many cities around the world are considering metros (subways) and commuter rail systems—which we collectively refer to as urban rail systems—as important parts of their integrated public transport system.

Urban rail systems combine an exclusive travel way and a rail-based vehicle technology to provide scheduled services along a sequence of stations. Compared with other modes of urban public transport—those where road- or rail-based vehicles operate in mixed traffic or enjoy varying degrees of segregation from other traffic streams—urban rail systems can feature substantially higher and sustained levels of passenger-carrying capacity, travel speed, punctuality, reliability, comfort, and other quality of service factors. By extending the

*Photo: Metro Luz Lotado, Lima, Peru. Source: Georges Darido, World Bank.*

geographic area that commuters can reach in a given period of time, these projects can provide high levels of accessibility in the corridors and zones served, which, in turn, contribute to various economic activities (Mitrić 1997, 2008). Thus, when carefully implemented urban rail can expand the long-term capacity of urban transport networks, improving mobility and accessibility for city residents and bringing economic development. Due to their potential to drive the long-term economic and spatial development of cities, urban rail projects appear on the investment agenda of most large cities in low- and middle-income countries.

Although urban rail projects can bring high rewards, if poorly planned or implemented they also can have wide-ranging negative impacts. They are megaprojects with important challenges in and interdependencies among the technical, institutional, financial, environmental, and social dimensions. They are capital-intensive and often high-risk projects. They tend to attract significant funding and some of the most qualified human capital. Thus urban rail projects can have important opportunity costs for a city or country. If poorly planned, designed, and executed, they can cost more, take longer to deliver, and attract fewer riders than originally planned. Such capital or operating cost overruns can significantly impact city government budgets and constrain spending on other necessary services. Therefore, urban rail projects must be considered and managed carefully throughout the project development process to maximize benefits and mitigate any potential negative impacts. Each urban rail project is unique to its local context, yet many developing cities have little or no experience in planning and implementing these complex projects.

Rail is only one of many modes of rapid transit, some of which, including high-capacity bus rapid transit (BRT), can provide similar levels of service to that of rail in certain contexts. This *Urban Rail Development Handbook* does not advocate the use of one rapid transit technology over another; such a decision should only be the result of proper alternative analysis that accounts for the needs and context of the specific metropolitan region. Although many of the conclusions are applicable to all modes of rapid transit, the handbook focuses on the key policy actions and considerations that decision makers should take into account when developing urban rail projects. For decision makers in cities considering urban rail projects, this handbook provides high-level guidance on the development of urban rail projects from planning through long-term operations. Even for decision makers who already have significant knowledge and experience with urban rail projects, the handbook may offer new points of view and synthesize good practice that connects their local experience to that of other projects around the world.

## Objectives

Cities across the globe are looking to improve transportation in response to the accessibility needs of ever-expanding urban and metropolitan populations. Planners have to find affordable, environmentally friendly, and socially responsible transportation solutions that can meet the accessibility needs of urban residents and support future economic development in urban areas. When appropriately planned and properly implemented as part of a larger public transport network, urban rail systems can provide rapid urban mobility and vital access to city centers from surrounding districts. Improved transportation enhances quality of life by giving citizens access to employment opportunities, essential services, urban amenities, and neighboring communities. High-performing urban rail services can help to reduce both traffic congestion and vehicular emissions. They also have the potential to drive local investment and the development of more walkable and livable communities when supported by enabling land use and development policies. Therefore, urban rail projects should be seen not only as infrastructure projects, but also as key opportunities for broader urban development.

This handbook synthesizes and disseminates knowledge to inform the planning, implementation, and operations of urban rail projects with a view toward

- Emphasizing the need for early studies and project planning
- Making projects more sustainable (economically, socially, and environmentally)
- Improving socioeconomic returns and access to opportunities for users
- Maximizing the value of private participation, where appropriate
- Building capacity within the institutions that implement and manage public projects.

Similar guidance documents exist for passenger rapid transit in general (Vuchic 2005, 2007; Vuchic and Casello 2007) and for BRT (ITDP 2017) and light rail transit (Mandri-Perrott and Menzies 2010), in particular. However, to the authors' knowledge, no such guidance exists specifically for urban rail systems. This handbook seeks to fill this knowledge gap in a practical way by providing experiential advice for tackling the technical, institutional, and financial challenges facing government officials and decision makers in project-implementing agencies when embarking on a new urban rail project. While many of the recommendations and guidance included in this handbook may apply to various forms of urban passenger rapid transit (including bus-based and rail-based modes),

the discussion and case studies presented are targeted specifically at metro or commuter rail solutions.

This handbook brings together the expertise of World Bank staff as well as the input of numerous international specialists and experts to synthesize international “good practices.” As a knowledge product, the content of the handbook is independent of any and all private or political interests. While the handbook references case studies, policies, and practices from different cities and regions, the processes and recommendations laid out are meant to be universally informative.

Rather than identify a single approach, this handbook acknowledges the complexities and localization necessary when approaching an urban rail project by helping to prepare decision makers to ask the right questions, consider the key issues, perform the necessary studies, apply adequate tools, and learn from international good practice all at the right time in the project development process. This approach provides information that can be used to make informed decisions adapted to local contexts, policies, and objectives. In this way, the material presented is intended as a practical, honest-broker guide to developing urban rail systems in cities both in high-income and in low- and middle-income countries. While much of the discussion focuses on the implementation of new infrastructure, there is also considerable value for decision makers managing or upgrading existing urban rail systems.

## Structure

This handbook walks project decision makers through each step of the project development process (see box 1.1), highlighting the key risk-reward decisions at each step and the techniques available (and resources required) to answer them. Other chapters highlight key themes and present tools that are applicable throughout the project development process. How individual readers might use this handbook depends on where they are in the decision-making and project development process. To guide different types of readers to the chapters that are most useful for their current circumstances, this section provides a road map of the handbook, introducing the content of each chapter. Along with the index and table of contents, this road map is a key tool for navigating the contents of this handbook.

This introduction provides readers with the objectives and value of the handbook and lays out key considerations that are essential for maximizing the benefits of any urban rail project. The rest of the chapters discuss specific steps in the project development process or key topics and analyses that apply across many steps of the project. Each chapter distills good practice and provides

**BOX 1.1.****Defining the Project Development Process for Urban Rail Projects**

In managing and implementing any large transportation infrastructure project, particularly an urban rail project, it is important to understand how the project evolves from planning through implementation to start-up and operations. Table B1.1.1 defines critical steps of the project development process as they are used throughout the chapters of this handbook. While some of the steps are necessarily sequential, others

**TABLE B1.1.1. Steps in the Project Development Process and Their Main Activities**

STEP	MAIN ACTIVITIES
System planning	<ul style="list-style-type: none"> <li>• Conduct diagnostic studies of urban mobility and land use</li> <li>• Develop an integrated urban mobility strategy</li> <li>• Identify priority corridors and define the needs and requirements of individual projects based on the long-term vision of the metropolitan region and its development</li> </ul>
Corridor planning	<p><i>Generate investment alternatives</i></p> <ul style="list-style-type: none"> <li>• Identify possible solutions in response to the needs of the corridor, scope of the investments, and any other constraints</li> <li>• Confirm that these alternatives can be economically and sustainably delivered and are aligned with the integrated urban mobility strategy</li> </ul> <p><i>Analyze investment alternatives and select a preferred alternative</i></p> <ul style="list-style-type: none"> <li>• Assess and select the most appropriate and cost-effective investment alternative that delivers on the interests of diverse stakeholders</li> <li>• Conduct high-level environmental and social analysis</li> <li>• Decide whether or not to pursue an urban rail project as the preferred alternative</li> </ul>
Preliminary design	<p><i>Initiate development of the urban rail project (preliminary design)</i></p> <ul style="list-style-type: none"> <li>• Put in place the systems to manage the project budget, schedule, and staffing</li> <li>• Undertake surveys to reduce or eliminate major project uncertainties through extensive geotechnical and site investigations, development of land acquisition plans, and development of utility diversion and protection plans</li> <li>• Assess the social, environmental, health, and safety impacts and risks related to the project and develop systems and plans for their management and mitigation</li> <li>• Identify and analyze options for project procurement and delivery, including contract packaging and pricing</li> <li>• Select the preferred option</li> </ul>

*(table continues next page)**(box continues next page)*

**BOX 1.1.****Defining the Project Development Process for Urban Rail Projects***(Continued)***TABLE B1.1.1. Steps in the Project Development Process and Their Main Activities** *(Continued)*

STEP	MAIN ACTIVITIES
Detailed design	<ul style="list-style-type: none"> <li>• Produce a design that underpins tender-ready cost, time, resource, and risk estimates commensurate with the chosen method of project delivery</li> <li>• Conduct additional studies of project integration with urban development and other transportation modes at the detailed (station) level</li> <li>• Receive all necessary permitting and approvals for awarding a contract and for initiating construction, including final designs, land titles, and utility relocation plans</li> </ul>
Procurement and financing	<ul style="list-style-type: none"> <li>• Arrange for financing (may be part of the delivery method in public-private partnership schemes)</li> <li>• Implement the project delivery method, contract pricing mechanism, procurement method, and bidding procedures for the project</li> <li>• Select the highest ranked project proposal(s) and award the contract(s)</li> <li>• Meet conditions for financial close</li> </ul>
Construction	<p><i>Build infrastructure</i></p> <ul style="list-style-type: none"> <li>• Manage all contracts for civil and electromechanical works and rolling stock</li> <li>• Oversee construction of the urban rail system to the specifications of the design and in accordance with project budget and schedule</li> </ul> <p><i>Conduct testing and preoperations</i></p> <ul style="list-style-type: none"> <li>• Test the system to ensure operations in accordance with design</li> <li>• If applicable, transfer asset responsibility from the project team to the operator</li> <li>• Set up any contingencies or warranties at start of defect liability period</li> </ul>
Operation and maintenance	<p><i>Operate the urban rail system</i></p> <ul style="list-style-type: none"> <li>• Conduct service planning and provide service that is safe, reliable, and meets the needs of users</li> <li>• Maintain the assets to support the longevity of the system</li> </ul> <p><i>Project closeout (at end of defect liability period, usually two to three years after start of operations)</i></p> <ul style="list-style-type: none"> <li>• Settle contractual accounts</li> <li>• Formally close the project and its support systems</li> </ul>

may be initiated in parallel (for example, financing and procurement). Some of these definitions may vary from those used in other sources, so this box serves as an important reference when digesting and sequencing the recommendations set out in

the chapters of this handbook. Readers should be aware of the complexities entailed and cognizant of local procedure regarding project planning and investment so as to properly contextualize the steps and activities discussed in this handbook.



examples from real-world projects. Each chapter concludes with a section that synthesizes key recommendations, providing a quick-reference guide for the fundamental issues that decision makers should consider in each step of project development and for each key theme.

The handbook is designed around the critical, high-level questions that decision makers should be asking throughout the project development process. While the chapters introduce important processes, approaches, techniques, and analyses that can support these questions, the handbook does not include significant technical detail on any one topic. Chapter references provide resources that can be consulted for additional technical details.

The chapters and their general content are as follows:

- *Chapter 2, Urban Rapid Transit as an Opportunity for Sustainable and Inclusive Development*, lays out the conceptual framework for how to approach urban rail as a development project that can improve the lives of all citizens and contribute to both poverty reduction and greater prosperity for all.
- *Chapter 3, Deciding Whether to Develop an Urban Rail Project*, discusses the steps necessary to decide whether or not to initiate an urban rail project as part of an integrated urban mobility strategy. These steps include diagnostic studies of urban transport and the development of an integrated urban mobility strategy, the generation and analysis of transportation investment alternatives, and the selection of a preferred alternative.
- *Chapter 4, Project Management Planning*, discusses project management planning, emphasizing the importance of proactive and sustained project management from the early stages of project planning through full implementation of the project.
- *Chapter 5, Designing an Urban Rail Project*, discusses many design features and options available for urban rail projects and identifies new trends toward international good practice. This chapter presents the advantages and disadvantages of individual design options, discusses the importance of designing urban rail projects as integrated systems that consider the interrelation of these options, and explains how to estimate project costs based on these design choices.
- *Chapter 6, Project Optimization*, highlights the importance of project optimization as an ongoing process in project development that is carried out by internal project staff complemented by the use of external experts. This chapter discusses the many project optimization tools—such as value analysis,

peer reviews, and value engineering—available for project-implementing agencies and the staffing, management, and other resources required to implement them effectively.

- *Chapter 7, Managing Risks*, outlines the practice of risk management as applied to urban rail projects, including the identification, evaluation, mitigation, and allocation of risks among project stakeholders. It describes the main risks present in urban rail projects, presents practical examples of how those risks have been managed or mitigated, and provides recommendations for effective risk management.
- *Chapter 8, Procuring the Project*, presents the key considerations when determining a project delivery model, contract pricing mechanism, and procurement method for urban rail. This chapter also presents recommendations on how to manage the bidding and selection process. This chapter is complemented by chapter 9, which focuses specifically on one type of potential project delivery models: public-private partnerships (PPPs).
- *Chapter 9, Structuring Public-Private Partnerships*, discusses how PPPs have been used to implement urban rail projects, best practices in involving the private sector, and lessons learned. This chapter also provides guidance on the decisions facing governments when structuring a PPP, including contract scope, risk allocation, definition of payment mechanisms, and performance monitoring.
- *Chapter 10, Maximizing Funding and Financing*, explains the difference between funding and financing, describes where project-implementing agencies can get the funding and financing needed for project development, and discusses the suitability of different financing vehicles. It also lays out useful considerations for making urban rail projects bankable—that is, able to obtain the long-term financing needed for their development—with a focus on the mobilization of private capital.
- *Chapter 11, Preparing for Construction*, highlights the importance of up-front studies, stakeholder management, and communication in preparing for construction of an urban rail project. This chapter outlines the different construction methods for at-grade, elevated, and underground segments of urban rail and discusses their relative advantages and challenges.
- *Chapter 12, Institutional Set-Up and Governance of Urban Rail*, presents trade-offs among different institutional and governance organizational structures for the implementation and operation of urban rail systems. This chapter also discusses the political, legal, jurisdictional, and, above all, financial

support needed to empower the long-term viability of these institutions and the operations of the urban rail system.

- *Chapter 13, Ensuring Operational and Financial Sustainability*, examines good practice for the sustainable operations of an urban rail system, including recommendations for operations service planning and performance monitoring, asset and maintenance management, and fiscal management.
- *Chapter 14, Addressing Social Impacts of Urban Rail Projects*, identifies key short-term (during construction) and long-term social impacts of urban rail projects and provides guidance on how to measure, mitigate, and manage these impacts to bring the greatest benefit (and fewest negative externalities) to all stakeholders and communities affected by the project. The chapter also discusses the importance of proper consultation and communication mechanisms to build support for the project among local communities and other stakeholders.
- *Chapter 15, Environment, Health, and Safety Management*, emphasizes the importance of implementing a comprehensive and adaptive environment, health, and safety management approach that identifies, mitigates, and manages environment, health, and safety impacts throughout the steps of the project development process.
- *Chapter 16, Improving Accessibility and Shaping Urban Form*, discusses the key relationship between urban rail systems and urban form and how to leverage land development to augment the benefits of regional, local, and universal accessibility from urban rail projects. This chapter presents frameworks for identifying opportunities for transit-oriented development and strategies for overcoming barriers to its implementation.
- *Chapter 17, Climate and Natural Hazard Resilience in Urban Rail Projects*, identifies climate and natural hazards and their impact on urban rail projects, discusses how to integrate resilience in transportation planning at a system and project level, and introduces tools for addressing climate and natural hazard resilience throughout the project development process.

### **Value for Readers**

The earlier chapters of this handbook (chapters 2–4) are the most relevant for policy makers who are just starting to consider an investment in a rapid transit system, perhaps including urban rail. These chapters have their greatest value for decision makers who need to perform the studies and planning necessary to

maximize the impact of rapid transit investments (chapter 2), decide whether or not to develop an urban rail project (chapter 3), and figure out how to manage its implementation (chapter 4).

For decision makers who are already planning or designing an urban rail system, later chapters discuss important aspects related to the project's design and optimization (chapters 5 and 6), risk management (chapter 7), procurement (chapters 8 and 9), funding and financing (chapter 10), construction (chapter 11), governance (chapter 12), and operations (chapter 13). Therefore, decision makers at any step of project development may find practical guidance in this handbook for how to improve their project going forward.

Additional chapters discuss how urban rail systems interact with development goals and shared prosperity, social impacts (chapter 14), environment, health, and safety (chapter 15), land use and urban form (chapter 16), and climate and natural hazard resilience (chapter 17). These thematic considerations apply throughout all steps of the project development process and are instrumental in determining the extent to which the urban rail system positively affects its host city. These chapters are must-reads for any decision maker working with urban rail projects, no matter their role or the current stage of the project.

Chapters of the handbook are distinct, but—given the interconnected and complex nature of urban rail projects—the recommendations and understanding from one chapter will reinforce and inform another (cross-referencing is provided where applicable). Readers at any stage of the project development process are encouraged to explore other chapters of the handbook, proactively looking ahead to important decisions that may come next or even looking back on decisions in earlier steps that may continue to affect project implementation.

This handbook summarizes essential information that decision makers and project managers should consider in developing an urban rail project. It is not intended to be an exhaustive review of all topics. Instead, it introduces each of the important steps and themes of project development and points readers to the most relevant detailed resources in each of these areas. The handbook does not cover various technical aspects—such as rail yards and rolling stock—in detail. Readers who wish to go deeper into a particular topic are encouraged to explore the references cited in each chapter and to seek technical advice from World Bank Group staff and other international experts. This handbook empowers decision makers and project managers to ask the right questions and to put in place the appropriate analytical and management tools for implementing an urban rail project. We hope that readers will find this handbook informative and actionable.

## Key Cross-Cutting Messages

Rapid transit systems, such as urban rail, do not exist in isolation; instead, they exist within complex metropolitan environments and are intended to support existing and future economic and social activities within the region. Rapid transit projects are not only about building infrastructure and deploying and operating vehicles. For projects to attain their development goals, deliver beneficial services, and improve the quality of life of the population in a sustainable way, implementing agencies need to accompany urban rail infrastructure with complex and wide-ranging policy reforms and actions.

While every local context is different, international experience suggests that certain policy actions are applicable across different countries and cities and help to maximize the impact of rapid transit investments, including urban rail. These policy actions are key enablers for project success and, therefore, must be considered before thinking about the technical aspects of any specific rapid transit solution. Implementation of these policy actions has implications across all steps of the project development process—project preparation, planning, design, procurement, financing, construction, and operations and maintenance—and requires the mobilization of stakeholders beyond the municipal government or transit agency in charge of a project.

Rapid transit projects done in the absence of these policy essentials will miss important opportunities to achieve greater development impact. Therefore, it is recommended that policy makers consider the following messages up-front and keep them in mind throughout the project development process:

1. Urban rail projects need to be developed as part of a broader urban transportation and land use strategy.
2. Effective metropolitan transport governance and coordination are key.
3. Urban rail projects should be part of a multimodal, hierarchically integrated transit system.
4. Establishing a strong funding policy for the entire transport system that ensures financial sustainability for the long term is fundamental.
5. Projects should be designed for long-term operational sustainability.
6. Urban rail projects should be approached as opportunities for internal capacity building and upskilling.
7. Successful project implementation requires strong champion(s) to drive coordination efforts and to manage both the policy and technical aspects.

8. It is critical to deploy strong communication strategies to address organized opposition, build and sustain support coalitions, and help projects to ride the political cycle.
9. It is very valuable to maintain flexibility in the design process to enable the implementation of solutions that are acceptable in the local context.

Each of these policy essentials is discussed in more detail below, with additional depth and examples provided throughout the handbook.

### **1. Urban rail projects need to be developed as part of a broader urban transportation and land use strategy.**

There is a self-reinforcing interaction between transportation, land use, housing, and economic development planning. Such an interaction requires that long-term visions for city development consider how the distribution of housing and job market densities will evolve and what transport solutions are needed to meet and foster this development. In particular, urban rail infrastructure has to be planned both in response to existing urban form and as a means to transform the long-term transport, economic, and land use patterns along the corridor (Salat and Ollivier 2017).

Urban rail project development should take a proactive approach in pursuing joint (re)development opportunities to unlock the urban rail system's potential to shape the urban form and bring additional value and revenue to the city or the project. Developments beyond the urban rail corridor and stations not only can bring new revenues to the operator, they also are essential for supporting a more economically vibrant, inclusive, and sustainable urban development pattern for local communities and the metropolitan region. An urban rail network is living infrastructure that responds to and proactively shapes city development; so, both urban rail development and land use have to be managed in close coordination, especially in fast-growing megacities.

### **2. Effective metropolitan transport governance and coordination are key.**

As part of broader urban transportation systems, urban rail projects require coordination among different levels (national, regional, and municipal) and ministries of government. Many urban rapid transit projects suffer because there are no clear roles and responsibilities beyond building the new infrastructure or because they are developed in the absence of policy and institutional coordination with the entities in charge of other urban transport modes or urban development (Kumar and Agarwal 2013). The bottom line is that the institutional framework needs to be considered when talking about

an integrated public transport network, and some degree of coordination is needed on issues such as physical, operational, and fare integration with other urban transport modes; overall system funding, fare structure, and revenue allocation; expansion projects; contingency plans; and opportunities for transit-oriented development.

### **3. Urban rail projects should be part of a multimodal, hierarchically integrated transit system.**

Hierarchically integrated transit systems (HITSs) refer to urban transport networks that support high-quality, multimodal service by integrating feeder services into higher-capacity rapid transit modes (Ardila-Gómez 2016). Developing urban rail projects as part of HITSs improves overall capacity, increases accessibility, and generates positive externalities. Full integration is particularly relevant for urban transport systems to become HITSs. Full integration requires the simultaneous achievement of three objectives: (1) physical integration (interconnection between different transport infrastructure); (2) operational integration (multimodal service planning); and (3) fare integration (interoperable fare technology as well as comprehensive fare and subsidy policy across the entire transit system). Having these three dimensions of integration is fundamental for maximizing the benefits of accessibility and ensuring long-term sustainability (Salat and Ollivier 2017; Zimmerman and Fang 2015).

### **4. Establishing a strong funding policy for the entire transport system that ensures financial sustainability for the long term is fundamental.**

Urban rail projects are expensive to build and to run. Farebox revenue is almost always insufficient to cover operating costs, let alone to fund capital expenditures. Therefore, governments looking to develop or expand urban rail systems should examine ways of complementing user revenues with other sources of income that can be used to subsidize transit operations. To become sustainable, urban transport systems require alternative sources of revenue. The capacity and willingness of users and society to commit funds are necessary conditions for mobilizing private sector financing and expertise.

### **5. Projects should be designed for long-term operational sustainability.**

Urban rail systems are long-lived assets that can shape the development of the metropolitan region for generations. The benefits from urban rail projects are diffuse and accrue over the long operational lifetime of the system. Decisions made to save money now can result in higher operational costs and costly capacity upgrades in the future. To maximize the benefits, urban rail systems have to

be developed to support the long-term operational sustainability of the system. Throughout development of the project, it is critical for project planning and project-implementing staff to be fully informed regarding the future operating and maintenance needs of the project and the system.

#### **6. Urban rail projects should be approached as opportunities for internal capacity building and upskilling.**

Adequate and experienced staffing is needed at all steps of project development and implementation. Given the size and complexity of urban rail projects and relative inexperience of most developing cities, urban rail projects may offer an opportunity to build critical internal capacity both within planning and implementing agencies as well as for domestic contractors and suppliers. If internal experience is lacking, outside consultants and partners can undertake certain functions of project development, such as planning, design, or project management. However, third-party expertise should be managed and directed by agency staff who are knowledgeable about the project, aware of its larger context, and dedicated to its success. This agency staff need to have the requisite technical, managerial, leadership, and communication skills to manage all contracts with third parties. Upon completion of their contract or the project step in which they are involved, third-party experts may no longer be available to assist in the resolution of any emerging problems. Therefore, it is important for project-implementing agencies to learn from experts throughout their involvement in the project. This upskilling can even be incorporated into contracts with these entities. Once third parties complete their contracts, internal project staff must take responsibility for the institutional project knowledge and provide the continuity necessary to assist in resolving problems and in carrying knowledge forward to new projects.

#### **7. Successful project implementation requires strong champion(s) to drive coordination efforts and to manage both the policy and technical aspects.**

Experience has shown that the development of a new urban rail system requires dedicated, committed, and effective champions who can access leadership quickly. Government agencies in charge of developing these projects should seek the appointment of a high-level and experienced project manager with the capacity to handle coordination with other government entities at the national and subnational levels. This champion needs to be empowered with the ability to make timely decisions and enough freedom from political interference to ensure agile management and risk mitigation and response. This role is critical for the



success of any project and cannot be outsourced to a consultant, no matter the quality and level of involvement of external advisers.

**8. It is critical to deploy strong communication strategies to address organized opposition, build and sustain support coalitions, and help projects to ride the political cycle.**

The benefits of an urban rail project are dispersed and accrue to large communities. Due to their dispersion and the delay between project implementation and the realization of project benefits, the majority of persons who stand to benefit are unlikely to mobilize to support the project. In contrast, costs or negative impacts fall to a few people who have an immediate incentive to mobilize (and who can mobilize more easily because they are few in number). Even small opposition groups can dominate media coverage and derail even the most carefully prepared project plans. Therefore public information, stakeholder engagement and management, and the building of support coalitions are integral parts of urban rail development. Urban rail projects need to have a well-crafted communication strategy that addresses strategic and tactical needs and is administered by a committed team that can react quickly to the evolving communication needs for the project throughout its development.

**9. It is very valuable to maintain flexibility in the design process to enable the implementation of solutions that are acceptable in the local context.**

Given the highly localized nature of impacts, the project design has to be flexible enough to consider the concerns and needs of local stakeholders, for whom a relatively small change in design (for example, the location of station access points) may make the difference in their decision to oppose or support the project. Minor refinements based on stakeholder input have proven to go a long way in ensuring stakeholder support. Accommodating stakeholder input not only strengthens support for the project, but also attains a more context-sensitive solution with more value and sustainability.

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## Additional Reading

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## 2

# URBAN RAPID TRANSIT AS AN OPPORTUNITY FOR SUSTAINABLE AND INCLUSIVE DEVELOPMENT

Georges Darido and Joanna Moody

As low- and middle-income countries continue to urbanize, cities are increasingly important engines of economic development. The challenge for many developing cities is to achieve economic growth that is also equitable, inclusive, and sustainable. Achieving this vision for prosperous and livable cities will require transport policies and systems that deliver sustainable mobility for all through accessibility, efficiency, safety, and appropriate environmental considerations (SuM4All 2017).

Urban mobility enables cities and their residents to flourish by providing universal accessibility to jobs, services, markets, and other socioeconomic opportunities that enhance quality of life. As cities grow, densify, and become congested, high-quality public transport is essential for achieving sustainable mobility and supporting economic development for all residents. Lower-income urban residents, in particular, rely heavily on public transport and forms of nonmotorized transport (walking and biking) for their daily travel. Without fast, secure, and affordable public transport, many people are forced to spend more time and limited income on travel (especially commuting) or greatly limit their job options and other opportunities. Moreover, urban

*Photo: A mother and child stand waiting to board a train. Source: iStock Photo.*

roads are often overused by private automobiles and motorized two-wheelers to the detriment of public transport and nonmotorized modes, resulting in excessive congestion, road injuries and fatalities, air and noise pollution, and other negative externalities (SuM4All 2017). Thus, dense urban areas require high-capacity rapid transit solutions on exclusive rights-of-way—such as metro, commuter rail, light rail transit (LRT), or bus rapid transit (BRT), described further in chapter 3—to provide safe, clean, and affordable transport.

Rapid transit projects—particularly urban rail—are megaprojects because they entail very large and essentially irreversible outlays of investment for long-lived assets. Implementing a new rapid transit system (or expanding an existing network) provides a rare opportunity for shaping urban form and developing a transport system that contributes to sustainable development. Rapid transit infrastructure often serves as the backbone of effective public transport in large cities, which in turn is the basis of widespread access via other sustainable transport modes, particularly walking and biking (SuM4All 2017). If well-planned and integrated into a transport network, rapid transit can deliver significant gains in job accessibility, safety, security, and other benefits to persons who need it the most, while unlocking other potential benefits from economic growth and agglomeration effects. However, if these megaprojects are not planned and designed with sustainable development in mind, they can impose a massive financial burden on governments with limited resources.

This chapter provides a framework for understanding how rapid transit can support sustainable development, including poverty alleviation and shared prosperity, in cities and metropolitan regions. It begins with a review of travel patterns by different user groups and highlights the importance of socially inclusive projects that benefit lower-income users, women, and persons with reduced mobility. It then defines four key attributes of a rapid transit system that have socioeconomic impacts on potential users—availability, accessibility, affordability, and acceptability, known as the four “As.” For each “A,” the chapter provides examples and tools for assessing and improving each of these attributes. If social inclusion and distributional impacts of these four “As” are considered for all potential user groups throughout the planning and implementation process, rapid transit can be an important catalyst for sustainable and equitable development.

### **Socially Inclusive Urban Transport**

Urban transport projects should be considered based on the travel needs of all residents in a city or metropolitan area (see chapter 3). However, aggregate measures of societal benefits and costs fail to account for the diverse travel

needs of different users. In order to evaluate the distributional impacts of urban rapid transit projects, it is important to understand the unique travel patterns and recurrent needs of all potential user groups. While a comprehensive review of the differences among all types of transport users and other groups is beyond the scope of this chapter, this section discusses the important and often underserved travel needs of residents with lower incomes, women, and people with reduced mobility. The four “As” conceptual framework and associated analytical and policy tools needed to address these distributional issues in regard to urban transport development, are presented in the next sections.

### **Urban Transport and Low-Income Residents**

Low-income residents in many metropolitan areas depend heavily on public transport services to carry out their daily economic and social activities. While public transport systems in cities around the world are used by people of all socioeconomic levels, significant evidence shows that low-income residents (and other individuals with no access to private means of transport) use public transport the most (Aworemi et al. 2008; Carruthers, Dick, and Saurkar 2005; JICA and MTC 2004).

In cities both in high-income and in low- and middle-income countries, residential or economic displacement and poor land use planning have pushed low-income residents toward peripheries (causing sprawl) or central districts that are underserved by high-quality transit (Vasconcellos 2001). In most cases, the result is a spatial mismatch in which formal employment opportunities are heavily concentrated in the city’s central business districts and few income-generating options in the formal sector are available in the outlying peripheries where low-income people live. This leads to longer average travel distances, longer travel times, and fewer mobility options for low-income people. Low-income travelers often need to transfer between different public transport services in order to get from their origin to their destination, creating an additional time burden (waiting at transfers) and, in some cases, cost burden (for systems without integrated fare structures or transfer discounts).

As cities grow horizontally, transport costs increase for low-income groups on the city periphery given the longer distances they need to travel in order to reach their desired destination. Low-income users of public transport tend to spend a larger share of their income on transportation (Gomide, Leite, and Rebelo 2004). This means that they often have to forgo other consumption in order to make mandatory trips (such as those to and from or looking for work). Together longer travel distances, increased number of transfers, and greater proportional monetary cost create a form of social exclusion, making jobs, schools, health facilities, social activities, and other opportunities less accessible for lower-income residents (Carruthers, Dick, and Saurkar 2005). In many

countries, access to health care is lacking, especially for low-income populations living far from the city center. When barriers to access health care exist, low-income individuals may miss important treatments and suffer complications (Syed, Gerber, and Sharp 2013), further reinforcing poverty and lack of opportunities.

### **Urban Transport and Women**

It is widely understood that women and men have different patterns of mobility (Meloni, Bez, and Spissu 2009). These patterns are defined mainly by social norms and gender roles, where the economy of care places a greater time burden on women—defining trip purpose, trip distance, travel time, transport mode, and other aspects of travel behavior (Uteng 2011). Compared with men, women rely more on public transport, make more complex trips involving different modes at lower speeds, and travel shorter distances, which can restrict their access to better employment and other opportunities (Uteng 2011). Women tend to travel more often in off-peak hours, when public transport service is less frequent and wait times (especially at transfers) are longer. Some studies have found that women are more often denied boarding on public transport vehicles, especially when traveling with children or packages. Even when they are able to board, vehicles are often not designed with appropriate spaces to place packages or for women (or the children that may be accompanying them) to sit.

Finally, women are more likely to be the victims of gender-based harassment or violence on public transport systems and, therefore, they are more often concerned with safety and security. Fear of personal safety not only affects quality of life for women traveling on public transport, but may also be an obstacle to accessing better education and employment opportunities. Safety and security are fundamentally a cultural issue, and therefore awareness campaigns, driver and bystander training programs, easy reporting mechanisms for victims, and increased enforcement and sanctions for offenders can help to combat social complacency.<sup>1</sup> Better bus stop and rail station design with good lighting and closed-circuit television technology can also help. In addition, in places where vehicles are extremely crowded (particularly during peak hours) and on routes with a high incidence of abuse, reserving an area in buses and urban rail cars for women can serve as a short-term solution.

### **Urban Transport and People with Reduced Mobility**

Public transport systems need to consider the needs of users with reduced mobility, including persons with impaired physical mobility, the elderly, children, and pregnant women. Many countries have well-established design standards or laws that govern universal access to public transport infrastructure, requiring



accommodations such as level boarding, elevators and escalators, tactile pavement and other tactile features, audible guides at entrances and escalators, special signage, lighting, and other assistance as well as designated areas on board vehicles and in stations (Babinard et al. 2012). Such standards apply to all new rapid transit investments, but many legacy systems still fall short of universal access for people with reduced mobility. Universal access to public transport is also compromised by the difficulties that people with reduced mobility face in navigating urban areas, so access to vehicles or stations is only part of the problem (see chapter 16). Such barriers to mobility constitute social exclusion since significantly reduced access to labor markets and other services for people with reduced mobility present greater challenges to staying out of the poverty cycle and negatively affect quality of life.

### Conceptual Framework: The Four “As”

This chapter proposes a framework for understanding how urban transport investments and related services can improve well-being and social inclusion, especially for the economically disadvantaged. Ideally, this framework should be part of a Poverty and Social Impact Analysis (PSIA) carried out during system and corridor planning (see chapter 3). Such a PSIA assesses the distributional and social impacts of policy reforms on different groups, with an emphasis on low-income and other vulnerable groups. A PSIA aims to inform the design of policies and programs by providing evidence of what has or has not worked and proposing changes or alternatives for better outcomes (World Bank 2003).

The four “As” framework considers the impact of the urban transport project or policy through the measurement of four attributes from the user’s perspective: availability, accessibility, affordability, and acceptability (Gomide, Leite, and Rebelo 2004):

- *Availability* refers to the connectivity and coverage of the urban (public) transport system. Public transport services are often distributed unevenly across a region, and lower-income areas often lag with regard to the availability and quality of rail and bus service.
- *Accessibility* refers to the ease with which an individual can access opportunities (for example, employment, health care, education, or other activities), given the spatial distribution of the city (land use), transportation infrastructure and services available (transportation supply), temporal constraints of individuals and activities, and individual characteristics of people.

- *Affordability* refers to the financial and opportunity costs that travel puts on an individual or household and the extent to which persons can afford to travel when and where they want. Public transport fares that recover all operating costs may price out lower-income users who rely most heavily on these services.
- *Acceptability* refers to the quality of urban rapid transit infrastructure and service for the user, including comfort, safety and security, and reliability.

The following sections describe each of the four “As” in more detail, outlining potential indicators to measure the distribution of each attribute across different sociodemographic groups. Decision makers can use this framework to make adjustments to rapid transit projects and to improve the potential economic and social development impact of investments. The next sections also describe analytical and policy tools helpful for planning, designing, and implementing urban rapid transit projects that address the travel needs of different user groups.

### **Availability**

Availability is the reach or coverage of high-quality public transport services. Availability is related to the supply capacity needed to serve existing or projected demand safely, efficiently, and reliably. In order to function efficiently, cities with high-demand corridors—serving more than 20,000 passengers per hour per direction—usually need some form of rapid transit as the backbone of their transport network. Once identified as part of an integrated mobility and land use strategy for the metropolitan region, such corridors require a comprehensive, multicriteria analysis of rapid transit alternatives to identify the most appropriate solution (see chapter 3).

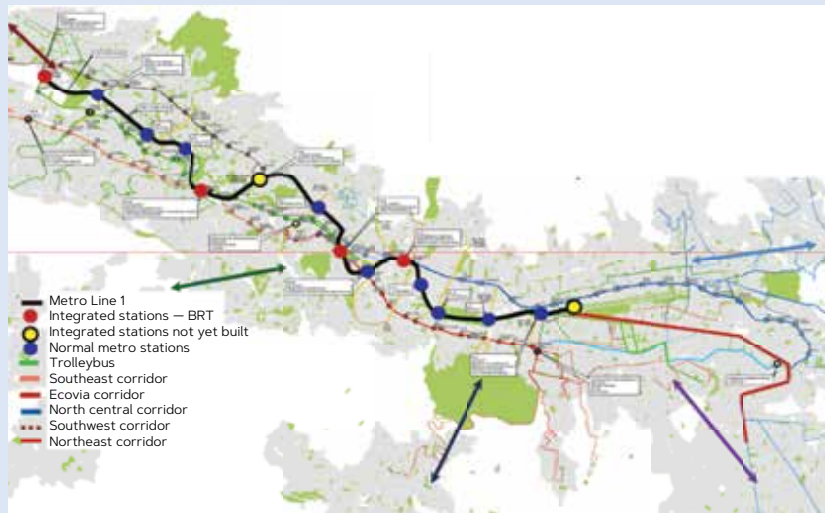
Rapid transit infrastructure by itself will not maximize the availability of urban transport. Instead, considering its carrying capacity and level of service, rapid transit is best at serving the corridors with the highest demand. It is imperative for rapid transit to be well integrated (physically, operationally, and in terms of fares) with other transport modes in a multimodal, hierarchical system that minimizes total travel times for users (including access times to or from stations by foot, bike, bus, or other modes; transfer times; and wait times) (see box 2.1). The coverage of this urban transport network should be compared with the geographic distribution of opportunities and land use in the metropolitan region (see box 2.2).

**BOX 2.1.****Multimodal Integration of an Urban Rail System from the Start of Project Development: Quito, Ecuador**

Adequate integration facilities around and inside mass transit stations are important factors in maximizing the social return on the project investment. Detailed studies need to consider carefully how passengers transferring from other modes can access stations and how safe and convenient it is for pedestrians and bicyclists to cross streets adjacent to stations. In Quito, Ecuador, the physical integration of Metro Line 1, bus rapid transit (BRT), trolleybus, and buses was considered from the outset of project conceptualization and planning (map B2.1.1). Metro Line 1 is integrated with

the BRT network at 6 out of 15 stations, and feeder buses are being reorganized around the remaining 9 stations. Fare integration is also planned for the system. By achieving physical, operational, and fare integration, Quito will have a fully integrated, multimodal public transport system.

Metro Line 1 also will solve a bottleneck prevalent in the extensive BRT network of the city. By solving this bottleneck and complementing existing BRT and bus services, the metro line will increase mobility and accessibility to opportunities and allow further expansion of the BRT network.

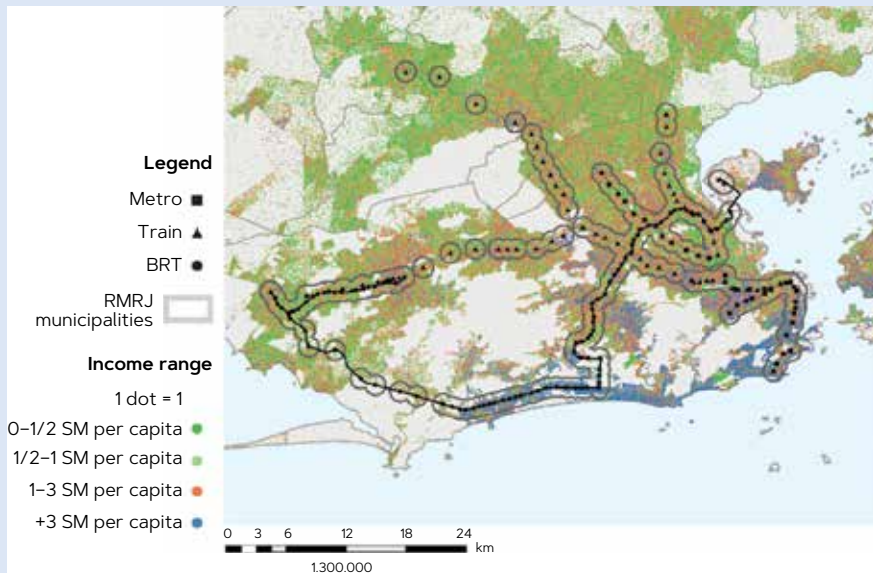
**MAP B2.1.1. Physical Integration between BRT Lines, Trolleybus, and Quito Metro Line 1**

Source: World Bank 2013, 26.

**BOX 2.2.****Considering the Availability of Public Transport in a Disaggregated, Geographical Poverty Impact Assessment: Rio de Janeiro, Brazil**

Map B2.2.1 represents the coverage of mass transport (metro line, suburban rail, and BRT) stations in Rio de Janeiro with 1-kilometer buffers as circles and income levels as colors (Marks 2016). The green dots represent households earning less than minimum wage, while red and blue dots represent households earning more than minimum wage. As a 280-kilometer network, Rio's metro, BRT, and suburban rail system connects some of the lowest-income residential

areas in the periphery of the city with job-dense parts of the metropolitan area. This figure underscores the importance of undertaking a geographical PSIA for any proposed urban rail project and of considering the impacts at both the corridor and network levels. In addition to assessing the spatial distribution of impacts, PSIA also have to consider the distribution of costs and benefits among different sociodemographic groups.

**MAP B2.2.1. Mass Transit Coverage and Household Income: Rio de Janeiro, Brazil**

Source: Reproduced under CC license with permission from the Institute for Transportation and Development Policy (Marks 2016, 26).

Note: BRT = bus rapid transit; RMRJ = *Região Metropolitana do Rio de Janeiro* [Rio de Janeiro Metropolitan Region]; SM = *salário mínimo* [minimum legal wage].

### Data and Analytical Tools for Addressing Availability

Table 2.1 lists some possible indicators used to assess the availability of urban rapid transit systems. These indicators include availability of services near where people live, frequency of vehicles and average waiting times, and time savings from origin to destination compared with alternative options. Service frequency is an important determinant of system ridership and availability.

An inventory of the available sources of data on transport supply and demand should be undertaken at project initiation. Then additional surveys can be used to fill major gaps, if any, in the available data. Detailed studies that quantify the availability of public transport and its relationship with the travel needs of different user groups are necessary at the outset of any urban rapid transit project.

### Addressing Availability throughout the Project Development Process

Consideration of rapid transit availability does not end with data collection and initial studies. Instead, measures of availability should be reviewed and updated as the project advances through the development process. Table 2.2 provides guidance for considering the availability of rapid transit through every step of the project development process in order to identify and incorporate opportunities to improve socioeconomic outcomes.

**TABLE 2.1. Example Indicators Used to Assess the Availability of Urban Rapid Transit Systems**

INDICATOR	UNIT OF MEASURE	UNIT OF ANALYSIS	DATA SOURCES AND REQUIREMENTS
Number or % of people within x meters of high-quality public transport service, disaggregated by socioeconomic characteristics	Number or % of people	Public transport coverage	Georeferenced public transport network and population data disaggregated by income
Modal share of trips between major origins and destinations in peak hours and peak directions	% of persons per hour	Transport corridor	Trip origin-destination modal share disaggregated by income and other characteristics
Headways and average waiting times for public transport passengers during different periods of the day <sup>a</sup>	Minutes	Route level	Service schedules or timetables
Total travel time on all modes between origin-destination pairs	Minutes	Trips per individual	Travel and user surveys, disaggregated by gender, demographic, and socioeconomic characteristics

a. Once the system is operational, also consider the regularity of services (see chapter 13).

**TABLE 2.2. Considering Availability throughout the Project Development Process**

STEPS OF PROJECT DEVELOPMENT	TASK	TOOLS AND DATA SOURCES
Project initiation	<ul style="list-style-type: none"> <li>• Measure and study urban transport supply and demand (see chapter 3), including “existing” travel times, coverage, and service levels by relevant population group and area</li> <li>• Create an integrated urban mobility and land use strategy (see chapter 3), including maps of “desired” travel times, coverage, and service levels by population group and area</li> </ul>	<ul style="list-style-type: none"> <li>• Origin-destination surveys and census data, demand studies, supply and service networks</li> <li>• Land use plans and spatial distribution of jobs, households, employed and unemployed population, car ownership, and other data by income group and other relevant demand characteristics</li> <li>• Poverty and Social Impact Analysis (PSIA)</li> </ul>
Planning	<ul style="list-style-type: none"> <li>• Propose and evaluate project alternatives (see chapter 3) with estimated indicators for availability by area and population group</li> <li>• Make adjustments to the project alignment, station locations, or other design parameters (see chapter 5) to maximize the availability of services to potential users, including disadvantaged groups</li> </ul>	<ul style="list-style-type: none"> <li>• Multimodal travel demand model or other transport planning model</li> <li>• Multicriteria alternatives analysis, project feasibility, and other early planning studies</li> <li>• Open Transit Indicators tool, see example for Zhengzhou Metro in chapter 16<sup>a</sup></li> </ul>
Design	<ul style="list-style-type: none"> <li>• Design the project to integrate with other modes and services physically and operationally (see section on policy tools to improve accessibility in this chapter), including other public transport, nonmotorized modes, and private vehicles</li> <li>• Consider levels of service and an integrated fare policy to set fares (see section on affordability in this chapter)</li> </ul>	<ul style="list-style-type: none"> <li>• System integration studies and other technical studies to support implementation (see box 2.1)</li> <li>• Citizen engagement (see chapter 14) to optimize the project design</li> </ul>
Construction	<ul style="list-style-type: none"> <li>• Plan and implement the feeder network and integration measures for the rapid transit system</li> </ul>	<ul style="list-style-type: none"> <li>• Engagement with affected people to minimize negative impacts</li> <li>• Surveys and workshops with potential users, including disadvantaged groups</li> </ul>
Operations	<ul style="list-style-type: none"> <li>• Evaluate the quality and level of service for each user group, including disadvantaged populations</li> </ul>	<ul style="list-style-type: none"> <li>• Real-time performance data from vehicle location, fleet management, and other advanced systems using a data standard such as General Transit Feed Specification (GTFS)</li> </ul>

a. See [https://www.transitwiki.org/TransitWiki/index.php/Open\\_Transit\\_Indicators](https://www.transitwiki.org/TransitWiki/index.php/Open_Transit_Indicators).

## Accessibility

Regional or urban accessibility<sup>2</sup> refers to the ease with which an individual can access opportunities (for example, employment, health care, education, or other activities), given the spatial distribution of the city (land use), transportation infrastructure and services available (transportation supply), temporal constraints of individuals and activities, and individual characteristics of people. In order for urban rapid transit investment to increase the opportunities available for all, it is important for project-implementing agencies to take into account the potential impacts of the investment on accessibility.

Urban rapid transit systems can enable regional accessibility, especially for people living in the periphery who travel long distances in search of better employment (Gwilliam 2002). An exclusive right-of-way with limited stops improves the speed, reliability, and other aspects of rapid public transport services, especially for longer distances. Faster travel speeds and more direct alignments translate into shorter travel times and greater access to socioeconomic opportunities. In this way, rapid transit can ease the effects of the jobs-housing spatial mismatch by increasing the accessibility of residents to formal job opportunities and other services in the city's central business districts. The economic activity that can result from connecting neighborhoods and workers with jobs is one of the social benefits that drive urban rapid transit projects. Equally important for poverty reduction is connecting lower-income residents with other services such as high-quality health care, training and education, and other activities. By reducing the transport barriers to these services, well-integrated rapid transit systems can help to stimulate social (as well as economic) capital.

Rapid transit improves accessibility the most when the system is well connected with other modes of transport, especially local, feeder buses and non-motorized transport options (see chapter 16). Thus, physical integration that minimizes vertical and horizontal distances and obstacles when transferring between rapid transit and other modes is a prerequisite to improving accessibility (see box 2.3).

### Data and Analytical Tools for Addressing Accessibility

Accessibility is a powerful lens with which to assess how an urban rapid transit project will benefit potential users as part of a multimodal urban transport network. Different indicators can be used to measure, analyze, and visualize the accessibility of rapid transit systems. The Sustainable Mobility for All initiative defines a key indicator of accessibility as “the proportion of population that has convenient access to public transport, disaggregated by age, sex, and persons with disabilities” (SuM4All 2017, 42). Many other indicators of accessibility can

**BOX 2.3.**

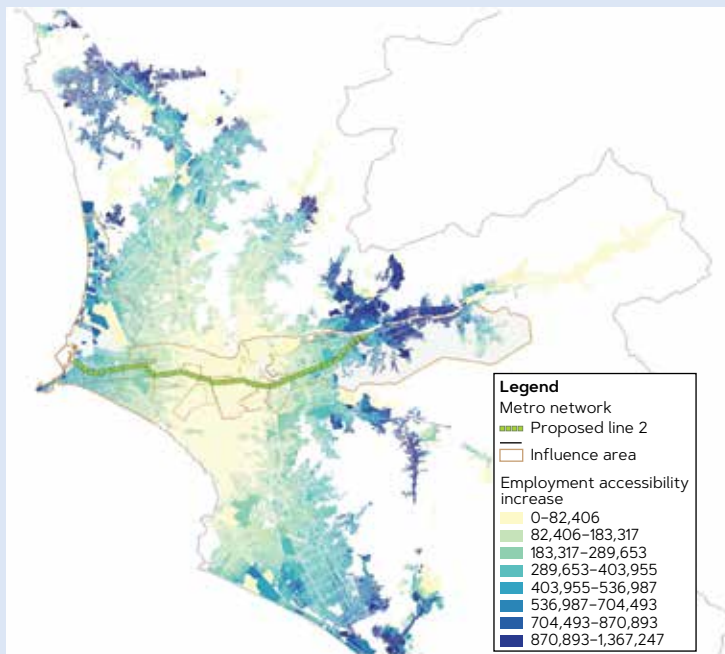
**Enhancing Regional Accessibility: Lima Metro Line 2, Lima, Peru**

Metro Line 2 is a prime example of how accessibility gains to lower-income residents can be a primary benefit of an urban rail investment when considered up-front in the project development process. Lima Metro Line 2 promises to increase access to jobs and other social services for all residents of the metropolitan region, including low-income populations living in the periphery of

the city. This benefit will be realized primarily by reducing travel and waiting times for the large number of people traveling along the metro corridor.

One indicator of regional accessibility used to evaluate the proposed Metro Line 2 is the number of jobs reachable by public transport within a 60-minute one-way commute in the area of influence of the alignment

**MAP B2.3.1. Overall Increase in the Number of Jobs Accessible by Public Transport in 60 Minutes: Lima Metro Line 2**



Source: World Bank 2015b, 86.

(box continues next page)



**BOX 2.3.****Enhancing Regional Accessibility: Lima Metro Line 2, Lima, Peru (Continued)**

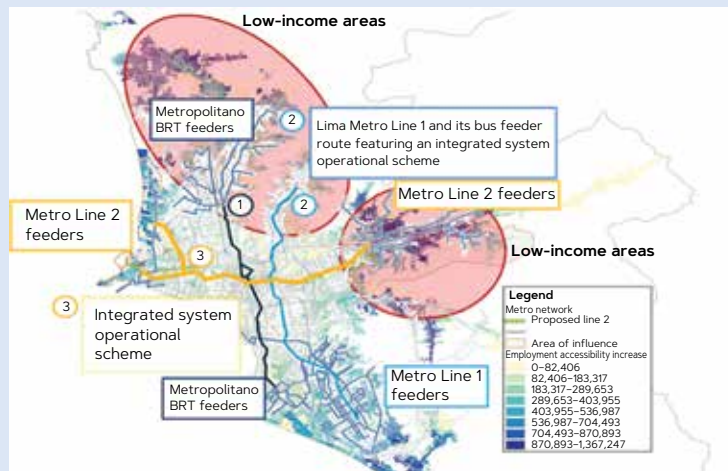
(see map B2.3.1). This indicator will be measured before (with 2014 as the baseline year) and after the project is completed using an impact evaluation study. Once Metro Line 2 is completed and well-integrated with Metro Line 1 and Metropolitan BRT, the number of jobs accessible within a 60-minute one-way trip is expected to increase up to 25 percent.

The indicator in map B2.3.1 represents the number of all formal employment opportunities for all categories of the population. It does not account specifically for the matching of certain types of jobs to the skills and needs of lower-income groups,

because such a level of detail is often not available in existing data sources. However, as a proxy of such a disaggregate analysis, an accessibility map can be superimposed on a map showing the location of lower-income (or other) groups (see map B2.3.2) to visualize potential distributional imbalances in accessibility gains from the project. Then, as the project progresses the distributional impacts on different groups can be considered in more detailed studies.

Following this good practice, the Metro Line 2 study considered not only the total

**MAP B2.3.2. Increase in the Number of Jobs Accessible by Public Transport in 60 Minutes for Low-Income Areas: Lima Metro Line 2**



Source: Adapted from World Bank 2015b.

Note: BRT = bus rapid transit.

(box continues next page)

**BOX 2.3.****Enhancing Regional Accessibility: Lima Metro Line 2, Lima, Peru** *(Continued)*

regional accessibility, but also the accessibility gains for low-income users. Map B2.3.2 illustrates how changes in job accessibility brought by the construction of Metro Line 2 correspond with low-income areas of the city. Lower-income areas on the

periphery of the city expect to see some of the greatest increases in access to job opportunities resulting from implementation of the new metro line and its integration with Metro Line 1 and BRT services in Lima, Peru.

and should be used, as accessibility is the most powerful criteria with which to measure the economic impact of rapid transit projects (see table 2.3).

The number of jobs accessible within a 45- or 60-minute time frame is a common indicator for evaluating how well the urban transport system is serving a particular spatial area or group of people (such as the most disadvantaged). Comparing this measure across parts of a region or mapping the measure for different sociodemographic groups allows project-implementing agencies to visualize the extent of spatial inequality in accessibility (box 2.3). By quantifying how many more formal employment opportunities lower-income urban residents can access in a 45- or 60-minute time frame, this measure is a critical benchmark for assessing the impacts of a rapid transit investment (Mehndiratta and Peralta-Quiros 2015). The same analytical tools can be applied to explore the access of different areas of the city and different sociodemographic groups to opportunities other than formal employment, such as education, health care, green space, and other services.

Data and computational difficulties are among the factors that have limited more widespread use of regional accessibility as a planning tool for rapid transit projects. Accessibility analysis requires basic spatial data on the host city's existing road and public transport system and planned rapid transit network. In addition, it is necessary to have spatially disaggregated data on indicators of interest such as population, jobs (both formal and informal sources of employment), schools and hospitals, parks and green spaces, and other activities of interest. Therefore, comprehensive census and household travel surveys are of primary importance.

**TABLE 2.3. Example Indicators to Assess the Accessibility of Urban Rapid Transit Systems**

INDICATOR	UNIT OF MEASURE	UNIT OF ANALYSIS	DATA SOURCES AND REQUIREMENTS
Total travel time between origin-destination pairs by mode, including time for access, wait, and in vehicle	Minutes	Trips per individual	Traffic and origin-destination surveys
Number or % of jobs within a 45- to 60-minute commute by public transport	Number or % of jobs	City-individual job accessibility	Georeferenced job locations or major activity centers
Number or % of people (of various categories) who can be reached in a given period of time from a given employment area	Number or % of people	City-employer worker accessibility	Georeferenced job locations or major activity centers
Number or % of health and education centers within a 45- to 60-minute commute in public transport; single-point or regional analysis	Number or % of centers	Weighted number adjusted for demographic changes per city-individual	Census data; social service cadaster; General Transit Feed Specification (GTFS) Transport Network

Recent advances have allowed for accessibility analysis using open-source software, significantly reducing the technological barriers to assessing accessibility in rapid transit project planning. Some user-friendly open-source tools for urban transport geospatial analysis include the Open Trip Planner Analyst, General Transit Feed Specification, and Open Traffic.<sup>3</sup>

### Policy Tools for Addressing Accessibility

The greatest policy tool for maximizing the accessibility benefits of urban rapid transit infrastructure is to consider its development as part of a multimodal, hierarchically integrated transit system (HITS). In such a system, rapid transit infrastructure serves as the high-capacity, high-frequency trunk of the rapid transit network; it needs to be easily accessed by formal and informal bus and taxi systems and by nonmotorized forms of transit. To ensure this access, three types of integration are critical for the success of any urban rapid transit project, but particularly for urban rail systems: (1) physical integration, (2) operational integration, and (3) fare integration. These three dimensions of integration are fundamental for maximizing the accessibility benefits and ensuring the long-term sustainability of any urban rail system (Salat and Ollivier 2017; Zimmerman and Fang 2015).

The most fundamental form of multimodal integration is physical integration: the interconnection between metro and suburban rail stations with bus terminals and other local accessibility infrastructure (for example, walking and cycling). One solution for dense urban areas is to build multilevel, multimodal stations with good signage and elevators and escalators to provide universal accessibility. In less dense areas or where legacy infrastructure already exists, separate stations may be constructed, but should be designed to minimize walking distances (both horizontal and vertical) and conflict points between modes, including pedestrians and bicyclists as well as vehicles.

The second type of integration is operational. A new urban rapid transit project often requires a reorganization of the existing public transport system into a trunk-feeder operation. To do this kind of integrated, multimodal service planning, it is necessary to account for the total time and cost of a journey for all types of users and trips. Such an analysis requires origin-destination data and a transport network and demand model that can account for the frequencies and reliabilities of different modes and routes, wait times, transfer penalties, and ease of access and egress to and from the overall public transport system. Operational integration is difficult to do, especially in places where public transport users are accustomed to hailing an informal minibus or taxi. Passengers do not like to transfer even when doing so minimizes their travel distance and wait time. At the same time, rapid transit lines on high-volume corridors in large cities function better when they are operationally integrated in a hierarchical manner that takes advantage of the performance characteristics of each individual mode.

A third type of integration—fare or tariff integration—goes well beyond having interoperable technology such as contactless smartcards to considering the fare structure and policy that best balance the social welfare of users and the financial sustainability of operations. Many cities have complex structures with different fares for different types of users, modes, times of day, distances, and transfers (see the section on policy tools addressing affordability). However, no matter the final structure, fares should be set along with funding policy at the multimodal system level, considering trade-offs between operational revenue and user affordability, especially for captive users of public transport.

### **Affordability**

Affordability refers to the financial cost that travel puts on an individual or household and the extent to which persons can afford to travel when and where they want (DETR 2000).<sup>4</sup> The financial cost of travel includes not only

the direct cost of fares that users must pay to reach their destination, but also the opportunity cost of other potential consumption sacrificed in order to make mandatory trips. Expenditure on transport plays a particularly significant role in the budget of a low-income households. While the top quintiles on the income scale spend more on transport in absolute terms than the bottom 40 percent on the income scale, the burden or share of transport costs is highest for the bottom two quintiles, especially for persons unable to walk to their destination (table 2.4; see also Carruthers, Dick, and Saurkar 2005). For low-income populations, spending more than 10–15 percent of income on public transport constitutes a serious burden. In some developing cities, the bottom quintile spends up to 30 percent of their income on travel for work (Carruthers, Dick, and Saurkar 2005).

Traditionally, affordability of transport was estimated using expenditure on public transport services as a percentage of income (as in table 2.4). This expenditure was then compared with a set percentage threshold, and if the expenditure was more than the threshold, public transport fares were considered unaffordable and a subsidy was needed (Gómez-Lobo Echenique 2007). However, this affordability benchmark approach has significant limitations. First, financial (observed) expenditure on transportation is not the same as the generalized cost of transportation for certain users (Serebrisky et al. 2009). For example, by accounting for the “shadow cost” (for example, discomfort, travel time, and physical demand) of walking trips, the expenditure on transport by low-income residents may increase substantially. Furthermore, low-income

**TABLE 2.4. Share of Total Household Income Spent on Public Transport in Select Cities**

CITY	% FOR AVERAGE HOUSEHOLD	% FOR HOUSEHOLDS WITH INCOME IN THE BOTTOM QUINTILE
Buenos Aires, Argentina	4	26
Chennai, India	8	19
Lima, Peru	10	20
Manila, Philippines	5	17
Mexico City, Mexico	3	19
Mumbai, India	9	23
Rio de Janeiro, Brazil	6	30

Sources: Based on per capita income data (U.S. dollars) for 2005 (Carruthers, Dick, and Saurkar 2005) with exception of Peru, which is based on data for 2010 (World Bank 2015b).

residents may demand fewer trips due to the high cost of travel and it is difficult to account for the burden of such unserved trips using available data.

Therefore, the literature on affordability of public transport suggests that more disaggregate measures of affordability across different sociodemographic groups and spatial areas of the city are needed to ensure that subsidies are benefiting the lowest-income users (Gómez-Lobo Echenique 2007; Serebrisky et al. 2009). This section discusses the data and analytical tools available for addressing rapid transit affordability and introduces the policy tools that may be informed by such an analysis. In general, the literature suggests that demand-side subsidies (direct subsidies to passengers rather than to operators) are more effective in increasing the affordability of public transport services.

### **Data and Analytical Tools for Addressing Affordability**

In order to study the affordability of urban transportation systems, it is important to have access to income and expenditure data (usually monthly); the amount of travel (trips per day) of a specific population group; the system's fare policy (including the offer of any targeted benefits for public transport); and, if possible, an understanding of the opportunity cost of the service (Gomide, Leite, and Rebelo 2004). Income data are often found in household budget and other multipurpose surveys. Table 2.5 presents an example of indicators often used to measure the affordability of urban transport services and the potential sources from which these data could be obtained.

As a first approximation, affordability can be expressed as a relation between the user's monthly spending on transport (related to the fares charged by the system) and the head of household's income. In many cases, affordability is also measured in terms of household expenditures as a whole. Therefore, any analysis of affordability should be at the individual or household level.

Gomide, Leite, and Rebelo (2004) offer one approach for calculating a household "affordability index" helpful for understanding the affordability of public transport in urban areas. This approach is based on a five-step method of calculating the affordability index for a city:

1. From the latest national census of household survey data, find the average per capita monthly income and the average for the bottom quintile of the income distribution for the city
2. Update these values to the reference year using per capita income growth rates
3. Determine the minimum public transport fare to travel 10 kilometers using a daily ticket

**TABLE 2.5. Example Indicators to Assess the Affordability of Urban Rapid Transit Systems**

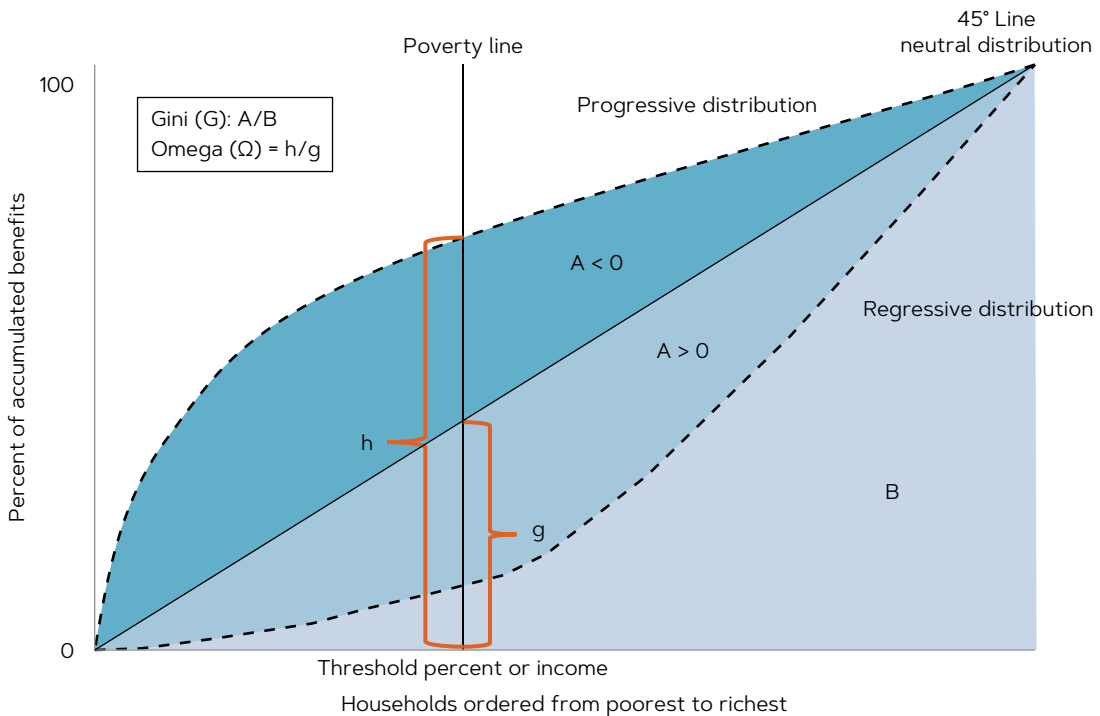
INDICATOR	UNIT OF MEASURE	UNIT OF ANALYSIS	DATA SOURCES AND REQUIREMENTS
Average household income or average per capita income per month	US\$ or other currency	US\$ per household or individual (head of household)	Household budget and other polls and surveys
Cost of public transport trip per passenger	US\$ or other currency	US\$ per passenger	Administrative surveys
Household or individual transport expenditure as a share of income, gross domestic product, or minimum wage	%	US\$ per household or individual	Household surveys; origin-destination surveys
Targeting efficiency of subsidized fares	% of beneficiaries within the bottom 40% or other low-income category	Individual	Household surveys; administrative surveys; national targeting mechanisms
The area between the 45° line and the Lorenz distribution curve over the area below the 45° line	Quasi-Gini coefficient	Relative benefit distribution (Lorenz) curve of households	Household travel survey and mobility study
Number or % of subsidy accruing to low-income households over the % of low-income households in the population	Ratio ( $\Omega$ )	Relative benefit distribution (Lorenz) curve of households	Household travel survey and mobility study

4. Calculate the cost for 60 trips (2 trips for 30 days in month) at this fare
5. Express this cost as a percentage of the average and bottom quintile monthly incomes.

Despite its attractiveness for estimating comparable affordability indexes across cities and countries, this affordability measurement is problematic. In particular, it ignores possible changes in fares due to supply responses needed to accommodate the fixed number of trips considered (Serebrisky et al. 2009). Furthermore, it is unclear what welfare interpretation can be given to such a measure or how it can be used to evaluate policy interventions. In spite of this, this measure may still be a useful first approximation to determine the hardships faced by certain groups of the population and as a possible indicator of when further analysis may (or may not) be warranted. However, when analyzing the distributive implications of affordability for a specific policy or set of policy alternatives, different indicators may need to be used.

An alternative method is to graph the Lorenz curve or relative benefit curve for the proposed policy (Komives et al. 2005). The Lorenz curve graphs the percentage of a subsidy accruing to the first  $k$ th rank of households, according to some measure of income, expenditure, or wealth distribution (see figure 2.1). Two indicators are associated with the relative distribution curve: the quasi-Gini coefficient ( $G$ ) and  $\Omega$  (see table 2.5). The quasi-Gini coefficient gives a summary measurement of the progressive or regressive nature of the subsidy policy in question. This coefficient is calculated as the area between the 45° line and the distribution curve (with a negative value when the curve is above the 45° line) over the area below the 45° line (see figure 2.1). The closer the quasi-Gini coefficient is to  $-1$ , the more progressive is the distribution of impacts (Serebrisky et al. 2009). Another summary measure of the distributive incidence of a

**FIGURE 2.1. Lorenz Benefit Curve and Associated Indicators**



Source: Adapted from Serebrisky et al. 2009.



subsidy is the  $\Omega$  value—the percentage of the subsidy accruing to poor households over the percentage of the population represented by poor households (see figure 2.1). This approach requires the analyst to define a threshold percentage or income value under which households are categorized as low income. The  $\Omega$  value is the percentage of the total subsidy accruing to this group; it is above 1 for a progressive subsidy and below 1 for a regressive one (Serebrisky et al. 2009).

The relative benefit curve is a useful tool for comparing the distributive impact of different policies since it gives a graphical representation of the relative incidence of benefits. When the curves for different policy interventions are superimposed on the graph, it is often possible to rank them according to their distributive impact. This is the case when different curves do not cross each other, in which case the highest curve will dominate the others in terms of progressiveness (Serebrisky et al. 2009).

From a practical point of view, detailed information on household travel patterns and socioeconomic characteristics is required in order to apply the proposed methodology. In many cases, a household survey and mobility study will be available for a given city; in others, especially in low- and middle-income countries where data collection efforts are less frequent, the information available may be sparser or outdated.

Before planning the implementation of a potential urban rapid transit project, it is important to analyze the affordability of existing urban transport services. This analysis is helpful for ensuring that fares are set to an affordable level to ensure ridership and inclusion of low-income groups. Table 2.6 provides guidance to government authorities in thinking about fare affordability through different steps of the project development process: project initiation, planning, design, and construction and operations.

### **Policy Tools for Addressing Affordability**

Fares are the greatest direct monetary cost to riders related to using any urban rapid transit system. Therefore, fare policy and structures need to be considered carefully in regard to the affordability of any public transport system (new or existing). First, consideration should be given to reducing operational costs and consequently the fares needed to recoup them (Gomide, Leite, and Rebelo 2004). While this can improve the aggregate welfare of rapid transit riders, the improved affordability that comes with a systemwide fare reduction is not targeted directly toward persons who need it most. Furthermore, if the government does not offset the loss of fare revenue, systemwide fare reductions may threaten the financial sustainability of the system operator (see chapter 13). Other levers within the urban public

**TABLE 2.6. Considering Affordability throughout the Project Development Process**

STAGE OF PROJECT DEVELOPMENT	TASK	TOOLS AND DATA SOURCES
Project initiation and concept	<ul style="list-style-type: none"> <li>Analyze the burden of public transport on the income of specific population groups</li> <li>Map how far it is possible to travel on a fixed budget for jobs and basic services</li> </ul>	<ul style="list-style-type: none"> <li>Household and origin-destination surveys, public transport revenue-administrative data, smartcard or high-frequency data (if available) as part of a Poverty and Social Impact Assessment (PSIA)</li> </ul>
Planning	<ul style="list-style-type: none"> <li>Conduct a comprehensive study on fares, systemwide externalities and their costs, and the distribution of burden or benefit for various social groups</li> <li>Define optimum transport subsidies</li> </ul>	<ul style="list-style-type: none"> <li>Fare affordability index; household surveys, administrative surveys, and data from existing social programs and national targeting mechanisms</li> </ul>
	<ul style="list-style-type: none"> <li>Identify existing entry points for well-targeted subsidies</li> </ul>	<ul style="list-style-type: none"> <li>Social protection registries, good practices in other rapid transit systems in similar cities</li> </ul>
Design	<ul style="list-style-type: none"> <li>Ensure fare integration across modes and apply targeted subsidy (geographic, categorical, or proxy means) where applicable</li> </ul>	<ul style="list-style-type: none"> <li>Smartcards, mobile phones, national targeting systems (proxy means)</li> </ul>
Construction and operations	<ul style="list-style-type: none"> <li>Implement policies to target subsidies to low-income users and to minimize revenue losses</li> </ul>	<ul style="list-style-type: none"> <li>Enforcement and technologies to deter fare evasion and fraud</li> </ul>

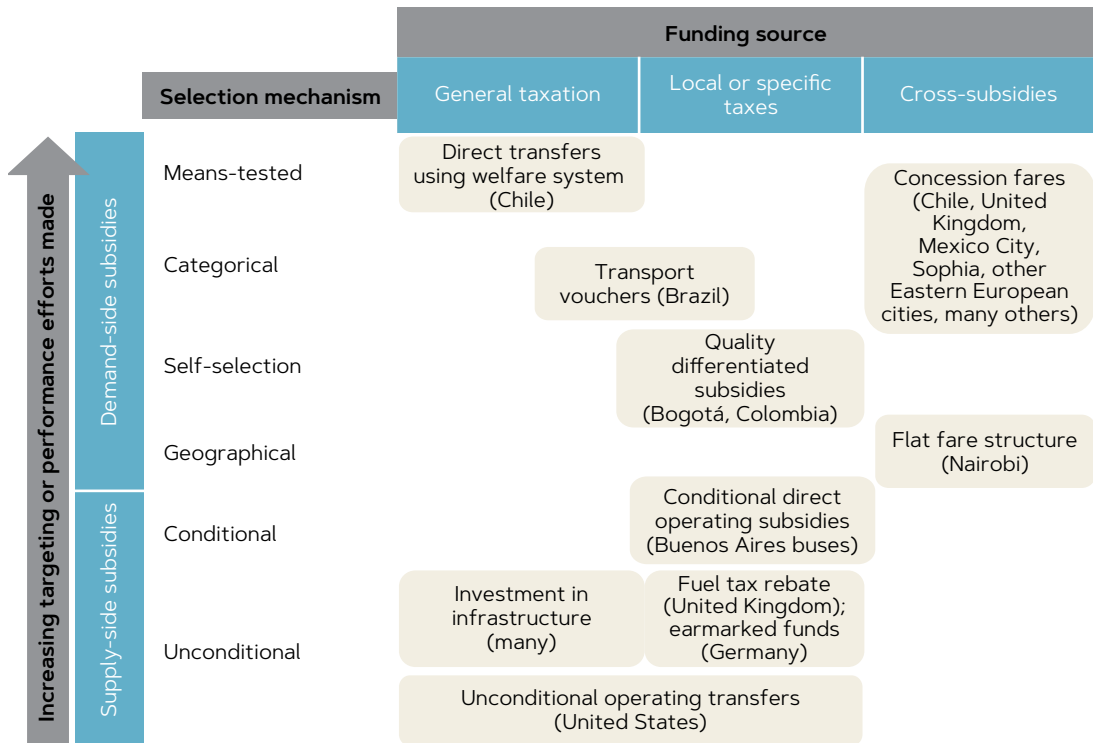
transport system's fare policy may prove more useful for policy makers wishing to address the dimension of affordability in a way that takes into account distributional effects.

Policy makers and project implementers need to study the impacts of structural changes to fare types and levels, fare integration, and concession of direct benefits, such as the distribution of vouchers and passes. When traveling longer distances, low-income users are often forced to make one or more transfers to reach their destination; a lack of an integrated fare system may disproportionately affect lower-income users and women and impose an additional financial cost on the inconvenience of their transfers. The bottom quintile of the income distribution includes a high proportion of adults who are working and therefore ineligible for concession (discounted) fares targeted to children, students, and the elderly (Carruthers, Dick, and Saurkar 2005). Therefore, government authorities overseeing rapid transit systems may want to consider other forms

of targeted subsidies (demand subsidies) that might better address the needs of low-income users, including passes and concessions based on income level or special discounts for persons traveling to look for work (Rodríguez et al. 2015) (see figure 2.2; box 2.4). Although they may be less-than-perfectly targeted, may distort residential location incentives, and are inferior to direct income transfers, targeted public transport discounts may be the most practical safety net for low-income workers (Gwilliam 2002) (see box 2.4).

Newly conceived direct subsidies for low-income riders may help to ensure the access of more disadvantaged segments of society to services and employment opportunities that will help to combat poverty (Gomide, Leite, and Rebelo 2004). All of these fare policy interventions can be implemented more easily with the existence of smartcard electronic fare collection systems.

**FIGURE 2.2. Typology of Subsidies, by Selection Mechanism and Funding Source**



Source: Adapted from Serebrisky et al. 2009.

**BOX 2.4.****Targeted Public Transport Fare Subsidies for Workers and Job Seekers****Vale-Transporte: Brazil**

The government of Brazil introduced the transportation voucher system in 1985 to ensure the mobility of low-income (formal) workers. This voucher system is a demand-side subsidy mechanism by which employers retain 6 percent of formal workers' earnings. In return, workers receive transport vouchers to cover commuting costs via public transport. The voucher system advances payment each month of the cost of round trips from home to work for eligible workers. The aid must be paid by the employer and is calculated on the basis of the full fare of the transport service—urban, intercity, or interstate public transport—that best fits the employee's need. The transport voucher is not part of a worker's salary or remuneration, nor is it part of any social security contribution.

One striking characteristic of the Vale-Transporte is that it provides an interesting and probably effective self-selection targeting mechanism. Workers can opt out of the system, and higher-income earners have the incentive to do so since 6 percent of their salary will generally be higher than what they spend on commuting (Serebrisky et al. 2009). In 2006, 50 percent of commuters using public transport in Brazil used the vouchers, including those working for temporary work agencies and domestic workers. Home service providers, subcontractor employees, and public servants are also eligible to receive the benefit (Government of Brazil 2009). The legislation makes public transport more affordable and encourages employees to use public transport instead of private cars, reducing traffic congestion, greenhouse gas emissions, and energy use.

**Targeted subsidies for low-income, unemployed youth: Johannesburg, South Africa**

In Johannesburg, South Africa, unemployed youth face high transport costs while looking for work (as much as 25 percent of minimum wage earnings per week). To understand the effect of targeted subsidies on employment outcomes, a policy intervention was implemented from 2013 to 2014 that provided low-income, unemployed youth with different types of subsidies (conditional or unconditional).

**Targeted subsidies for low-income job seekers: Washington, DC**

A pilot experiment in Washington, DC, explored the impact of randomly allocated transit subsidies among low-income job seekers who are captive public transport riders (have no alternative mode of transport). The results suggest that beneficiaries of the subsidy apply to and interview for jobs, on average, 19 percent more than comparable individuals only receiving standard job search assistance and that the subsidies benefit those who live far from open job vacancies the most (Phillips 2011). This suggests that subsidized public transport can stimulate employment above other existing forms of government assistance by enabling low-wage workers, who tend to live far from available jobs, to ride the city's urban rail system more frequently and hence to search more intensively for jobs.

**Daily spending cap: Sydney, Australia**

In Sydney, Australia, job seekers and people who are unemployed can apply for a concessions entitlement card. With this card, beneficiaries pay concession fares on trains, buses, ferries, and light rail with a daily spending cap of US\$7.50.

While the final scale and scope of a transport demand subsidy program for lower-income groups may well be a political decision based on a city's financial situation and other objectives, certain tools and indexes can help to structure the conversation regarding who should receive financial aid and how much. An example of this is the use of a fare affordability index or other measure derived from the relative benefits Lorenz curve to measure the financial impact of a standard bundle of transit trips per month for each member of the household based on his or her individual characteristics and travel patterns. While a helpful approach, there is no accepted normative manner of determining what share of income spent on transport would be considered unaffordable for a family. Affordability will depend on the alternatives (how practical walking and cycling are as alternatives to public transport) and other costs of living, including housing (Mehndiratta, Rodríguez, and Ochoa 2014).

From an economic welfare perspective, policies aimed at making public transport more affordable, including integrated tariffs and targeted subsidies, lead to positive distributional outcomes if set at an affordable rate. An electronic fare collection system and integrated tariffs can have immediate positive impacts on the quality-of-life and travel conditions of the low-income population, and a detailed study of the costs and benefits of other aspects of fare policy needs to be carried out regularly during operations of any public transport system.

## Acceptability

Acceptability relates to the quality of the user experience, including aspects of safety, security, comfort, and reliability of services. A well-designed rapid transit project removes barriers for potential users and provides good quality of service for its riders.

In many low- and middle-income countries, poor quality of public transport services can result from inadequate or nonexistent regulation, uncontrolled competition between service providers, and generally inadequate business models. In such cases, urban rapid transit development may be conceived as a catalyst for sector reforms to overcome barriers to safer, more secure, and inclusive services. Introducing rapid transit in a major travel corridor can reduce rates of road crashes or injuries and fatalities if well-maintained vehicles are operated on exclusive rights-of-way with protected access points. Rapid transit projects typically improve not only travel conditions, but also safety and security in and around stations, thereby fostering social inclusion and improving quality of life in these neighborhoods. Since low-income populations are more likely to be captive users of public transport, they are likely to benefit disproportionately from the quality of service improvements that come with rapid transit investment.

### **Addressing Acceptability during Project Planning and Design**

While the acceptability of services is often monitored during operations, it must also be considered in the project development process. The planning and design of rapid transit systems can have a significant influence on universal accessibility, station amenities and security, and other features that improve passenger comfort and quality of service. Accordingly, when planning and designing rapid transit systems, policy makers should consider implementing complementary measures that enhance their acceptability among all users, especially disadvantaged groups. The following are some of the actions known to improve user acceptability:

- Incorporating the needs of different users into intelligent transportation systems, including providing a variety of fare products that work for persons who are unbanked or who lack access to mobile phones and increasing the signal of contactless fare cards for women using purses (Yang 2017)
- Providing safe and accessible crossings for pedestrians and bicyclists and other urban amenities around station areas (see chapter 16)
- Expanding universal accessibility features for customers with visual, hearing, and mobility impairments (elevators, ramps, handrails, large-print and tactile signs, audio and visual real-time information systems, accessible vendor machines, and reserve seating for the elderly, pregnant women, and persons with other special needs)
- Addressing passenger comfort in stations and vehicles, including maximum occupancy levels (given system and infrastructure design capacity)
- Supporting way finding, including easily understandable signs and other user information

### **Addressing Acceptability during Operations**

User satisfaction surveys are a regularly used tool for monitoring acceptability of urban rapid transit service once a system is operational. These surveys, along with operational data, define the level of satisfaction in various user segments (main and disadvantaged users) together with their needs and expectations. In order to differentiate user perceptions by income or another observable attribute, the survey may collect basic passenger demographic and socioeconomic information. Table 2.7 lists example indicators used to measure and monitor the acceptability of urban rapid transit systems. For each of these measures, if disaggregated data are available, it is best to segment the population by

income, gender, and other sociodemographic characteristics to analyze whether certain groups face a higher burden than others.

Once the project is designed and constructed, operational system planning is the most basic tool for improving rapid transit acceptability (see chapter 13). Actions to consider during system operation include:

- Providing reliable service, including schedule adherence, actual on-time performance, real-time information to users on arrivals and departures, and mean time or distance between incidents or failures

**TABLE 2.7. Example Indicators to Assess the Acceptability of Urban Rapid Transit Systems**

INDICATOR	UNIT OF MEASURE	UNIT OF ANALYSIS	DATA SOURCES AND REQUIREMENTS
Passenger satisfaction with quality, safety, security, and reliability of services, disaggregated by user group	Self-reported level of satisfaction	Trips per individual	Road user satisfaction surveys, origin-destination surveys, semantic analysis of social networks
Crowding level in vehicles and on station platforms	Number of passengers per square meter	Vehicle or station platform	Fare card and other operational data; vehicle and station platform capacities; vehicle weight
Number of reported crimes or incidents (by route, time of day)	Reported offenses or incidents	System	Police or other reports, disaggregated by gender and other user characteristics
Share of stations or stops with seating, shelters, adequate lighting, closed-circuit television cameras, and other amenities	% of stations	System	Administrative data
Reduction in road injuries and deaths along project corridors	% or number of injuries or deaths per 1,000 people	Individual	Traffic surveys, police reports, hospital reports
Share of stations with universal design features	% of stations <sup>a</sup>	System	Administrative data
Number of direct project beneficiaries who are female or low-income or who have other user characteristics	Number of beneficiaries with given characteristics	Individual	Traffic surveys, census data, Geographical Information Systems data

a. This indicator is most applicable for existing systems that have yet to upgrade all of their facilities. New systems should be designed and constructed with 100% of stations having universal access features.

- Ensuring passenger safety and security, including proactively monitoring and addressing concerns of passengers throughout the network, such as programs to address gender-based violence and harassment through staff training and protocols and public campaigns

### Potential Unintended Effects of Rapid Transit Project Development

Despite the notable positive impacts that urban rapid transit projects may bring to cities and their citizens, these projects can also bring unwanted consequences that may drive opposition to a project. Beyond the economic and financial viability of a rapid transit project (see chapter 3), decision makers and implementing agencies still need to consider other potential impacts from the outset based on a thorough stakeholder analysis (chapter 14). Thinking about the following issues early in the process allows an opportunity to find planning, design, construction, and operations solutions that can ameliorate negative consequences, especially for disadvantaged groups:

- *Gentrification and neighborhood displacement.* Rapid transit projects often require significant expropriation of land and involuntary resettlement. Transport systems that improve accessibility may also hasten an increase in land prices, which is good for homeowners but can also increase tax burdens. Increasing land prices and new developments can also drive up rents for lower-income residents in these neighborhoods (World Bank 2015a, 27). To mitigate short-term and long-term negative social impacts, transport planning needs to be complemented by land use planning and appropriate social housing policies that support affordable units for existing residents (see chapter 16).
- *Last-mile connectivity.* Rapid transit systems need to be well connected (physically, operationally, and in terms of fares) to other urban transport modes, particularly feeder bus routes and nonmotorized modes, in order to ensure first-mile, last-mile connectivity. In most cases, this requires reorganizing existing bus services and harmonizing the technologies for fare collection, user information, and operational management practices. Careful planning and negotiations with private and public bus operators are required to avoid competition and provide seamless services for users.



- *Informal public transport operators.* In cities in many low- and middle-income countries, informal operators serve a significant share of trips as small private businesses with vehicles ranging in size from minivans to buses. Often these services are loosely organized and of poor quality because of intense competition on the street and a lack of investment in assets. However, these services often provide a viable option to users in lower-density environments and other areas underserved by formal public transport services. When introducing a new rapid transit system, rather than banning or competing with these services, planners are advised to consider ways to cooperate with informal operators and to incorporate them into an integrated public transport network. A multifaceted strategy may include helping the most capable operators to meet basic requirements to bid for new feeder routes or permit complementary service areas; improving their operations with better user information, management practices, and access to financing; and perhaps providing compensation for those operators that cannot operate any longer in the new system (see chapter 14).

Urban rapid transit infrastructure investment should be considered with the necessary complementary policies and regulatory measures to mitigate unintended effects. For urban rail systems in particular, social and environmental impacts and recommendations for their identification, management, and mitigation are discussed in chapters 14 and 15 of this handbook. Chapter 16 discusses housing, land use, and transit-oriented development policies as they relate to urban rail.

### **Ensuring That Urban Rapid Transit Projects Work for All**

The data and analytical tools for each of the four “As” can provide important support for decision makers in government authorities who wish to maximize the benefits of their urban transport system and ensure its inclusive distribution. Each of the four “As” needs to be considered from the very outset of urban mobility and land use planning for the metropolitan region and be part of a multicriteria analysis of rapid transit alternatives (see chapter 3).

When investing in new rapid transit infrastructure, the specific application of these tools will evolve throughout the project development process, but the tools are most beneficial when applied up-front. Table 2.8 summarizes general advice for each step of project development for decision makers and project-implementing agencies to consider.

**TABLE 2.8. Considerations for the Implementation of Inclusive Urban Rapid Transit Projects throughout the Project Development Process**

STEP OF PROJECT DEVELOPMENT	TASK	TOOLS AND DATA SOURCES
Project initiation or concept	<ul style="list-style-type: none"> <li>Locate available economic opportunities and disadvantaged groups geographically within the city as part of a Poverty and Social Impact Assessment (PSIA)</li> </ul>	<ul style="list-style-type: none"> <li>Secondary sources to analyze job market and services in the metropolitan areas and to identify accessibility constraints, especially in low-income areas</li> </ul>
Planning	<ul style="list-style-type: none"> <li>Evaluate alternative alignments and station locations as part of multicriteria analysis, including availability and accessibility indicators of disadvantaged populations</li> </ul>	<ul style="list-style-type: none"> <li>Isochrones maps and accessibility indicators developed using georeferenced databases of populations by income group from census or household data, jobs (formal and informal), and public services</li> </ul>
	<ul style="list-style-type: none"> <li>Identify mobility patterns of different income segments and potential user groups</li> </ul>	<ul style="list-style-type: none"> <li>Origin-destination surveys, qualitative methods</li> </ul>
	<ul style="list-style-type: none"> <li>Introduce participatory planning mechanisms</li> </ul>	<ul style="list-style-type: none"> <li>Consultations with potential user groups (citizen engagement)</li> </ul>
Design	<ul style="list-style-type: none"> <li>Consider complementary policies to mitigate unintended effects on disadvantaged populations—including affordable housing, land use planning, transit-oriented development, integrated fare policies and demand-based subsidies</li> </ul>	<ul style="list-style-type: none"> <li>Focus groups and consultations with local stakeholders and beneficiaries; land use planning tools; affordability analysis</li> </ul>
	<ul style="list-style-type: none"> <li>Study the physical, operational, and fare integration of the rapid transit project with complementary modes</li> </ul>	<ul style="list-style-type: none"> <li>Designs optimized to minimize physical barriers; integrated fare policy; operational service plans and complementary interventions</li> </ul>
Construction and operations	<ul style="list-style-type: none"> <li>Monitor and evaluate project impacts by geographic region and sociodemographic group (for example, incomes, workforce participation, land values)</li> </ul>	<ul style="list-style-type: none"> <li>User surveys and an ex post impact evaluation study</li> </ul>

## Conclusions and Recommendations

Public transport is the single most important mode of transport in many urban areas worldwide. Rapid transit systems on exclusive rights-of-way play a critical role in promoting social inclusion and quality of life for all as part of a broader,

hierarchically integrated multimodal public transport network. This final section synthesizes some of the most important recommendations from this chapter for how to ensure that urban rapid transit projects effectively improve opportunities and bolster prosperity for all.

***Rapid transit investments—including urban rail—are important opportunities to shape economic development in a socially inclusive manner.*** This role is particularly true in cities where large populations and disadvantaged groups rely on public transport services to carry out economic and social activities. If distributional impacts are considered carefully throughout the planning, design, and implementation process, rapid transit investments can be a catalyst for socioeconomic development, poverty alleviation, and shared prosperity. These benefits are possible because of the large size of the investment, the higher carrying capacity and quality of service that comes from dedicated rights-of-way, and the duration of the assets. A rapid transit line, as the high-capacity, high-quality backbone of an integrated public transport system, needs to be planned, designed, implemented, and operated to serve the maximum number of people while considering the unique needs of different types of users and the distributional impacts.

***Consider the four “As” from the outset (during system and corridor planning) and throughout project development to enhance the socioeconomic impact of a project.*** Indicators for the availability, accessibility, affordability, and acceptability of an urban rapid transit system should be used to evaluate the impact of project alternatives on different sociodemographic groups and spatial areas of the city. Along with the PSIA, this evaluation needs to be incorporated into the project planning and design process. Policy options, analytical tools, and other considerations have been described throughout the chapter to enhance the four “As” for all potential users. Among the most important policies for enhancing social inclusion are multimodal physical, operational, and fare integration (with appropriately targeted subsidies) of the rapid transit project with the larger transport system.

***Rapid transit projects also need to be complemented by other policy and development measures in order to mitigate negative impacts.*** Introducing rapid transit investments often involves significant restructuring of travel patterns, which can have unintended consequences on existing neighborhoods and services. These effects can be mitigated by complementary measures, such as affordable housing, land use policies, transit-oriented development, and incorporation of local and informal bus and other transport service operators into the public transport system.

## Notes

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1. See, for example, the *Hazme el Paro* campaign in Mexico City: <https://blogs.worldbank.org/transport/no-one-helps-nadie-me-hace-el-paro-preventing-violence-against-women-public-transport>.
2. For a discussion of the difference between regional accessibility and local and universal accessibility and guidance on how to maximize the benefits from all three in the context of urban rail development and its impact on urban form, see chapter 16.
3. These tools are available free of charge. See <https://www.tidigitaldata.com/urban>.
4. In this chapter, affordability of the urban rapid transit system is considered from the perspective of the user. A different, but also important, perspective on affordability is to determine whether the up-front investment of the system is affordable for a city or country given its fiscal constraints and limited resources (see chapter 3) and whether the long-term operations of the system are financially sustainable given operating revenue (fares) and costs (such as maintenance and capital renewals) (see chapter 13).

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# 3

## DECIDING WHETHER TO DEVELOP AN URBAN RAIL PROJECT

Georges Darido, Joanna Moody, and Slobodan Mitrić

Rapid transit projects, particularly urban rail, may be among the largest transport investments ever made in a city or metropolitan region. As one rapid transit alternative, urban rail can support important benefits that extend beyond the high-demand corridor in which the line is built: improving accessibility and providing wide-ranging economic, environmental, and social benefits to the region (see chapter 2). Although well-integrated urban rail development can bring significant benefits, it requires large and essentially irreversible outlays of investment capital on long-lived assets in complex, interconnected, and uncertain urban systems (Mitrić 1997). Urban rail development is a high-risk investment and difficult to evaluate. Accordingly, the decision whether or not to develop an urban rail project is not trivial; it should be made only after evaluating and comparing the potential benefits and costs of alternative investments at the transportation system (network) and corridor levels.

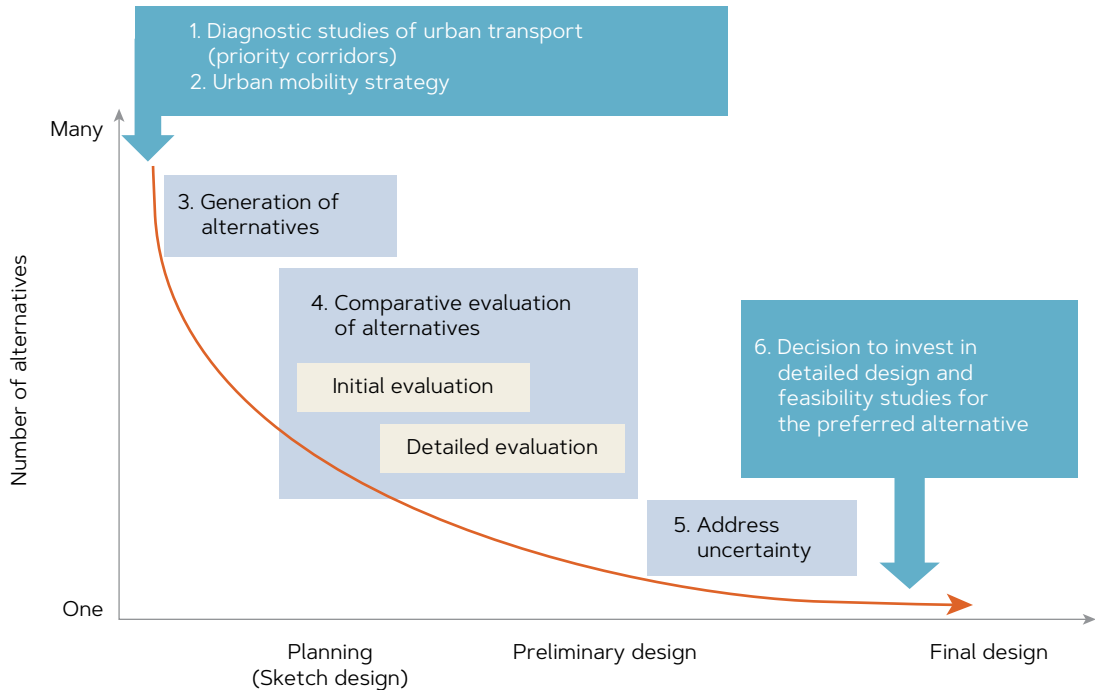
Careful scrutiny and informed decision making before making the investment are even more important given the well-documented history of cost overruns and traffic-revenue shortfalls in large-scale urban transportation projects. In recent decades, the results of ex post evaluations for urban rail and other transport megaprojects

*Photo:* A bus passes underneath the Slussen rail overpass in Stockholm, Sweden, 2009. *Source:* Neil Hester via Flickr (CC BY-NC).

have diverged significantly from the results of ex ante estimations of construction costs, length of construction period, and ridership levels (Naess et al. 2015; Nicolaisen and Driscoll 2014). In urban rail projects, poor-quality planning studies have overestimated ridership (demand) by about 40 percent, often accompanied by cost overruns averaging 45 percent (Flyvbjerg 2007). This poor-quality forecasting occurs even in high-income countries with strong institutions, experienced firms, rich data sources, state-of-the-art tools, ample study budgets, well-established planning and decision-making processes, and active participation by citizens and interest groups capable of providing additional checks on the results of project feasibility studies (Mitrić 1998). In low- and middle-income countries lacking data and the strong technical, institutional, or financial capacity to perform rigorous diagnostic studies and evaluate rapid transit alternatives as part of an integrated urban mobility strategy, demand and cost forecasting errors remain a recurring issue (Mitrić 1998). This historical record calls for great care regarding the technical quality of forecasting activities for ex ante evaluations and highlights the key role that planning studies play during the decision-making process.

Urban rail projects have particular features that make project study, planning, and decision making technically complex, time-consuming, and costly. This chapter discusses these issues and presents a sequence of steps (figure 3.1) to guide readers from conducting a diagnostic study through evaluating transportation alternatives and making an informed decision on whether or not to develop and implement an urban rail project. This process entails six steps:

1. Conduct supply- and demand-side diagnostic studies of urban transportation needs, including analysis of (a) current land use patterns and future urban development, (b) trip origin-destinations, (c) travel patterns, (d) socio-economic data, and (e) interaction between supply of (transport infrastructure and services available) and demand for urban transportation. These analyses culminate in the identification and prioritization of problems and selection of objectives and key performance indicators for the urban transportation system.
2. Develop an integrated land use and urban mobility strategy that clearly identifies (a) priority corridors for rapid transit development, as well as (b) changes to traffic management, policy, regulation, and institutional structure to support the new or improved infrastructure.
3. Generate investment alternatives for the priority corridors identified to resolve or manage the transportation problems in line with selected objectives.

**FIGURE 3.1. Steps in Determining Whether to Pursue an Urban Rail Project**

4. Conduct a comparative evaluation of investment alternatives.
5. Address uncertainty in the evaluation of alternatives.
6. Communicate the results to project decision makers, who then decide whether to carry the preferred alternative (in the case of this handbook, urban rail) from planning to design.

Following such a logical structure is intended to help cities and project decision makers to develop their projects in a transparent and objective way, while still providing flexibility to tailor the process to the local context. However, large differences exist between this conceptually sound structure and its practical applications. Given their scale and potential impact, rapid transit projects are planned and implemented in a social and political environment in which the polarization of diverse stakeholder interests leads to tense and protracted decision making, often requiring repetitive cycling between the decision phase and earlier planning phases. It also means that the initial studies on which project decision making is based have to be designed to respond to the requirements of diverse stakeholders. Recognizing that the rational process presented in this

chapter is surrounded by a political economy, it is important for decision makers to focus on those steps in the process that they can influence. However, political pressure should never be an excuse for insufficient planning or failure to consider urban rail systems carefully against other competitive rapid transit alternatives and as part of a larger, integrated urban mobility strategy.

Although the cost of planning studies and analysis of alternatives can range from US\$1 million to several million U.S. dollars, this cost is usually negligible as a share of total investment in a project. For example, preliminary design studies in the United States often cost 2–4 percent of project construction costs, while the final design can cost 7–11 percent of project construction costs (TCRP 2010, 22). Often the main constraint is not cost but the short time frame imposed on the planning and preliminary design phases. The ability to create a long-lasting political commitment in favor of the project depends greatly on the quality and acceptance of the sketch design and preliminary studies. This up-front investment is also critical for identifying the alternative transportation investment that best meets the needs of project stakeholders within the available budget and time constraints. This investment in deliberate up-front planning helps to solidify stakeholder buy-in and to maximize the benefits of the development; it can also avoid costly project redesign in later phases of project implementation.

This chapter presents guidance on the following:

- Good-practice development of an integrated urban transportation strategy
- Generation of investment alternatives that meet the objectives of that transport strategy
- Comparison of these alternatives at a level of detail that balances the cost of evaluation with the desired accuracy of results

These steps will produce a clear presentation of alternatives under different possible scenarios, allowing decision makers to decide whether to invest funds in studying and designing one tentatively preferred alternative in considerable detail.

### **Diagnostic Studies of Urban Transport**

The first step in planning any large urban transport project is to diagnose the existing conditions and needs of the urban transportation system. The objectives of this diagnostic study are twofold:

- To collect and synthesize the data necessary to evaluate the performance of the current urban transport system

- To develop and calibrate the forecasting and evaluation models that will be used in subsequent phases of the decision-making process

These diagnostic studies enumerate transport needs and challenges, identify their underlying causes, and set planning objectives and their corresponding performance indicators.

The content of any diagnostic study is dependent on the context of the host city—its patterns of land use and activity, spatial distribution of people in different sociodemographic groups, and other factors. First, some relevant data may already be available (for example, Geographic Information System [GIS] land use information and socioeconomic information from a census); a transport model may even exist that could be updated. Second, the focus of a city-specific study depends on its current and future demographic, economic, and financial contexts. These contexts vary widely around the world, given differences in income distribution, urbanization rates, motorization levels and trends, land use and travel patterns, existing modal split, relative roles of public and private sectors in the provision of public transport services, subsidy practices, level of road network development, and perceived urgency of transport or economic problems.

### **Demand-Side Diagnostic Activities**

On the demand side, diagnostic activities involve a household travel survey to capture household demography, economics, motorization, and activities (including origins and destinations). Demand-side studies also include socioeconomic data on the distribution of population, income, and jobs as well as willingness-to-pay surveys to assess the values of time of different types of people. Home-based data collection is then supplemented by traffic and passenger counts (including trips by nonmotorized modes) and diverse studies of local economy and urban patterns, including land use development. In addition to household travel surveys, new methods of passive collection of “big data,” including crowdsourcing and mobile phone call data records, can help to inform how people move around the city. All of this information informs the city on when and where people travel and the key problems that users face given existing travel constraints. It can be used to identify and prioritize corridors where high-capacity public transport is necessary to meet demand and to determine how passengers may shift from other modes if an urban rail line or other supply intervention is implemented.

### **Supply-Side Diagnostic Activities**

On the supply side, diagnostic activities collect data on the urban transport system, including infrastructure such as roads, bike lanes, and sidewalks as well

as existing or planned transport services and land use developments. Supply-side studies consider services provided by taxis or fleets of privately owned vehicles outside of formal public transport service. Although such routes are traditionally hard to capture, new open-source tools are available that use crowdsourcing and cell phones to map these routes throughout the city.<sup>1</sup> Supply-side studies also consider the institutions and policies that plan, operate, and regulate urban development patterns, infrastructure, and transport services. This information is useful for identifying the planning objectives and their performance measures.

In addition to a review of supply infrastructure and institutions, it is important to incorporate a public expenditure review for the urban transport sector in the city. Such a review evaluates fluctuations in local economic activity and summarizes the flow of capital as well as operations and maintenance spending across all sources for urban roads and public transport services during the preceding 5–10 years. It may suggest potential funding constraints for any future investment project or program, which can be especially important given the large jump in both capital and current spending that a new or expanded rapid transit system (including urban rail) would require.

While it is not yet common practice, it is highly recommended that these early diagnostic studies be used to develop (or update) a city-level transportation model that is well calibrated to explain and explore current conditions (base year). Since these diagnostic studies and models lay the foundation for a more detailed evaluation of project alternatives, their quality will affect the quality of all subsequent phases of the decision-making process.

## **Demand Modeling**

Key factors in the success or failure of an urban rail project are its ridership and corresponding operating revenue.<sup>2</sup> Therefore, demand and revenue modeling and forecasting are crucial activities throughout the decision-making process. Travel demand forecasting is an analytical process for predicting patterns of travel demand in a region, traffic volumes in transport systems, and required service levels of transport facilities. Forecasting begins with modeling current travel behavior in a region, including when and how often people travel, where they travel, what mode they use, and what path or route they take. These models can then be used to predict how these behaviors will evolve in the future. Such forecasting most often uses a mathematical modeling approach to describe the causal relationship between land use and socioeconomic conditions and demand for transportation systems or services (by mode).

Travel forecasting supports good strategic and policy decision making and is necessary to inform any major infrastructure development. Travel forecasting is best applied first in the analysis of alternatives to compare different modal and service options and how they meet the travel needs of a region. Travel demand forecasting can be refined throughout the project development process, providing crucial data for other analyses, including preliminary and detailed project design, social and environmental impact analysis, risk assessment, cost-benefit analysis, and financial planning.

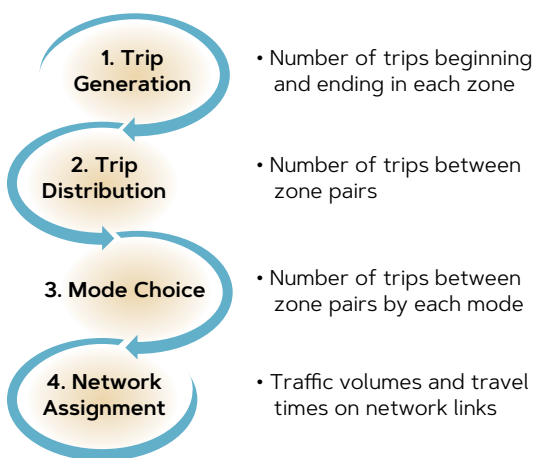
The quality of outputs and predictions made by travel demand forecasting models depends on the quality of the input data used to calibrate the model to base-year conditions. Most travel demand forecasting models require current and accurate information on the following:

- The sociodemographic characteristics of the regional population of potential and actual trip makers, including age, gender, income, vehicle availability, household size, and employment status
- The origin and destination of trips among geographic zones, trip purposes, and the socioeconomic and demographic factors of households or individuals making these trips
- Network description and attributes of all modes within the existing and planned transport system, such as travel times and costs, service frequencies, routes and stations, and number of transfers
- Land use, including activity, density, and mix of uses (type of commercial or residential)
- Other mobility policies or interventions planned around the corridor of interest, such as road or airport development, demand management, and parking
- Land use and development plans in the area

In most cases, these data come from national or regional censuses,<sup>3</sup> travel surveys, traffic counts, and historical data for mature public transport networks, including transport system inventories (schedules and GIS) and information and communication technology (ICT) applications, such as Global Positioning Systems (GPS), vehicle tracking, and Integrated Circuit (IC) card fare payment records. Once these prerequisite data are collected and verified, they can be used throughout the decision-making process in different travel demand modeling techniques that range in their level of complexity and application (see table 3.1).

**TABLE 3.1. Summary of Demand Modeling Techniques for Rapid Transit Corridors**

INDICATOR	FOUR-STEP MODEL	STRATEGIC OR SKETCH MODEL
Level of detail	Detailed, disaggregate model that captures travel demand and assigns it to the existing land use patterns and urban transport supply	Systemwide, coarse-grained, aggregate
Cost	More data and resource intensive to build and update	Relatively inexpensive to build and operate
Use and limitations	Current or shorter-term simulation of demand and modal split for different supply-side scenarios; can be particularly useful for considering alternative transportation investments (such as urban rail)	Suitable for exploring long-term futures and programming of multiple rapid transit lines in a network; can fail to capture nuances among different corridors or neighborhoods of the city

**FIGURE 3.2. Four-Step Travel Demand Model Process and Its Outputs**

Source: Modified from Ho 2016.

### The Traditional Four-Step Model

The four-step model is the most commonly used technique for modeling travel demand. This model generates and then distributes trips among geographic zones, factors trips by mode, and assigns trips to the road and transit networks (see figure 3.2).

The four-step travel demand model simultaneously addresses a broad range of system changes, accounts for modal competition, and evaluates long-term interactions between land use and the urban transportation system. Therefore, this approach (or even more advanced activity-based models) is recommended for project feasibility studies or detailed analysis of a preferred project alternative in step 2 of the decision-making framework described in this chapter. However, the four-step model requires

significant data and analytical resources, requiring both monetary investment and development time. Furthermore, its complexity may wrongly suggest unsupported accuracy if the model does not have sound inputs or is poorly structured, calibrated, and tested (Ortúzar and Willumsen 2011). In some cases, it may be more appropriate to use a simpler forecasting technique, such as incremental forecasting models or sketch planning, commensurate with the level of detail needed for the current step.



### **Strategic or Sketch Models**

Although it is often worth spending significant analytical and monetary resources to carry out a full four-step model to forecast travel demand for the metropolitan region and to use this information to evaluate different corridor improvements, the cost is often too high to apply the model for many alternatives. Furthermore, the requisite detailed, current socioeconomic and trip information may not be available. For these reasons, lower-level demand estimation techniques, such as incremental forecasting models or sketch planning, may be appropriate for early strategic planning, when analysts are more interested in modeling long-term changes in land use and demographics and understanding the trade-offs among many alternatives rather than in obtaining an accurate estimate for a single project.

Incremental forecasting models estimate base-year trip tables from existing travel survey and network data, factor these trip tables based on long-term changes in land use and demographics, and then “pivot” trip tables using elasticities of demand to account for shorter-term changes in service, such as changes in fares, service frequencies, or speeds (Ortúzar and Willumsen 2011). The advantage of the incremental forecasting model is its simplicity and its communicability since the results require limited analysis and are linked directly to real, measured travel data. Although this approach can be useful for modeling existing and near-future system conditions, it is very difficult to apply this technique when origin-destination patterns may shift dramatically with major changes in the transport network, such as a new, expanded, or highly upgraded urban rail system.

Sketch planning models are a simplified four-step process that uses skeleton networks to describe service characteristics of the transport system (usually at a district level). Like incremental forecasting models, sketch planning models have the advantage of quick development time and limited data requirements, but they often lack the geographic granularity of the zones used in traditional four-step models. For this reason, sketch planning models give aggregate forecast results that can be useful for strategic- or policy-level analyses, but are not applicable for facility- or operational-level analysis (Ortúzar and Willumsen 2011). They can be useful for informing the decision of whether to develop a rapid transit project, but results need to be refined and additional analysis undertaken to get more detailed demand forecasts for specific planning and design decisions for a single project.

### **Demand Modeling in Low- and Middle-Income Countries**

Low- and middle-income countries may face additional challenges and uncertainties in demand modeling due to a more dynamic development future and the

possibility of large-scale changes in travel behavior (such as motorization) due to economic and population growth. Therefore, it is important to review the entire forecasting process and to ensure that all assumptions and inputs for model structure, calibration, and validation are objective and transparent. In addition, it is possible to employ two techniques to enhance the quality of forecast results (Ho 2016):

- First, analysts should segment the population of trip makers to understand the composition of forecasted demand. Understanding how demand along the planned rapid transit line varies by income class, for example, can help to inform the fare and discount policy of the public transport system.
- Second, it is important to examine the variability of forecast results under different futures to get a sense of the robustness of demand under uncertainty in economic growth, demographic change, and other factors given existing land use and development plans.

When preparing to conduct a demand forecasting study during initial project development, it is important not to underestimate the effort involved. Many metropolitan regions in high-income countries have a planning organization dedicated to travel forecasting and have in place the necessary data and qualified and experienced technical staff to update or expand their four-step model relatively quickly. In many low- and middle-income countries, this institutional and modeling infrastructure may need to evolve over time. Low- and middle-income countries may need to spend additional resources to gather the necessary data, train agency staff, and develop the analytical model before the forecasting study can begin.

It is important to consider and choose carefully the most appropriate method for the specific institutional and project circumstances. This can often mean considering a less-advanced travel demand forecasting method first and then cooperating with national-level agencies and international experts to build up the technical capacity to employ more advanced state-of-the-art models (such as activity-based modeling or microsimulation). In such cases, efforts should be made to gather detailed socioeconomic data on population, income, and employment distribution through an updated census and household survey of travel demand or detailed land use and GIS data.

### **Using the Demand Outputs**

The outputs of demand modeling are used throughout the six-step process when deciding whether to pursue a rapid transit investment. Base-year demand models are used to understand current conditions and identify priority corridors

in need of capacity expansion and infrastructure investment in the first diagnostic and strategy-development steps. Near- and long-term forecasts are then used for comparative evaluation of investment alternatives and succinctly communicating the results of these evaluations to project decision makers.

### *Base-Year Demand Modeling*

Demand models carefully calibrated to the present (base-year) conditions are useful both in the diagnostic study and immediately afterward in the urban transportation strategy-making process. Base-year conditions provide compact descriptions of complex travel behavior across the city and can help to identify key corridors where high-capacity public transport may be needed to meet existing demand. Careful calibration of these base-year models is also needed to forecast future demand more accurately.

### *Near-Term Demand Forecasting*

Demand forecasts developed from these base-year models are then used to evaluate different transportation alternatives. Ridership forecasts that come out of these models inform the results of economic and financial analyses of alternatives since ridership determines the number of people benefiting from any new infrastructure or service as well as the amount of fare revenue generated. Furthermore, elasticities from demand models permit forecasting of modal shifts based on fares and service attributes of any planned transportation alternative. Demand studies are, therefore, fundamental to the decision to develop a rapid transit project and a necessary input to many other prerequisite studies. Furthermore, for procurement strategies that outsource system operations and share demand risk between the public sector and a private partner, these demand models must be of the highest quality in order to determine appropriate compensation schemes for long-term operations and maintenance (see chapters 8, 9, and 10).

### *Long-Term Demand Forecasting*

Since the economic lives of urban rail systems are typically quite long (greater than 50 years), the need for long-term forecasts of demand and revenue poses multiple challenges. A tension exists between short-term and long-term forecasts. Both are based on a transport demand-supply model calibrated for the present conditions. To reduce ridership and revenue risks, models can be designed for maximum accuracy for current conditions and short-term (for example, first-year) forecasts. These models are generally poorly suited for long-term forecasts due to the difficulty (even impossibility) of producing credible long-term forecasts of the demographic, economic, and land use factors

underlying transport demand. Moreover, the need for long-term forecasts is not limited to the urban rail alternative; it extends to all other (lower-cost and shorter-lived) rapid transit options being evaluated in a given context. These forecasts are also subject to deep uncertainty. Therefore the outputs of these models should be expressed as reasonable ranges of ridership that take into account modeling error as well as uncertainty in the future. These ranges, while not accurate point estimates, can be useful for comparing the relative benefits to users of different transportation alternatives, but they do not guarantee any minimum level of ridership on completion of the project.

### Development of an Integrated Urban Mobility Strategy

The data, models, and objectives arising from the diagnostic step are necessary inputs for an integrated urban mobility strategy. This strategy identifies key transportation corridors for capacity expansion and recommends long-term transportation investment packages to alleviate current issues and plan for future growth of demand. This strategy is a package of actions, which may include the following:

- Investments in road or public transport infrastructure
- Policies for allocating existing street space among modes
- Pricing and subsidy policy for both public transport and urban road subnetworks
- Institutional changes and regulation, particularly in the relative roles of the public and private sectors in the provision of public transport service
- A combination of these (see box 3.1)

Integrated urban mobility strategies connect transportation infrastructure, pricing, policy, and management solutions with land use considerations and other sustainable development goals such as shared prosperity and social inclusion (see chapter 2) or environmental sustainability.

The details of the development of such a strategy are beyond the scope of this handbook and the subject of numerous publications (see, for example, May 2005). For the purposes of this handbook, it suffices to remember that the development of a new rapid transit system or the expansion of existing rapid transit infrastructure is only one measure within an urban mobility strategy. To meet the numerous development objectives of the host city, the development of other infrastructure and services, use of new management

**BOX 3.1.****Key Components of an Integrated Urban Mobility Strategy**

Transportation master plans are often used to visualize the long-term transportation infrastructure network throughout the metropolitan region. However, such plans are often static and focus exclusively on the provision of new infrastructure. As such, they may be complemented by a mobility strategy that considers the short- and mid-term phasing of development to reach the long-term vision, may have a more limited area of interest, and may account for constraints on resources. Furthermore, an integrated mobility strategy identifies infrastructure measures in combination with management, pricing, and land use measures to achieve better performance against transportation policy objectives (May and Roberts 1995). Possible types of measures include, but are not limited to, the following:

- *Land use and development.* Density and mix of development (zoning); location relative to transport infrastructure; infilling and control of peripheral development (sprawl); land reserves for endowments, public facilities, infrastructure, and services
- *Transport infrastructure.* New rail (or light rail) lines; bus rapid transit (BRT) or other exclusive bus right-of-way; new stations (bus or rail); pedestrian and bicycle facilities; multimodal integration and transfer facilities; park-and-ride facilities; parking supply; new highways; highway improvements

- *Pricing.* Parking charges (on- or off-street); road pricing; fuel prices, carbon taxes; public transport fare levels and structures
- *Management.* Service frequency improvements (bus or rail); bus route restructuring; bus priority; urban traffic control and demand management (such as coordinated signaling); traffic calming; one-way streets; parking control (on-street, public or private lot); car- or ride-sharing regulations; passenger information; telecommunications
- *Information and attitudes.* Public awareness and education; apprenticeship and university degree programs in critical trades related to transport infrastructure development and operations; internal capacity building within public authorities and project-implementing agencies

Urban transport strategies require integrating measures into a package that is balanced in its treatment of modes (road and public transport), geographic areas in the city, and groups of users. An integrated approach—in which provision of infrastructure, management of existing infrastructure, pricing of infrastructure use, and land use are coordinated—can significantly reduce the scale of urban transport problems. For dense urban areas with severe congestion and high-capacity corridors, the provision of new rail infrastructure may form part of such a strategy, but has to be complemented by other measures.

Source: Adapted from May 2005.

and pricing practices, and land use policies must complement investment in rapid transit. It is only after completing an urban mobility strategy and prioritizing transportation corridors that decision makers can advance to the design and evaluation of different transport alternatives (such as urban rail) for the key corridors.

### **Generation of Investment Alternatives**

At the conclusion of strategic planning, corridors are identified as top priorities for improvement and investment. The generation and evaluation of alternatives identify the most desirable alternative that solves the transport and related problems of a given corridor, is cost effective, and is affordable. Analyzing and comparing reasonable investment alternatives are required to decide which type of project to pursue.

A sound analysis of alternatives is critical for identifying the type of transportation investment that provides the greatest social and economic value to the host city (within a fiscally constrained environment). This analysis is conducted prior to making the decision to plan and design a transportation project. The most desirable option has to be demonstrated with analytics and not predetermined from the outset. The need for such an assessment is especially relevant given the size and complexity of rapid transit solutions and even more important in the case of low- and middle-income countries where the opportunity cost to society is likely higher.

A standard principle of problem solving is to examine all relevant options. However, investment planning for large public transport systems tends to be constrained by the cost of studies, by the temporal window of political and economic opportunity, and by other specifics of the local context. It is important to consider a range of transportation alternatives that include all reasonable and promising choices available to decision makers, while keeping the number of alternatives as small as possible to reduce the time, cost, and complexity of the analysis process.

The usefulness of the evaluation of alternatives in the transportation investment decision-making process rests in large part on the choice of alternatives (Vuchic and Casello 2007). The set of alternatives must meet the corridor's goals and objectives for improvement that were determined during the diagnostic studies. These alternatives should be structured to isolate the differences in performance among potential supply-side solutions (such as road versus bus versus rail investment) in solving the transportation problems outlined in the urban transportation strategy. Only then can technical analysis produce the information that decision makers need when selecting a particular project.

After considering potential sources of uncertainty in the evaluation of alternatives, the end result is the information necessary to decide whether to undertake detailed planning of one tentatively preferred option.

### Typical Alternatives

In a given corridor considering urban rail development, the range of alternatives should include a no-build transportation system management alternative, one or more urban rail alternatives, and other rapid transit options (such as light rail or BRT) (see tables 3.2 and 3.3). The no-build alternative is included in the

**TABLE 3.2. Main Physical Characteristics of Metro, Light Rail, and Bus Rapid Transit**

COMPONENT	METRO	LIGHT RAIL TRANSIT	BUS RAPID TRANSIT
Running way	Rail	Rail	Road
Type of right-of-way	Underground, elevated, at-grade	Usually at-grade (some elevated or underground)	Usually at-grade (some elevated or underground)
Segregation from traffic	Total segregation (no interference) with right-of-way protection	Usually longitudinal segregation (at-grade intersections), with some full segregation applications	Usually full segregation, with some applications of longitudinal segregation (at-grade intersections)
Type of vehicle	Trains (multicar)	Trains (two or three cars) or single cars	Buses
Type of propulsion	Electric	Electric, with few diesel applications	Usually internal combustion engine (diesel or compressed natural gas); growing number of applications with hybrid transmission, battery-electric, or hydrogen fuel cell
Speed	30–40 kilometers per hour	20–30 kilometers per hour	20–30 kilometers per hour
Stations	Level boarding	Level boarding or stairs	Level boarding
Payment collection	Off-board	Usually off-board	Off-board
Systems	Signaling, control, user information, advanced ticketing (magnetic or electronic cards and mobile phone payment)	Signaling, control, user information, advanced ticketing (magnetic or electronic cards and mobile phone payment)	Control, user information, advanced ticketing (electronic cards), traffic signal priority at intersections, fleet management systems
Service plan	Simple; trains stop at every station between terminals (some express services or short loops)	Simple; trains stop at every station between terminals	From simple to very complex

Sources: Adapted from FTA 2009; UN-Habitat 2013; Vuchic 2007.

**TABLE 3.3. Impacts and Requirements for Metro, Light Rail, and Bus Rapid Transit**

INDICATOR	METRO	LIGHT RAIL	BUS RAPID TRANSIT
Required permanent roadway space	Low impact on existing roads	Two lanes (narrow, 5–8 meters)	Two to four lanes of existing roads (7–15 meters)
Distance between stations	Medium to high (1 kilometer or more)	Short to medium (500 meters or more)	Short to medium (400 meters or more)
Flexibility	Low (operates on fixed tracks)	Low (operates on fixed track)	High (buses can operate inside and outside busways)
Traffic impact during operation	Less congestion (does not interfere with surface travel)	Variable (takes some space from traffic)	Variable (takes space, but reduces traffic interference from buses)
Construction impacts	High (takes longer time, can involve excavation or construction of an elevated structure)	Low to medium (depending on type of construction)	Low to medium (depending on type of construction)
Integration with existing transport providers	Limited potential	Limited potential	Good potential
Maximum frequency	High (20–30 trains per hour)	High (20–30 trains per hour)	Very high (40–60 buses per hour per platform)
Reliability	High (no interference from other traffic)	Medium to high (depending on traffic interference)	Medium to high (depending on traffic interference and manual control, could be affected by bunching)
Human safety	Fully segregated from all road users, so lower risk of accidents	Segregated from traffic only, some risk to other road users	Largely segregated from traffic, some risk to other road users
Noise	Low (depending on insulation)	Low to medium (depending on tracks)	High (internal combustion engine and rubber tire on roadway)
Air pollution	No tailpipe emissions; power generation pollutants depend on energy source and technologies used	No tailpipe emissions; power generation pollutants depend on energy source and technologies used	Tailpipe emissions for internal combustion engines and power generation pollutants for alternative powertrains; power generation pollutants depend on the engine, fuel, and emission control technology

*(table continues next page)*



**TABLE 3.3. Impacts and Requirements for Metro, Light Rail, and Bus Rapid Transit**  
(Continued)

INDICATOR	METRO	LIGHT RAIL	BUS RAPID TRANSIT
Greenhouse gas emissions	38–68 grams per passenger-kilometer	38–100 grams per passenger-kilometer	28–204 grams per passenger-kilometer
Passenger experience	Smooth ride, high comfort (depending on occupancy)	Smooth ride, high comfort (depending on occupancy)	Irregular ride (sudden acceleration and braking), medium comfort (depending on occupancy)

Source: Adapted from Gwilliam 2002; Halcrow Fox 2000; UN-Habitat 2013; Wright and Fjellstrom 2003.

analysis to provide a benchmark for comparing other more capital-intensive alternatives that include the development of new infrastructure. In general, as the exclusivity of the right-of-way increases, so does the initial investment cost.

This suggested range of alternatives highlights the trade-offs inherent among different levels of capital expenditure, public benefit, and risk over time. Each of these alternatives is, in fact, a family of alternatives, and the specific design elements must be refined throughout the evaluation process in order to match the needs of the specific corridor within a predefined time frame. Each alternative has to be feasible within the economic and political environment of the host country and city and be refined until it is operationally, physically, and financially reasonable. In this way, there are no irrelevant alternatives (Kain 1992), and each alternative in the analysis is competitive along at least one dimension: cost, benefit, or risk.

#### *The No-Build Transportation System Management Alternative*

The no-build alternative is a family of alternatives that represent the range of possible interventions that do not include investment in new infrastructure. The no-build alternative can range from “do almost nothing” to a comprehensive package of improvements in transportation system management and services and changes in pricing and policy.

Many studies speciously define the no-build alternative as the “do almost nothing” alternative that includes no transportation improvements other than those already funded and under development in the metropolitan region. In many cases, this is not a viable option given the city’s existing transportation issues (identified in the diagnostic studies) and the objectives of the urban transportation strategy. For cities with corridors in need of significant capacity expansion, an alternative that represents no additional infrastructure expansion

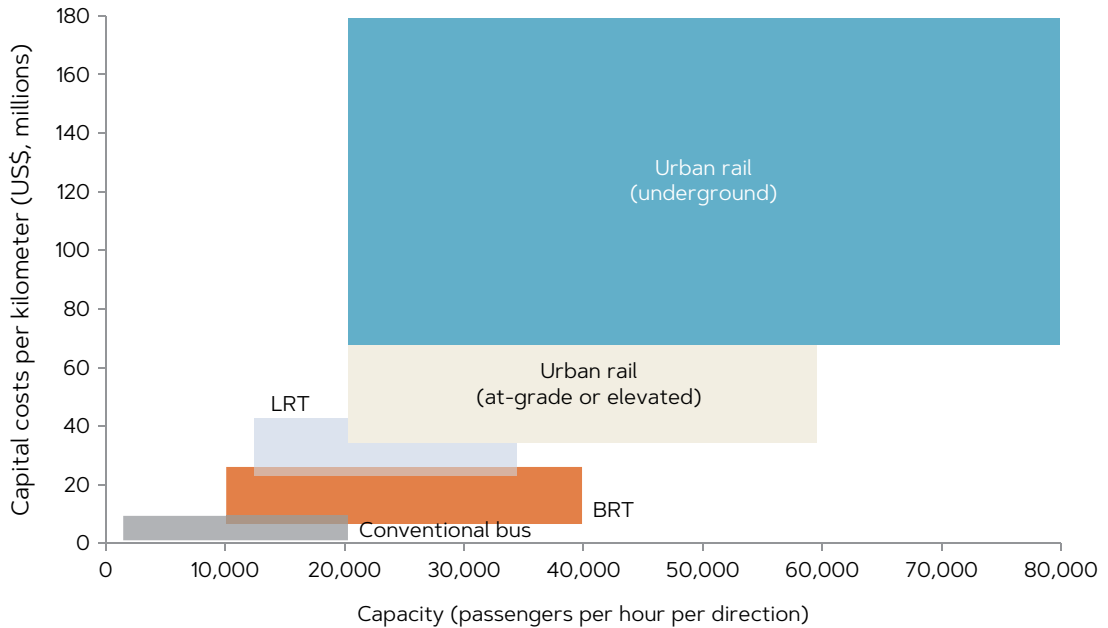
or system improvement would lead to many negative consequences (costs), including unreasonable levels of congestion and suppressed development (Kain 1992). Although the “do almost nothing” alternative often represents no additional capital expenditure and may seem to be a “zero-cost” alternative, it is important to consider the substantial opportunity cost associated with no investment. This opportunity cost includes the time and value lost due to congestion, pollution, accidents, and other negative externalities from failure to invest in critical infrastructure development or service improvements.

When evaluating a rapid transit system against a no-build alternative, it is important to consider a package of lower-cost improvements to existing road infrastructure, new traffic management strategies (including transit signal priority), improvements in bus service and routing, improvements in transport facilities for walking and biking, or a combination of these interventions as the baseline. For rapid transit systems with existing lines, new operational strategies can help to leverage existing infrastructure assets to improve service, save money, or promote energy savings.

The no-build system management alternative should thus represent the best possible transportation solution through improvement of existing infrastructure and systems. It is designed to address specific transportation problems in the corridor and to demonstrate the extent to which these problems can be solved without a major investment in new urban rail or other infrastructure. Therefore, the transportation system management alternative (rather than the “do almost nothing” alternative) should serve as the baseline for evaluating the added costs and benefits of an urban rail system or other rapid transit alternative (FTA 2005).

### *Rapid Transit Alternatives*

Rapid transit alternatives include bus rapid transit, light rail transit (LRT), and urban rail systems (metro or commuter rail). One alternative is to construct (or expand) an urban rail system. For corridors with demand volumes that warrant the consideration of high-frequency, high-capacity urban rail, bus rapid transit and LRT may only be competitive alternatives to urban rail if they are introduced on dedicated, off-street rights-of-way with signal priority over or separate signaling from other street traffic (figure 3.3). Urban rail systems and other rapid transit alternatives that involve dedicated rights-of-way often require the highest level of capital investment, but provide superior service to street-based formats (which are cheap but quickly become congested) (Mitrić 1997). For very dense cities, urban rail networks may be the best way to cope with very high travel volumes in the long term.

**FIGURE 3.3. Comparison of Initial Cost vs. Capacity for Rapid Transit Modes**

Source: Adapted from UN-Habitat 2013.

Note: BRT = bus rapid transit; LRT = light rail transit.

In all cases, it is also important to consider that any rapid transit technology is a summation of technical solutions; there is room to tailor the mode to the needs of the host city and its urban form. These rapid transit alternatives, including urban rail, are all groups of alternatives since costs and performance may vary widely depending on the travel way location, system technology, infrastructure and vehicle specifications, governance framework, and many other design parameters (Mitrić 1998).

There is no dominant mode of rapid transit across contexts; rather, there is often overlap in their capacities, capital costs, and operations and maintenance costs (figure 3.3). It is important to consider multiple alternatives that are designed to be competitive along at least one dimension of cost, benefit, and risk given the specific corridor of interest. It is also important to recognize that road and public transport improvements can be packaged together as part of an integrated urban mobility strategy to address myriad needs. Alternatives should be multimodal and emphasize the importance of system integration.

Furthermore, any urban rail investment option will likely be packaged with complementary investments, policies, and institutional innovations, the combined effect of which has to be evaluated carefully over time.

### **Level of Design of Alternatives**

The level of detail in the design of alternatives will directly affect the accuracy of estimates of capital and operating costs as well as benefits and impacts. Although the project development laws of different countries define these levels of design in different ways, it is common to progress through three design levels when developing a project: sketch design, preliminary design, and detailed (prebid) design.<sup>4</sup> One way to distinguish the level of detail at different steps of project development is by the precision of the representation of space and scale on maps used in project analysis. Sketch design during planning considers the project design at the metropolitan region (1:50,000 scale) to corridor level (1:5,000). Preliminary design moves from corridor layout to station level (1:500), while detailed design for bidding and construction requires 1:500, 1:100, and even 1:50 for specific sites.

For a design and its corresponding cost estimates to serve as a solid base for project appraisal, it is ideal to have all alternatives completed at a detailed design level, thus reducing uncertainties in estimates of project costs, risks, and benefits to a minimum.<sup>5</sup> However, this would be a very expensive approach in any context where multiple alternatives to an urban rail investment are considered and, therefore, beyond the means of most host cities or countries. Decision makers have to reconcile the obligation to consider all relevant investment alternatives with the desire to increase the level of detail in the design of those alternatives and thus reduce the risks related to construction costs. Most alternatives at the transport system level are completed at the sketch-design level, rather than the preliminary or detailed design levels. When evaluating modal alternatives at the corridor level, the design would benefit from greater certainty; it should be done at the preliminary design level in which all major project uncertainties (including social and environmental) have been identified and adequately assessed.

When multiple alternatives are considered and one alternative is an urban rail project, the issue of design level and evaluation cost is resolved by organizing the design and evaluation process in several stages, starting with multiple options and converging to one. It is common to start with evaluating many alternatives using cost and benefit estimates done at the least expensive, sketch-design level. From this sketch-level evaluation, two or three of the best alternatives can be chosen and compared with the “no-build transportation system management” alternative and with each other in additional detail.

The definitions of all variables should be as comparable as possible across modes, their valuation (and weight) should be defensible, and the process should be transparent and easily communicated to decision makers.

After this staged evaluation of alternatives, decision makers can choose a preferred modal option to be completed at the preliminary design level (see chapter 5). At this stage, it is advisable to analyze the different combinations of design features (such as average speeds, type of rolling stock, station design, and location of depots and workshops) for a single modal option. Finally, it is always advisable to allow the possibility of backtracking if the costs at the detailed design level turn out to be much higher than those available at the preliminary evaluation stage. Project optimization tools may be useful in such cases (see chapter 6).

## Evaluation of Alternatives

Due to the requirements for long-range forecasting, the high risks linked to the scale of investments, and the breadth of possible impacts, urban rail projects stretch the general methodology for economic evaluation to its limits. Historically, being revenue earning, urban transport investments were evaluated using financial analysis carried out solely in monetary terms (costs and revenues), typically from the point of view of private investors and without reference to other public transport options. Then, economic evaluation expanded the agenda to include social benefits that can be expressed easily in monetary terms. Both of these analyses—financial and economic—are required in current applications (World Bank 2011). The two are done in exactly the same way, only with different numbers. They are also done in the same way whether the level of detail in the design of alternatives is low or high, with corresponding levels of accuracy in the demand models (Belli et al. 1998; Mackie, Nellthorp, and Laird 2005).

The current trend in economic evaluation is toward making evaluation more complex by considering impacts that are not expressible either in monetary or in monetized (shadow-priced) terms (Boarnet 2007). This emerging, complex, and expensive multicriteria evaluation structure can capture a huge complementary array of other social impacts and concerns related to the project (see chapter 14). This current trend notwithstanding, the ordinary practice is guided by the capacity of most decision makers and analysts evaluating alternatives. The maxim for a practitioner should be to do the traditional economic and financial analyses and then to increase the level of complexity (in a multicriteria analysis) as called for by the specific setting and available resources. Given the difficulties of valuing and long-range forecasting even the basic impacts

(such as costs and travel times) of urban rail and other transportation investments, the economic evaluation of alternatives should be limited to only these very basic impacts that can be most easily monetized. All other positive and negative externalities (see table 3.3) should be considered in the multicriteria evaluation framework.

### **Economic Evaluation**

Economic evaluation<sup>6</sup> is a fundamental tool for understanding the positive (and negative) impacts of an urban rail project relative to the necessary investment. Economic evaluation is useful for comparing various transportation improvement alternatives, establishing priorities for approved projects, and determining if an urban rail project should be undertaken and how it should be done. Defining the purpose of the economic evaluation will help to determine what benefits and costs should be included as well as other aspects of the analysis (Transportation Economics Committee 2010).

The appropriate level of effort to be invested in the economic evaluation depends on its expected payoff; when the proposed project has very high costs and far-reaching benefits, such as urban rail development, it is worth investing considerable effort to determine whether benefits exceed costs and to identify the most economically advantageous project. Conversely, the analytical effort should not be greater than what would be lost by pursuing a project that is not cost beneficial or by selecting the less cost effective of two projects. In most situations, the incremental payoff from choosing the right alternative far exceeds the resources consumed in doing the economic evaluation (Transportation Economics Committee 2010). In any analysis, effort should be concentrated on estimating and evaluating the benefits and costs that are largest and that differ the most among the various modal alternatives and project design options.

Structuring an economic evaluation for a project starts by considering which and whose impacts (costs and benefits) should be considered. Economic evaluation generally considers all benefits and costs that accrue to anyone, including stakeholders such as the regional or metropolitan government, the project-implementing agency, financiers, private partners (if applicable), current and potential users of public transport, and the general public. With differing stakeholder objectives, economic evaluation can be used to highlight certain types of impacts. For example, in communicating the benefits of a project to a municipal transportation authority, the project-implementing agency might highlight reduced traffic congestion or improved safety, while users may be more interested in improved accessibility and the general public may be concerned with the impacts that accrue to residents or businesses (particularly during construction) within the jurisdiction sponsoring the project. Due to the diverse stakeholder

interests, the perspective and scope of the evaluation has to be established and protected before it is begun.

### *Common Economic Benefits*

Several benefits are most commonly considered in the economic evaluation of transportation projects,<sup>7</sup> including the following:

- *Passenger travel time savings or delay reduction* defined as the difference in generalized travel time for an entire journey from origin to destination before and after project implementation. For a journey by urban rail, total travel time would include walking time from the origin to a station entrance (access), waiting time, travel time within the vehicle(s), transfer time (if applicable), and time from station exit to destination (egress). Time savings is expressed in monetary terms by multiplying the travel time saved by the estimated distribution of the value of time of future users.
- *Change in consumer surplus for passengers*, including any change in fares, together with any changes in accessibility, transfers, headways, convenience, and service frequencies. A consumer surplus approach is one way to quantify the positive externalities from a project as part of a larger transport network with many possible spillover effects.
- *Changes in the operating costs of urban transport*, which relate to potential cost savings from replacing urban bus services and associated road maintenance costs with urban rail services, assuming the migration of passengers from other modes and associated reduction in vehicles per kilometer on the roads. Fares paid by users are not included in any economic evaluation since they represent a net-zero transfer of cost (from user) to benefit (to operator).
- *Changes in externalities of the urban transport system*, which relate to the expected reductions in road vehicles per kilometer by various modes (particularly private cars) due to the expected modal shift to the new urban rail system. This modal shift can reduce the number of traffic accidents, the emission of local air pollutants and greenhouse gases (GHGs), congestion, and the need for parking facilities. Each of these externalities can be quantified and monetized by calculating the physical change (for example, changes in GHG emissions) and multiplying it by the estimated unit savings from available sources (for example, World Bank 2011).

### *Summarizing Results of Economic Evaluation*

The net effect of all discounted benefits and project costs over the lifetime of the project is then aggregated into a useful measure that summarizes the

benefit-cost comparison for project decision makers at the current time. Several measures are typically used to summarize economic evaluations—including benefit-cost ratio (B/C) and payback period—but the most common for comparisons of alternatives are the net present value (NPV) and the economic internal rate of return (EIRR).

- NPV is the net discounted benefits minus the net discounted costs (in current currency). The greater the NPV above zero, the greater the overall benefit of the project less its costs.
- The minimum attractive EIRR is the discount rate for which the discounted benefits equal the discounted costs in current U.S. dollars or other preferred currency (or the net present value of the project is zero) (Belli et al. 1998).<sup>8</sup>

The most appropriate method depends on the circumstances. Project-implementing agencies may choose to use multiple measures to represent the results of the economic analysis, since different indicators can yield slightly different rankings of alternatives.

In addition to aggregate indicators of economic evaluations, it is also important to consider how benefits and costs are distributed among different sociodemographic groups and geographic areas of the city (see chapter 2), particularly accounting for differences in willingness to pay and value of time.

### *Critical Evaluation Decisions*

Large, long-lived, rapid transit infrastructure investments shape the development of the city and its economy for generations. Standard economic analysis tools are not able to accommodate this adequately—after about 20 years, all benefits are discounted to virtually nothing. Therefore, the choice of evaluation horizon and discount rate can have a large impact on the results of the analysis and must be chosen carefully to address the value from projects that accrue to future generations. These corrections are imperfect, and it is important to carry out any economic analysis in a multicriteria framework that accounts for nonmonetized benefits compatible with the long-term vision for development of the city.

*Evaluation Horizon or Time Period.* Since benefits and costs are summed over future years, the evaluation horizon can affect the outcome of the economic and financial analysis. The evaluation horizon starts with the first expenditures and extends through the useful life of the alternative or some future time at which meaningful estimates of effects are no longer possible. Formally, the planning horizon must be equal to the economic life of the longest-lived option included



among the alternatives being evaluated. Normally, urban rail alternatives are the longest lived. Therefore, other shorter-lived rapid transit alternatives may need to account for multiple capital investment cycles during the longer evaluation period dictated by the inclusion of an urban rail alternative (see box 3.2). In general, economic evaluation for rapid transit alternatives should account for benefits and costs for a 50-year period and include residual benefits for even longer-lived assets in line with the long-term vision for the city.<sup>9</sup>

Schedules for both the proposed project and its alternatives should maximize benefits relative to costs. In some situations, project schedules can be very complex, particularly when project alternatives involve phased construction or major rehabilitation during the period of analysis. The optimum timing for each alternative can be established after costs and benefits have been estimated. The timing of each option can then be tested through sensitivity analysis using different dates. This reveals the impact of project timing on the results of the economic evaluation.

*Social Discount Rate.* In addition to the evaluation time horizon, another important assumption that affects the cash flows of the alternatives and, therefore, their economic and financial evaluations is the choice of social discount rate. The social discount rate is used to express future benefits and costs in present value terms. Discount rates are widely used in economics to reflect the fact that money in the future tends to have less value than money today and the fact that up-front costs are often more salient than future benefits. The discount rate reflects the value of money considering the opportunity cost of investing in the particular project instead of elsewhere. The discount rate has to be adjusted

### **BOX 3.2.**

#### **Illustrative Comparison of Economic Evaluation Time Horizons for BRT and Rail Alternatives**

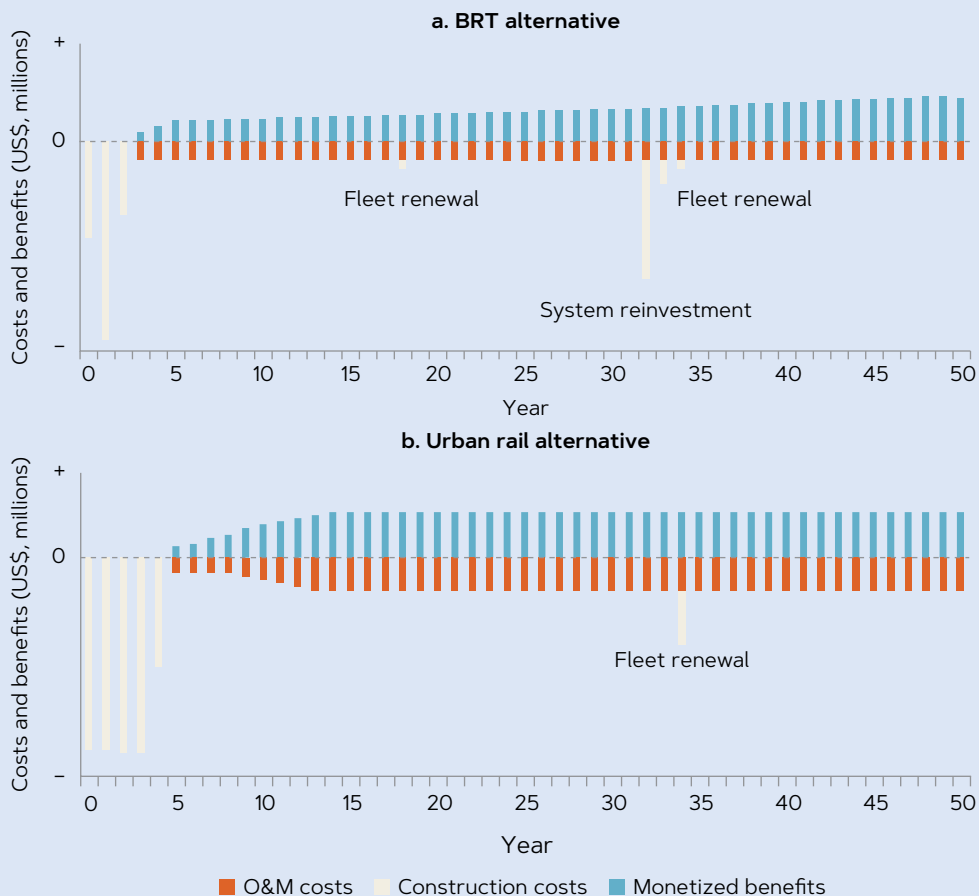
Figure B3.2.1 shows illustrative cash flows for bus rapid transit (BRT) (panel a) and urban rail (panel b) investment alternatives over a 50-year evaluation horizon. For the BRT alternative, many of the infrastructure components

will need to be replaced, requiring significant capital re-investment within the longer evaluation horizon. In contrast, the urban rail system will not require a full reinvestment as long as assets are maintained each year.

*(box continues next page)*

**BOX 3.2.**  
**Illustrative Comparison of Economic Evaluation Time Horizons**  
**for BRT and Rail Alternatives** (Continued)

**FIGURE B3.2.1.** Illustrative Net Flow of Benefits and Costs for a BRT and an Urban Rail Alternative over a 50-Year Evaluation Horizon



Note: The numeric values for costs and benefits associated with urban rail and BRT are system- and context-dependent, so the vertical axes representing costs are not to the same scale in each panel. This caveat should be included if the illustration is quoted. BRT = bus rapid transit; O&M = operation and maintenance.

to consider expected inflation; in this way, standard economic analysis links social discount rates to the long-term growth prospects of the country where the project is implemented.

The discount rate used should reflect not only the likely returns of funds in their best relevant alternative use (that is, the opportunity cost of capital or “investment rate of interest”), but also the marginal rate at which individuals are willing to save in the country (that is, the rate at which the value of consumption falls over time—the “consumption rate of interest”) (Belli et al. 1998). In general, higher economic growth prospects normally imply a higher discount rate for a particular country. Likewise, lower economic growth projections imply a lower discount rate. For example, holding all else constant, a 3 percent gross domestic product (GDP) per capita growth rate translates into a 6 percent discount rate, and a GDP per capita growth rate of 1–5 percent yields a discount rate of 2–10 percent (World Bank 2016).

High discount rates reflect a higher value for returns and costs today than for returns and costs in the future. This tendency usually penalizes projects such as urban rail and other transportation infrastructure development that involve high investments at the beginning of the project, with all expected returns materializing in the future over a long system lifetime (see box 3.3). For this reason, a high social discount rate (12 percent or higher) is not recommended for large-scale public infrastructure projects such as most urban transportation alternatives (Lopez 2006; Weitzman 1998).

As the discount rate falls, projects with benefits emerging in the long run become more attractive. Thus, public investment programs can be dramatically different depending on the specific discount rate used in practice.

In France, the official discount rate is 4 percent for a 30-year period, decreasing to 2 percent over time (World Bank 2016).

Regardless of the social discount rate chosen, it is good practice to calculate the NPV of the project for a range of discount rates. It is also good practice to present the benefit-cost analysis results as an EIRR, which is the social discount rate at which the present value of project benefits exactly equals the present value of costs (or  $NPV = 0$ ). A higher EIRR typically indicates that a project is a better return on investment in current monetary terms.

### **Multicriteria Analysis**

Multicriteria analysis frameworks were developed to mitigate difficulties that human decision makers have in handling large amounts of complex information in a consistent way. Formal multicriteria analysis frameworks can incorporate both monetary (quantitative) and qualitative benefits and costs, usually

**BOX 3.3.****Declining Discount Rates for Public Infrastructure Projects with Long-Term Impacts: United Kingdom and France**

In the past, World Bank infrastructure projects often assumed a 12 percent discount rate when calculating economic and financial internal rates of return. However, a much lower rate, between 4 and 8 percent, has been observed recently for large public transport projects with long-lived benefits.

Some countries have moved toward using a declining discount rate for projects, like urban rail developments, with broad impact and long-term benefits. For example, in analysis of public policies and public investments, the official analytical guidelines of the U.K. government specify a discount rate structure that decreases over time (see table B3.3.1).

**TABLE B3.3.1. Discount Rate Structure in the Official Guidelines of the United Kingdom**

PERIOD (NUMBER OF YEARS)	DISCOUNT RATE (%)
0–30	3.5
31–75	3.0
76–125	2.5
126–200	2.0
201–300	1.5
301+	1.0

Source: HM Treasury 2003, 97–100.

providing an explicit relative weighting system for the different criteria (Department for Communities and Local Government 2009).

The trend has been to use multicriteria analysis to enlarge the evaluation agenda by adding impact categories that are difficult to quantify in monetary terms for a traditional economic evaluation. These impacts range from local ones (for example, poverty reduction and access to jobs, education, and health care) to global ones (for example, GHG emissions and climate change). Some of these impacts have been incorporated into ex ante project evaluation. Many other effects are difficult to value but may still be included in an analysis if they are considered critical to making the choice among alternatives. The following impacts are critical benefits of rapid transit development that are more difficult to quantify and, therefore, rarely captured in economic evaluations:

- *Accessibility.* The rapid transit project may promote interconnections between residential and employment areas and social facilities (for example, hospitals, schools, and health care) by lowering the obstacles to travel within the city. Although the economic evaluation quantifies improvement in travel time savings, it does not directly quantify the associated private benefits of increased accessibility for residents (see chapter 2).
- *Compact city growth and economic agglomeration.* Integrated land use and transport planning can help to focus urban growth along an upgraded rapid transport network (see chapter 16). Over many years, this strategy may be able to reduce substantially the intensity of energy consumption and GHG emissions of urban areas and improve economic growth by concentrating economic activity and facilitating business connections. But these long-term secondary impacts are not quantifiable in a traditional benefit-cost analysis.
- *Equity.* These impacts result from projects that increase the transport system's affordability and diversity.

In the context of planning urban rapid transit systems, given the difficulties of valuing and forecasting even the basic long-range impacts (such as travel times), it is advisable to limit the economic evaluation to the most basic impacts and to put everything else in a multicriteria evaluation framework. Such a framework would consider not only the perspective of the project-implementing agency and system operator, but also the experience and preferences of potential users. Considering the availability, accessibility, affordability, and acceptability (safety, cleanliness, and quality) of the transport alternative for travelers is key when considering how a modal alternative might compete with other modes and how its many benefits might be distributed (see chapter 2).

## Financial Analysis

Financial analysis uses many of the same calculation methods and measures as economic evaluation, but it considers only the project's expected cash inflows (revenues) and outflows (costs) over the operating life of the project, not all of the economic benefits. In a conservative financial analysis, the overwhelming share of cash inflows is earned from passenger fare revenues, either directly or allocated to the project through revenue settlement. Revenue expected from other sources—such as station advertising, renting of commercial spaces, and station area development—may also be considered. Cash outflows consist of the project capital investment outlays, estimated debt service payments, and operating costs (including maintenance and renewal, taxes, and fare subsidies).

The results of a financial analysis are often expressed as a financial internal rate of return (FIRR), calculated as the discount rate for which the financial NPV (discounted revenues minus discounted costs in current dollars) of the project is zero. Just as when calculating the EIRR, when calculating the FIRR, choosing a reasonable project schedule, time horizon for the analysis (50 years or more), and discount rate are of critical importance for obtaining meaningful estimates. Furthermore, sensitivity and scenario analyses are needed to understand the uncertainty in these estimates.

For urban rail projects and other public investments, while the EIRR is often positive—implying that, at some positive discount rate, future benefits outweigh project costs—the FIRR is almost always negative. This result reflects the very substantial capital costs in the initial years that cannot be fully recovered from fare and other revenues during the evaluation period. The vast majority of international experience with urban rail projects suggests that fare revenues will not cover capital costs, and therefore public expenditure in infrastructure will not be repaid. Considering only operating costs, some projects may become cash positive after a certain time; for others, fare revenues may remain insufficient to cover operating costs and the project will require a lifelong operating subsidy. Using financial analysis, it is possible to calculate the fare that the system would need to charge in order to turn the FIRR positive, but these fares are often high enough to raise concerns of affordability and equity (see chapter 2).

It is essential to plan for the finances of a prospective urban rail operator, if for no other reason than to get a handle on operating subsidy requirements as a function of demand, revenue, and operating cost forecasts. Financial evaluation in this sense consists of forecasting the basic financial reports for at least the first, fifth, and tenth years of operation of capital-intensive alternatives. These reports include an operating income statement, a statement of sources and applications of funds, and a balance sheet. They are first done assuming 100 percent equity financing and then repeated for any option with a different financing structure. Such financial analyses are critical inputs when choosing between different project delivery methods and operational models (see chapters 8, 9, and 10).

At the early project appraisal stage, the analysis can be performed as if a single project-implementing agency were to pay for all costs and accrue all revenue. As the project continues to develop toward bidding and as different procurement plans are considered, it may be necessary to consider the financial viability of the project from the perspective of both a public project-implementing agency and a possible private partner in the construction or operation of the project. In this case, the analysis may need to include cash flows between the public and private entities as well as between the entities and the project.

## **Fiscal Analysis**

The financial feasibility of urban rail projects has to be demonstrated for both construction and operations and should be done in a fiscally constrained context. Such a demonstration requires not only a financial analysis of the project, but also a fiscal analysis of the host city and country to estimate the impact of the urban rail development and other alternatives on the costs and revenues of different levels and sectors of government and to determine a project's affordability for the metropolitan region.<sup>10</sup> The affordability of a project will depend heavily on the procurement (contract) method chosen for implementing the project (see chapters 8 and 9), the available funding and financing sources (see chapter 10), and the operations and maintenance plans for the system (see chapter 13). Therefore, fiscal analysis should be refined along with the level of detail of the alternative design and should explore the procurement rules, procedures, and laws that apply to the particular project and how different procurement arrangements might enable the delivery of value for money in achieving the alternative's development objectives. Given the scale and impact of rapid transit projects, governments may need to consider developing new laws and regulations to promote their construction and operations.

## **Reviewing the Results**

In most cases, the design (and evaluation) of alternatives in the urban transport decision-making context is done by consultants commissioned by the host city or country government. In rare cases, the work is done by technical services belonging to the city or national institutions. At the end of this phase, for each alternative there will be a project design with a corresponding forecast of investment and operating costs over a period equal to the economic life of the longest-lived alternative and a demand scenario for the same period that dictates the social benefits of the investment. The level of detail may be low for the initial evaluation of alternatives, but higher when more detailed evaluation is completed. Each alternative is presented as an annual benefit-cost and cash-flow sequence for each year in the adopted planning horizon.

A large investment and a broad array of potential consequences are involved in planning urban rail and other large-scale urban public transport systems. Furthermore, numerous assumptions have to be made to present each alternative as an annual series of costs and benefits or revenues. Once initial evaluations are complete, it is essential to obtain an independent technical review of the analysis. There are many ways to organize and fund such a review. A common arrangement is for the host city or country to commission independent consultants to carry out prefeasibility and feasibility studies,

while setting up a follow-up and quality control committee with a mixture of political and technical experts. In an arrangement common in the context of development banking, the review committee also includes members selected by the cofinanciers.

The agenda for a technical review of first-pass results of alternatives analysis is large, but projections of investment costs and patronage top the list, as these categories make or break the results for any one alternative. Therefore, the experts chosen for this review need to have considerable experience and access to data on the costs for comparable systems and transparent information on the quality of the base-year demand model—including its ability to replicate the current relationships between land use factors and household economics, on the one side, and the distribution of travel by mode and routes, on the other—as well as the assumptions behind the longer-term forecasts. It is axiomatic that numbers coming out of the base-year model are the most credible. The credibility of forecasts for subsequent years falls steadily, becoming mere speculation beyond 10 years in spite of the surface sophistication of the analysis.

### **Dealing with Uncertainty in the Evaluation of Alternatives**

In a deterministic world with known laws and no uncertainty in the political, economic, or social context of the urban transportation system, the final output of the evaluation of alternatives (supplemented by multicriteria analyses and checked by independent reviewers) could be presented to decision makers as single-value costs and benefits for their consideration. In the absence of uncertainty, a single option would outperform all other alternatives, and, in essence, the evaluation would decide which option to implement. In the real world, subjective variables as well as stochasticity in how future demand and supply will develop require analysts to account for risk and uncertainty when evaluating each alternative, particularly when it comes to forecasting construction cost and ridership.

The two main approaches to handling risk and uncertainty in the evaluation of alternatives for the decision-making process are sensitivity analysis and more advanced probabilistic approaches.

#### **Sensitivity Analysis**

Manual sensitivity analysis is a simple, powerful, and transparent tool for testing the robustness of the first-pass evaluation of alternatives. It consists of rerunning the analysis with different values of key inputs into the design and testing process, which are subject to uncertainty. These inputs may be large categories



(for example, investment costs, patronage, and fare revenue) or different values of important parameters adopted in the first-pass analysis (for example, the discount rate, the timing of investment, the length of the construction period, and the value of travel time). Given the impact of capital costs, operating and maintenance costs, and ridership (related to revenue and many benefits) on the economic and financial viability of any transportation alternative, it is important to consider the impact of at least a  $\pm 20$  percentage point margin of error on the forecasts of costs and demand (growth). These impacts should be explored individually, but also in combined risk scenarios, such as a future where initial demand is lower and construction costs are higher than originally projected.

A variant of this method is to seek the “switching values” of key inputs or evaluation assumptions. The switching value is often defined as the point at which the NPV of an alternative equals zero or the point at which the relative ranking of alternatives changes. The simplest way of doing sensitivity analysis is to focus only on the net flow of benefits and costs reflecting the differences between any two alternatives from the socioeconomic analysis, that is, total annual costs and benefits. Or, in a more disaggregated approach, the work backtracks to wherever the key numerical inputs were inserted into the demand and cost estimations that underlie the original socioeconomic analysis. The manual method is practical only when both the number of variables and the number of tested values are small; otherwise, the method becomes unwieldy and the results confusing.

### **Probabilistic Approaches**

In a probabilistic approach, manual selection of tested values for the variables is replaced by a random generation of values. The most common method used for evaluating the uncertainty in rapid transit alternatives analysis is Monte Carlo simulation. To implement this approach, the analyst specifies the probability distribution for each variable being tested and the measures of its central tendency (for example, range and mode). A random number-generating algorithm is then used to create a large set of possible scenarios based on plausible values of the uncertain variables, resulting in a probability distribution of the decision criterion (for example, the marginal rate of return) (Mackie, Nellthorp, and Laird 2005). The Monte Carlo method may be strongly conclusive in the sense that it points to one design option as being the most attractive. The weight of the conclusion(s) depends on whether the selected probability distributions are defensible.

An emerging probabilistic approach is “robust decision making” or “decision making under deep uncertainty,” now making inroads into sectors facing major global uncertainties, for example, water and power (Bonzanigo and Kalra 2014;

Lempert et al. 2013). In this approach, the analyst must identify key variables with uncertainty and the expected range of values for each, but does not have to specify the form of each distribution. An algorithm then generates hundreds of future scenarios, sampling uniformly across each range to test the robustness of evaluation outputs to combined uncertainties. The method is not, and is not meant to be, conclusive because it does not weight scenarios or potential futures by any likelihood of occurrence. The scenarios it produces are used to identify domains of success or vulnerability of the design options being evaluated, allowing analysts and decision makers to work jointly on identifying robust and flexible project implementation plans.

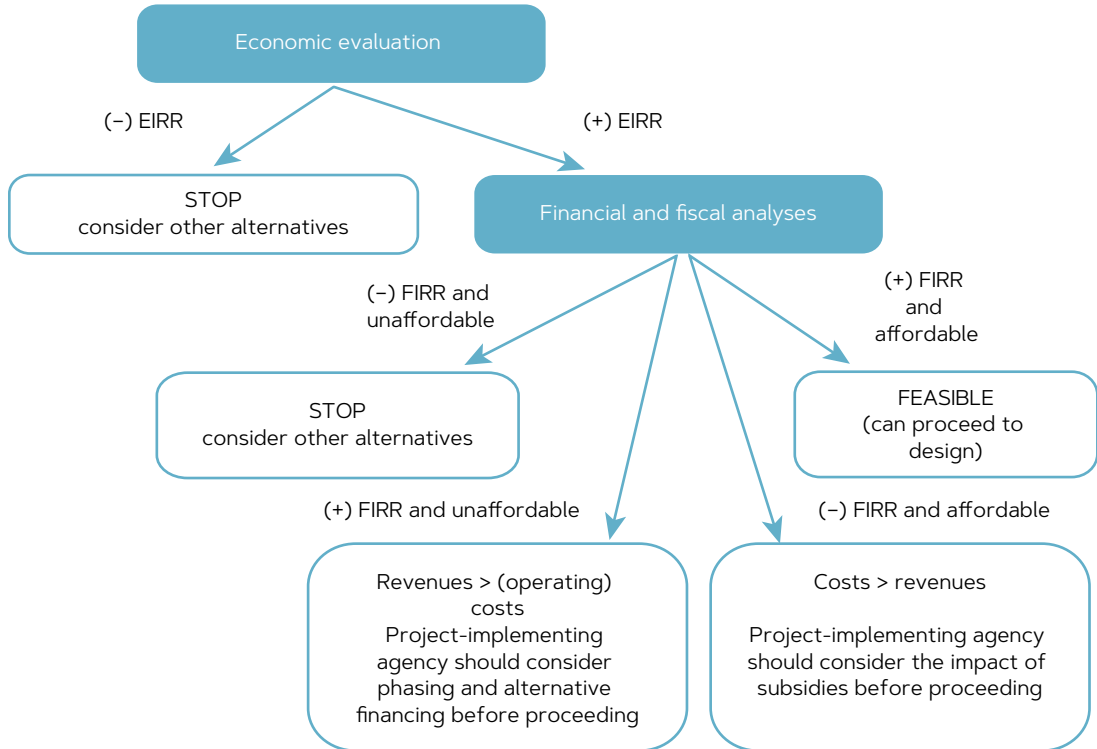
The use of one or more of these methods is obligatory in the process of evaluating large-scale public transport alternatives that are subject to major uncertainties in several socioeconomic and technical categories. Depending on the local context, it may be practical to use the manual method early in the process (when comparing many alternatives at a sketch-design level) and then to move to a probabilistic method at the next stage (when the number of alternatives is smaller and the designs are of higher quality). No matter which method is used, analysts should not present the outcome to decision makers in a decisive form; they should instead highlight which options perform best under certain future scenarios (some of which may be more likely to occur than others).

### **From a Study to a Decision**

The logical decision-making process presented in this chapter begins with diagnostic studies of the urban transport system and development of an urban mobility strategy at a metropolitan level and then proceeds to the generation and iterative evaluation of investment alternatives under uncertainty at the corridor level. The evaluation of each investment alternative begins with an economic evaluation followed by a financial and fiscal analysis (and perhaps a multicriteria analysis of other positive and negative externalities that are difficult to quantify). Figure 3.4 presents a decision tree that shows how to synthesize the findings from each of these analyses to determine which investment alternatives are feasible and which require further analysis before proceeding to final project selection and design.

By staging the process, decision makers considering transportation investment can benefit from an analysis of different transportation alternatives and an understanding of trade-offs among different developments, but only invest the time and cost needed for an in-depth study on a project that

**FIGURE 3.4. Flowchart for an Alternatives Analysis Leading to the Decision on Which Alternatives Are Feasible and Which Require Additional Consideration**



Note: EIRR = economic internal rate of return; FIRR = financial internal rate of return.

may actually be implemented. This staging can reduce the cost of deciding whether or not to develop an urban rail project and may also reduce the time needed so as to fit into a limited window of political or economic opportunity. Keeping track in electronic format of the various data that have been prepared and of the results of various analyses is critical to maintaining transparency and credibility of the decision-making process and can facilitate external review of results and further study in case the political or economic environment changes.

At the end of this analysis of alternatives, decision makers identify a provisionally preferred alternative for the particular corridor and make a decision to invest tens of millions of U.S. dollars in the detailed design of the

provisionally preferred transportation alternative (figure 3.1). The rest of this handbook is written for decision makers who determine that an urban rail system is the provisionally preferred alternative for a given corridor.

In practice, in many low- and middle-income countries, the preferred investment is often chosen through an informal process and dialogue, not through a quantified analysis of costs and benefits (Bonzanigo and Kalra 2014). Even in high-income countries, ex post studies of numerous large public projects depict a planning process that only nominally follows the steps described here and is susceptible to the bias of favoring a specific proposal. Collectively, these shortcomings suggest that there is room for improvement in the appropriate and rigorous application of analyses of alternatives in the transportation decision-making process.

If studies are conducted without protection from a political and economic environment that clearly favors a single alternative, the process is in danger of corroding into “decision-based evidence making” rather than “evidence-based decision making” (Kain 1992). Therefore, it is important to provide the autonomy of analysis necessary to ensure the evaluation of alternatives rather than the justification of a prechosen solution (Flyvbjerg 2009). At the heart of this matter is the relation between the analytic work and the decision making. The analysts who carry out the evaluation of alternatives do not make the final decision on whether to invest millions and billions into this or that public transport project; rather, public municipal officials and cofinanciers decide what to develop. They need to be informed of the results of technical evaluations in a way that clearly highlights trade-offs among costs and benefits and demonstrates how the project fits within the existing political and economic environment and greater urban mobility strategy.

In an uncertain world, with large amounts of money at stake over very long planning horizons, a healthy attitude is that all long-term forecasts dealing with highly interactive social systems are provisional and suspect and all single-value outcomes are false. This is no cause for decision paralysis or for rejection of analytic approaches to project planning. Rather, it is a cause for rejecting a “justification” approach to planning and for adopting a process in which “analysts and decision makers together compare the scenarios with available evidence to determine if they are sufficiently plausible to hedge against” (Bonzanigo and Kalra 2014, 7). In this collaboration between analysts and decision makers, care must be taken so that the evaluation does not corrode into a decision-based evidence-making process.

## Conclusions and Recommendations

This chapter introduces the “ideal” decision-making process for deciding whether or not to develop an urban rail project. This process consists of six steps:

1. Conduct diagnostic studies of urban transport.
2. Develop an integrated urban mobility strategy and identify priority corridors.
3. Generate investment alternatives for a given corridor.
4. Conduct a comparative evaluation of alternatives.
5. Consider uncertainty.
6. Communicate results of the analysis to decision makers.

Each of these steps requires the careful collection of data and application of different analytical techniques to explore both demand- and supply-side responses to possible transportation interventions. The details of these methods are presented in this chapter. This conclusion synthesizes key, overarching messages.

***In-depth planning studies should come before a decision is made to pursue engineering studies, design, or procurement of any rapid transit project.*** Only after careful diagnostic study and consideration of alternatives can decision makers determine that a rapid transit project, such as urban rail, is the appropriate investment for addressing the mobility and accessibility needs of their city’s residents. These in-depth planning studies and alternatives analysis are a significant investment (on the order of millions of U.S. dollars), but are necessary before undertaking engineering studies and design (on the order of tens of millions of U.S. dollars).

***Alternatives analysis is an up-front investment that is necessary to maximize the socioeconomic returns of any urban rail investment and should be undertaken without modal bias.*** A sound alternatives analysis is critical for identifying what type of transportation investment provides the greatest social and economic value to the city (within a fiscally constrained environment). This alternatives analysis must be conducted prior to the decision to design any specific transportation project. If a rail option is the most desirable alternative, this conclusion should be demonstrated with analytics and not predetermined from the outset. This imperative is especially relevant given the size and complexity of any rapid transit solution, particularly urban rail, and even more

important in the case of low- and medium-income countries where the opportunity cost to society is high.

*Rapid transit projects, particularly urban rail, are complex and long lived and produce widely distributed benefits that are often hard to capture in monetary terms for project evaluation.* Their evaluations should incorporate the following recommendations:

- Long planning horizons and low or declining discount rates for economic evaluation
- The quantification of direct travel time savings and user benefits in the economic evaluation and the exploration of broader economic and social externalities as part of a multicriteria analysis framework
- Consideration of the short- and long-term financial and fiscal feasibility of the project
- Exploration of uncertainties in the estimates using sensitivity analysis or more advanced probabilistic approaches

*Recognizing that the ideal decision-making process often differs from actual practice, decision makers should focus on creating a comprehensive and objective framework that considers alternatives from multiple dimensions.* This chapter assumes that the decision-making process proceeds in a logical sequence—from a diagnosis of problems through the design of corrective alternatives to a comparative evaluation. Although this sequencing is ideal for choosing the transportation investment that maximizes benefits and minimizes costs, in practice the decision whether to invest in a rapid transit project is often driven by available budget and political economy. Careful evaluation is important to support the decision-making process and to achieve maximum value from large transportation investments, but it should not preclude action. Doing nothing or delaying a decision on whether to invest in rapid transit for many years may not be acceptable. Therefore, a careful balance must be struck between the time available for analysis and other decision-making considerations.

## Notes

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1. See, for example, the Digital Matatus Project in Nairobi, Kenya (<http://www.digitalmatatus.com/about.html>).
2. Operating costs are also important, but they are subject to a high degree of managerial control and hence a much lower level of uncertainty. They are discussed in more detail in chapter 13.
3. When several years of census data are available on compatible zoning, they are a unique source for investigating detailed trends in city development. They allow urban planners to identify areas in which new population or employment has to be encouraged or restrained in relationship with land use planning and transport supply. This information is useful not only for designing or comparing rapid transit alternatives but also for programming network development of all urban transport over a period of two or three decades.
4. The International Association of Public Transport provides similar guidance through three steps: emergence, feasibility, and design.
5. The minimum that remains may still be considerable given uncertainties in procurement and construction.
6. Depending on the country and sector, many terms are used to describe economic evaluation, including socioeconomic analysis and benefit-cost analysis. Here the term economic evaluation is used when all benefits that can be expressed in monetary terms are compared with costs; the term multicriteria evaluation is used when other factors are included in nonmonetary terms.
7. All of these benefits are actually reductions in the costs or negative impacts of transportation.
8. For all alternatives, the determination of the EIRR refers to a specific pair of alternatives. In other words, it is a comparative measure and requires that alternatives be evaluated against a “base case,” which is often the lowest-cost traffic management alternative. Given the higher confidence in traffic and revenue forecasts in early years, one option is to use the first-year rate of return as an additional summary measure in economic evaluation.
9. It is common to simplify the work by selecting a shorter planning horizon, for example, 20 years, and inserting a residual value for longer-lived options. The justification for this is that discounting, especially when high discount rates are used, quickly reduces the value of future costs and revenues. This is one of several weak aspects of the current practice in the design and evaluation of options when the decision agenda includes options with sharply different system lives.
10. Fiscal analysis considers project affordability from the government perspective. Affordability from the user perspective is discussed as part of the four “As” framework in chapter 2.

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# 4

## PROJECT MANAGEMENT PLANNING

Ramon Munoz-Raskin, Joanna Moody,  
and Edward Fleischman

Urban rail projects are extremely complex. Cost increases, schedule delays, and changes in scope can occur, but they can be controlled and mitigated through careful project management planning. Literature suggests that the projected costs of most transport infrastructure projects are underestimated; the actual cost of rail projects is 45 percent higher, on average, than the original estimate (Flyvbjerg, Bruzelius, and Rothengatter 2003, 15). Project management planning is needed to preempt such issues or, if they are unavoidable, to minimize their impact on project implementation. Project management planning establishes the structure of control and mechanisms needed for project staff to complete a project within the expected budget, scope, and schedule and to conform to the plans and specifications established for the project. Practice shows that, without good project management planning, project implementation can suffer catastrophic consequences. To mitigate all avoidable challenges, adequate management planning efforts need to be made up-front and throughout the project development process.

Project management planning is a basic tool for achieving project reliability and successful implementation. It establishes the institutional arrangements that ensure accountability. It also establishes the tasks necessary to manage and implement a major urban rail project,

*Photo:* World Bank staff oversee construction works, Lima Metro Line 2.

*Source:* Julio César Casma, World Bank.

including defining the procedures that will govern all technical aspects. The level of project management planning needs to be commensurate with the size and complexity of the project and with the technical capacity and capability of the project's team and stakeholders. Although the cost and staffing effort needed for project management planning is specific to each project, these costs have to be estimated carefully and included in the budget for the project up-front.

In addition to assisting in managing the design and construction of the project, project management planning also informs the administrative structure that will implement these procedures. Project management planning is, therefore, needed at all steps of project development and implementation and is a "living" approach that varies in emphasis and detail as a project advances through design, construction, start-up, and operations. Project management planning must anticipate the development of the project, putting in place the structure and control needed for the next step (or steps).

Project management planning can help to convince partners and financiers that a project is reliable. The project control structure provided by good project management planning practices—coupled with a solid project team and good judgment—lends confidence that the project is and will be managed properly. For the project to be trustworthy, implementing agencies should have a data-driven implementation plan and adequate controls. These elements are inherent to project management planning and are not only important for the success of the project, but sometimes even required for initial approvals and financing. Some seasoned funders, such as the U.S. Department of Transportation's Federal Transit Administration (FTA), require a project management plan for any urban rail project that receives federal discretionary funding so as to reduce the risks of cost increases and schedule delays (FTA 2016). Project management planning is especially important for organizations with little experience implementing urban rail projects (see box 4.1). It is common practice in more experienced implementing agencies. Furthermore, it is a key asset for avoiding perverse industry practices such as strategic misrepresentation.

In the case of most low- and middle-income countries, urban rail projects may be among the largest megaprojects advanced in their modern history, heightening the importance of the project and careful project management planning. Since experience with megaproject management is often limited in these countries, project management planning principles are usually not as prevalent, which creates greater project risk. The learning curve for planning and implementing urban rail projects is very steep, both in the public and private sectors and throughout the whole project development process. Given the critical importance of an urban rail megaproject to a country's economy (as a percentage of gross domestic product [GDP] and as a potential key driver of economic productivity and development) and considering that cost underestimation and overruns for

**BOX 4.1.****The Importance of Project Management Planning for Building Stakeholder Confidence in Unpracticed Agencies: Washington, DC, United States Silver Line**

In 2004, the U.S. state of Virginia commissioned the Silver Line Metro project—the first (23-mile) segment of a metro rail connection between Washington, DC, and Washington Dulles International Airport. In 2007, management of the project was transferred to the Metropolitan Washington Airports Authority (MWAA), which operates Washington Dulles International Airport. With expertise in the operation and construction of airport facilities, the MWAA had little experience managing a large rail transit project. However, with deliberate and structured project management planning, this inexperienced agency was able to gain credibility with investors and deliver a major urban rail project.

Concerned about MWAA's lack of experience with rail transit projects and with design-build contracts (the procurement method chosen for the project), the federal government delayed approval of the project's funding assistance in January 2008. Among other items, MWAA had to strengthen its project management planning to provide greater confidence that the project would be completed within the agreed-upon budget, schedule, and scope. Based on this expanded and deliberate project management planning initiative (and other requirements that were fulfilled), the federal government reversed the earlier decision, and the project received US\$975 million in funding for phase I, out of a total project cost of US\$3.14 billion. Thus, the implementing agency's project management capability was an important consideration in the approval of funding for this project.

This case study illustrates that project management planning lends confidence to the project's investors and political decision

makers that a project has all of the elements needed to implement it as promised with respect to schedule, cost, and scope. Project-implementing agencies need to demonstrate to funders and financiers that their project management approach is trustworthy and reliable. Funders and financiers, in turn, should demand a demonstration that the project is in good hands and the implementing agency is able to deliver the entire project on time and within budget. In the case of MWAA and the Silver Line, good project management planning proved this point and allowed the project to move ahead into construction (see image B4.1).

**IMAGE B4.1. Construction Work in Fairfax, Virginia, on the Metro Silver Line Phase I to Washington Dulles International Airport**

Source: © Dulles Corridor Metrorail Project. Reproduced with permission; further permission needed for reuse.

rail projects are relatively common in low- and middle-income countries (Flyvbjerg, Bruzelius, and Rothengatter 2003, 16), structured approaches to project management planning are essential if budget and costs, schedule, and scope matter.

This chapter discusses how a multidisciplinary project management team can use project management planning principles and tools to support project success. The chapter begins with a deliberation on how a project should be organized to facilitate communication between and within agencies and to identify and mitigate risks throughout the project development process. This is followed by a discussion of the fundamental planning management tools that should be used in managing the implementation of any major capital project—in particular, an urban rail megaproject—such as scope, budget and cost control, schedule control, and risk evaluation. The chapter concludes with a discussion of how the focus of project management planning evolves throughout the project development process, including design management, procurement and land acquisition management, construction management, and project start-up, testing, and operation. The general principles of project management planning introduced in this chapter are vital for success in every project, but even more so in urban rail projects in low- and middle-income countries, where previous experience with similar endeavors may be limited or nonexistent.

### **Project Management Organization**

A broad base of technical disciplines is needed to implement any complex project, including urban rail projects. A naive approach would have planners take the lead during planning, engineers take the lead during design, and construction managers take the lead during construction. However, a multidisciplinary approach is necessary throughout the project development process. It is important to include planners, engineers, construction managers, rolling stock specialists, and operation specialists as well as financial and legal teams in project management planning throughout each step. For example, during planning, engineers should be proactive to identify and mitigate any issues that may develop as the project advances into preliminary and detailed design (see chapter 7 on risk management). During design, construction managers should be involved, because engineering decisions affect construction methodology and costs (see chapter 11). As the project moves through the various steps of implementation, cost estimators, project schedulers, transit operations managers, and specialists in document control, social and environmental issues, legal, financial, procurement, communications, and land acquisition, among others, should also be consulted. Including specialists from all areas

throughout the project development process makes it easier to anticipate and mitigate problems before they develop and to maximize the potential to deliver the scope agreed upon within the budget and schedule.

In instances when there is little operational experience, it may be advisable to engage a “shadow operator” to review project plans and designs and to support decision making. Such a “shadow operator” can help to ensure that the system is planned and designed to allow efficient, flexible, and cost-effective operations after completion. Although involving this broad range of technical expertise is important, a core group of managers and decision makers responsible for implementing the project needs to be empowered to take quick, decisive action, given appropriate input from many perspectives.

### **The Core Project Management Team**

Much of the success of project management planning lies in the involvement of multidisciplinary teams, but it is also important to balance the holistic planning process with decision-making expedience. Usually, while a broad technical committee with representatives of various disciplines makes recommendations, an executive decision-making body with a small number of executive-level members makes project decisions. These decision makers have to be informed during all the steps of project development and on all areas of the project. Technical details have to be communicated to them clearly and concisely. Recognizing that decisions are also made under constraints of the current political economy, the core project management team needs to be large enough to be aware of all of the elements necessary to make decisions, but small enough to move nimbly within the political or economic window of opportunity. The appropriate size of the core project management team will depend on the local context and level of capacity and experience of the project-implementing agency; the team should be structured with the discretion to act quickly and to avoid bureaucratic hurdles that could affect the project’s ability to deliver.

### **The Role of Consultants**

Adequate experienced staffing is needed at all steps of project development and implementation. Given the size and complexity of major urban rail projects, certain functions of project development can be outsourced or supplemented by outside consultants. For example, consultants can directly advise the project sponsor, who can delegate some project management and decision-making responsibility to them; they can be involved directly in design studies; or they can advise project management responsible for construction on behalf of construction contractors or equipment suppliers. No matter what role they play in a given project, consultants should be managed and directed by internal agency staff

who are knowledgeable about the project, aware of its larger context, and dedicated to its success. This internal staff should have the requisite technical, managerial, leadership, and communication skills to manage the team of consultants proficiently. Integrated project teams with a mix of consultants and agency personnel, as well as colocation of the project team, have worked successfully. In the case of agencies that are undertaking an urban rail project for the first time or that have not done so in a long time, it may be vital to import international state-of-the-art experts.

The use of consultants should be structured carefully and reviewed to ensure that conflicts of interest do not exist and that the proper agency oversight of consultants is conducted. Consultants cannot and should not substitute the role of the project-implementing agency; rather, they should support the agency as technical advisers. Although they are experts in their fields, consultants are, by their very nature, transient. Accordingly, on completion of their contract or the project step in which they are involved, consultants will no longer be available to share their project experience or assist in resolving any emerging problems.

It is important for project-implementing agencies to learn from contractors and other experts throughout construction of the project. This upskilling can even be incorporated into contracts with these entities. External consultants can be useful in generating capacity within low-capacity institutions if training is built into their contracts, if they interact often with internal project staff, and if there is a systematic way of collecting and disseminating the information generated by them. Such knowledge sharing needs to be included explicitly in contract negotiations up-front since it is unlikely to come naturally from consultants who want to protect their own knowledge and competitive advantage for future business propositions. In this way, once consultants complete their contracts, internal project staff (who generally stay with the project through its entire development) have to take responsibility for the institutional project knowledge and provide the continuity necessary to assist in resolving problems once contracts with consultants have ended.

### **Internal Capacity Building for the Implementation of Urban Rail**

For cities with long-term transportation strategies that call for additional urban rail lines or network expansion, it is important to use every project to maintain and build institutional knowledge regarding planning, design, construction, and operation within the project-implementing agency. In addition, many local areas may lack the skilled labor necessary to implement certain urban rail construction methods (see chapter 11) or to operate and maintain the system assets and services once constructed. For these reasons, municipalities may have to train new, skilled labor to build and maintain urban rail projects (see box 4.2).



**BOX 4.2.****Illustrative Examples of Labor-Force Training for Urban Rail Construction: TUCA and the Crossrail Apprenticeship Program in London, United Kingdom**

A prime example of long-term investment in skilled labor markets for urban rail construction (and maintenance) is the Tunneling and Underground Construction Academy (TUCA) established in London by Crossrail Ltd. and then transferred to Transport for London. In 2008, Crossrail was faced with a shortage of tunneling engineers—more than 50 percent of engineering graduates were not working in the rail profession, the average age of an engineer was 56, and 70 percent of companies supplying professional construction services reported a shortage of suitable recruits (Blin and Eldred 2016). Recognizing a local need for underground construction professionals, Crossrail established TUCA, the only specialist soft-ground tunneling training facility in Europe, to provide key skills required to work in tunnel excavation, underground construction, and infrastructure. The establishment of TUCA was only one small part of a larger skills and

employment strategy for the Crossrail project. TUCA helped to build not only the infrastructure of the Elizabeth line, but also the long-term institutional and labor capacity to maintain the city's entire urban rail system in the future (Blin and Eldred 2016; Pascutto 2010).

Crossrail Ltd. and its main U.K. contractors—including Bombardier Transportation, MTR Crossrail, and Network Rail—also created an apprenticeship program that matched local engineers, construction, and other professionals with roles that support the construction of the Elizabeth line, manufacture of new Class 345 rolling stock, as well as future operations of the railway (Dempsey 2017). Since the start of the program in 2009, Crossrail has created more than 1,000 apprenticeships that help to build technical knowledge in the local labor market and a sustainable workforce for the long-term operations of the system (see image B4.2.1).

**IMAGE B4.2.1. Local Engineers and Other Professionals Matched with Contractors by the Crossrail Apprenticeship Program**

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### **The Importance of Communication**

Communication is another important aspect of project management. Communication between all parties—whether it is among different units of the project-implementing agency or between the project-implementing agency and other government stakeholders, its suppliers and contractors, or the general public—is one of the keys to a successful project. This section focuses on the importance of communication and benchmarking among high-level project decision makers, technical staff, and consultants of the project-implementing agency. Communication and interface between management and utility owners, other transportation service providers, and contractors are discussed in chapter 11, while communication with the general public is discussed in chapter 14.

Even with expert staff and consultants, a lack of communication can be disastrous to project implementation. Day-to-day project management is normally led by a project director or manager, but all units and groups working on the project need to own and take project management planning seriously. Regular meetings should be held with all specialties involved in the project. Participatory workshops should be held to bring all units into the discussion and preparation of each successive step of project development. Such events can help to achieve a sense of collective ownership of the project and its management.

Furthermore, in complex projects such as urban rail, various outside agencies and external stakeholders are involved in project development. A coordinating committee made up of representatives from these outside agencies should be set up to allow constant communication among all of these parties. Outside agencies should include government agencies that can affect or be affected by the project, public utility companies, railroads, and other private entities. This coordinating committee should report directly to the project manager. Communication with political decision makers and financial partners is also crucial to the success of a project. Project briefings with both internal and external groups should be held on a regular basis.

### **The Importance of Continual Benchmarking**

Effective communication helps to promote stakeholder buy-in, build support, and anticipate possible problems throughout the project development process. While communication among different parties is supported by regular workshops, communication from one step of the project to the next is supported by regular documentation, reporting, and updating of project management plans. Document control systems are key.

Since urban rail projects are large scale and involve long timelines and large budgets, complex systems and processes are needed to manage implementation of the project. Systems are needed to collect, assess, and maintain project

status information and data that are timely and accurate. These systems provide current information on project implementation, progress, changes, and issues that is helpful for managing the project's budget, schedule, and scope. In addition, a document control system is needed to handle the vast number of documents that will be developed and refined as the project is implemented. Computer applications have been developed to track and analyze these components. New technologies, such as Building Information Modeling (BIM), which was originally used to improve collaborative graphic design of buildings, now allows the global management of infrastructure from the generation of plans through construction and operations.

Whatever program is chosen, staff must be able to understand the needed inputs, have the capacity and time to use the system, and be able to analyze the outputs from these programs. Systems should be chosen or designed commensurate with the realities of the implementing agency and the scale of the project. Many agencies overly specify the functionality of the system, generating large inefficiencies. Instead, in choosing a computer program, the goal is to select an application that has only the necessary functions to be cost effective and to meet the needs of project management planning.

## Fundamental Project Management Planning Tools

Some fundamental project management planning tools are needed to manage the implementation of any major urban rail project. These tools are applied throughout the project development process to determine and refine the project scope, control the budget and cost, control the schedule, and evaluate and manage risks (see figure 4.1).

### Project Scope

After the planning process establishes a preferred project or alternative, a baseline scope should be developed. The baseline scope refines the project broadly defined in the previous alternatives analysis planning process, which is discussed in chapter 3. It includes the physical description of the project, such as the location of guideways, stations, station amenities, access and egress, intermodal features, central control facilities, maintenance and storage facilities,

**FIGURE 4.1. Scope, Budget, and Schedule: Three Fundamental Variables to Be Managed**



and administration facilities. The baseline scope includes the vehicles, control systems, communications, power distribution, fare collection, and support equipment for the project.

This baseline scope is developed further in the detailed design of the project. Almost all projects need to be refined or changed as they advance in the project development process. Although changes to the project scope should be controlled, revisions will occur as the project definition evolves in an orderly manner throughout the project development process. A change control procedure is needed to manage deviations from the baseline and ensure that any changes in scope increase the overall value of the project. The procedure should provide a system that identifies changes, records them, assesses them for their impact on cost, approves them if appropriate, and ensures that approved information regarding changes is disseminated appropriately throughout the project team. Without a change control procedure, the project risks incorporating changes that increase costs or affect the schedule without a proper analysis of these impacts or a record of why changes were advanced in the first place. This lack of a record can create additional institutional memory challenges later.

### **Budget and Cost Control**

Accurate cost estimation is one of the keys to successful project management. Global experience suggests that implementing agencies often obviate or fail to include specific project line items when creating a project budget or are mistakenly optimistic about the level of contingency and project funding. From project inception, realistic cost estimates need to be developed from the best available information for all capital and operating cost items, as discussed in chapter 5. These estimates have to include all costs related to preparation and planning (for example, studies), project management, construction, supervision, and operation and maintenance. Early cost estimates are, of course, based on many uncertainties and variables and will have a larger margin of error. However, since cost estimates developed during project feasibility studies or during preliminary engineering are usually the basis for project financing, care must be exercised in preparing these early estimates and accounting for their uncertainties.

A contingency fund or line item should be established to provide funding for budget changes caused by unanticipated site conditions, design revisions, estimation uncertainties, inflation, and other unforeseen costs—which often occur in urban rail projects. Although a contingency fund is necessary, wherever possible, risks should be priced and specifically allocated in all contracts in order to avoid conflicts, cost overruns, and delays. A cost estimation group is needed to update forecasts of the project's costs to completion based on a recurring analysis of refined cost estimates, contract commitments, and expenditures

compared with the budget. Updates need to occur at entry into different steps of project development, and, at that time, both allocated (by line item) and unallocated (general for the project) contingencies need to be revised commensurate with the level of detail of the project's design. If costs change significantly enough to affect the project's financing, they should be communicated quickly to senior management and project partners for analysis and corrective action.

A project's costs and budget have to be incorporated into the project's overall reporting and tracking system. Project cost reporting details current costs and future estimates of costs. This information is then used to identify trends and forecast costs at project completion. Budget reporting identifies the available project funding. This information is used to identify and proactively address cost variances between actual and forecast costs and budget. This reporting helps to eliminate surprises as the project moves through implementation, providing confidence to decision makers and financiers that current project costs are accurate. Table 4.1 presents an illustrative example of a

**TABLE 4.1. Illustrative Example of an Executive-Level Monthly Cost Reporting Chart**

*US\$, thousands*

PROJECT ELEMENT	BASELINE PROJECTED COST (JANUARY, YEAR 1)	LAST UPDATED FORECAST COST (JUNE, YEAR 1)	CURRENT FORECAST COST	CHANGE FROM PREVIOUS MONTH	CHANGE FROM BASELINE
Project management plan	45,000	45,000	45,000	0	0
Preliminary engineering	25,000	25,000	25,000	0	0
Environmental assessment	26,000	26,000	26,000	0	0
Final design	53,000	60,000	60,000	0	7,000
Project supervision	170,000	170,000	170,000	0	0
Right-of-way	160,000	165,000	250,000	85,000	90,000
Construction contracts					
Tunnel segment A	245,000	280,000	288,000	8,000	43,000
Elevated segment B	160,000	170,000	170,000	0	10,000
At-grade segment C	80,000	80,000	85,000	5,000	5,000
Stations	424,000	424,000	420,000	(4,000)	(4,000)
Systems	208,000	208,000	208,000	0	0
Vehicle contract	105,000	105,000	105,000	0	0
Unallocated contingency	500,000	449,000	359,000	(90,000)	(141,000)
<b>Total project cost</b>	<b>2,201,000</b>	<b>2,207,000</b>	<b>2,211,000</b>	<b>4,000</b>	<b>10,000</b>

Note: Numbers are for illustrative purposes only and not based on actual project data.

format that could be used in higher- or executive-level monthly cost reporting to complement more detailed cost tracking at the level of the technical, multidisciplinary project management team. In table 4.1, the current forecast cost along with the change from the previous month is displayed for each main project element.

Continuous and accurate reporting and analysis of cost variances are key to managing and administering a major urban rail project effectively. The causes, impacts, and proposed measures to mitigate cost variances should be discussed at regular status meetings held on at least a monthly—if not weekly—basis, depending on the speed of the construction works. Significant issues occurring between meetings should be communicated immediately without waiting for the next regularly scheduled meeting.

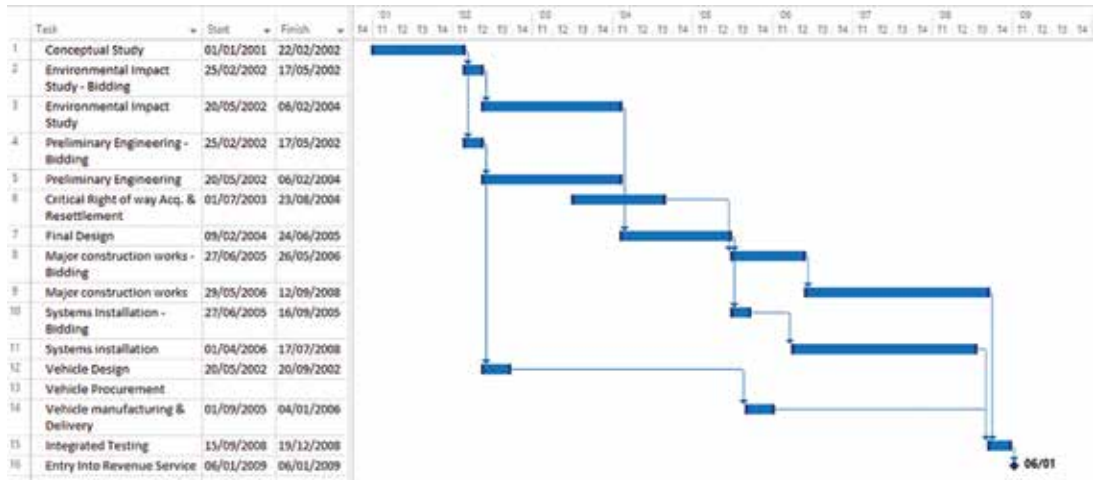
### **Schedule Control**

In addition to costs and budget, schedules are another primary tool of project management planning. Schedules allow managers to anticipate upcoming events, to review progress, and to modify work plans as necessary to meet project milestones. Understanding and keeping track of project critical paths is fundamental to project success. Considering the complexity of major urban rail projects, schedule control needs to be done with professional tools, qualified staff, and a direct communication line to the project management team. Schedule reports often have different levels of detail depending on the intended use. The project management team has to account for all aspects of a critical-path schedule and should summarize these aspects into dates for high-level deliverables for executive-level managers.

#### *Detailed Critical-Path Schedule*

The project management team uses a detailed master program schedule to analyze potential delays and proactively adjust work elements to meet schedules. Due to their complex and varied deliverables, major urban rail projects need to have dedicated staff to conduct scheduling using state-of-the-art scheduling software. The master program schedule is developed based on detailed project schedules and is updated with established procedures by responsible and qualified specialists, leaving a documented record. It includes all project items, including bidding processes, environmental processes, financial approvals, right-of-way acquisition schedules, design schedules, construction schedules, supplier schedules, and start-up and testing schedules. A critical-path schedule includes details of all work elements that, if delayed, would affect the project completion date. Figure 4.2 provides an example of a detailed critical-path project schedule.

**FIGURE 4.2.** Illustrative Example of a Simplified Critical-Path Schedule for an Urban Rail Project as a Gantt Chart



Note: Tasks, with start and end dates, are for illustrative purposes only and are not based on actual project data.

### *Milestone Delivery Schedule*

Progress against the overall project schedule needs to be reviewed continuously so that resource reallocation or other corrective action can take place as early as possible to avoid delays. While the master program schedule is a powerful tool for project management, summary tables should be available for executive-level staff who monitor project schedules. Table 4.2 illustrates a higher-level schedule that tracks monthly changes in task completion. This format allows executive-level staff to focus on the areas with schedule changes and to allocate contingency funds toward the completion of certain tasks if warranted. A simple tool such as this communicates schedule changes that affect other work areas or the project completion date to higher-level decision makers. Monthly progress meetings should include schedule updates with discussions of alternatives to control and mitigate delays. It is recommended that these progress meetings also address project cost, risk, and other key strategic areas of the project that relate to the schedule.

### *Geographic Schedule*

Most contractors and owners rely on critical-path schedules as the primary tool for planning and tracking progress. A critical-path schedule is most often visualized as a Gantt chart (as in figure 4.2). In the case of urban rail projects where parts of a line or system could be elevated or at-grade, while others are

**TABLE 4.2. Illustrative Example of a Major Project Milestones Monthly Tracking Chart for an Urban Rail Project at the End of Preliminary Design in Preparation for Design-Build Delivery**

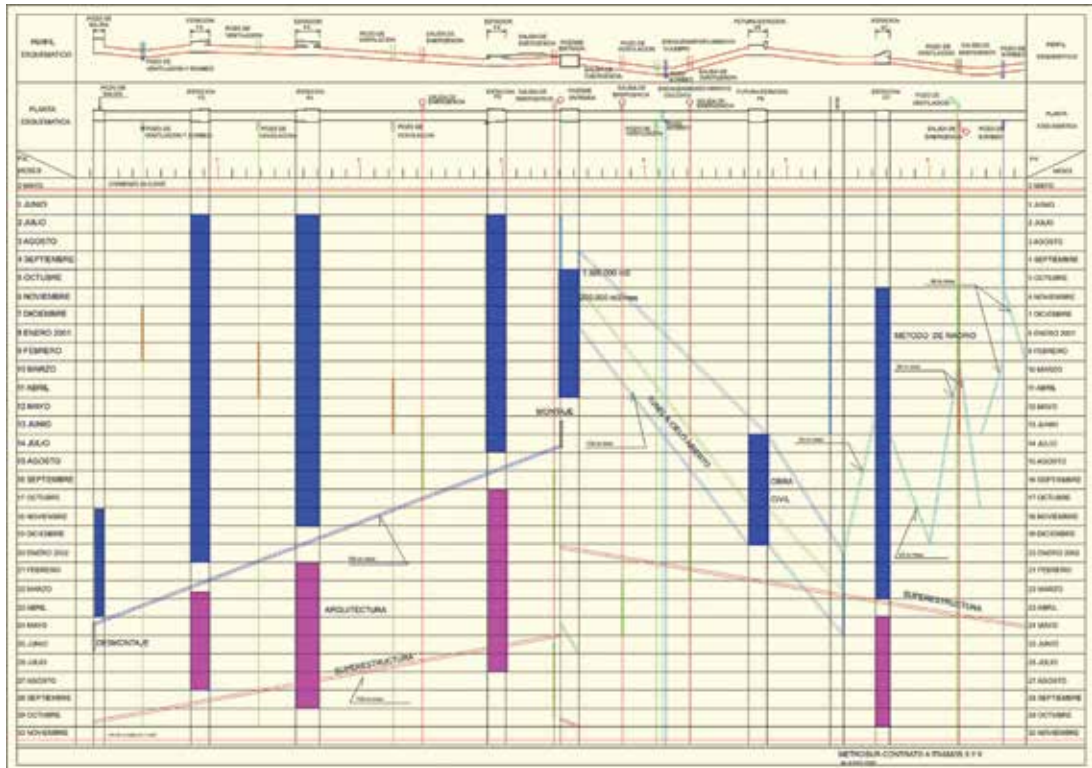
ILLUSTRATIVE MAJOR PROJECT MILESTONE	INITIAL FINISH BASELINE DATE (JANUARY YEAR 0)	REVISED FINISH DATE (AUGUST, YEAR 1)	ACTUAL (A) OR FORECASTED (F) FINISH DATE	CHANGE FROM REVISED BASELINE
Concept study	October, year 1	September 30, year 1	(A) September 30, year 1	Completed on schedule
Environmental impact study published	October, year 2	October, year 2	(A) December 6, year 2	Delayed, 2 months
Preliminary engineering complete	December, year 2	February, year 3	(A) May 18, year 3	Delayed, 3 months
All significant rights-of-way acquired	September, year 3	November, year 3	(F) May, year 4	Likely delay, 6 months
Public-private partnership bidding and award	January, year 4	March, year 4	(F) June, year 4	Likely delay, 3 months
Final design	January, year 5	March, year 5	(F) June, year 5	Likely delay, 3 months
Start of first major construction activity	February, year 5	April, year 5	(F) July, year 5	Likely delay, 3 months
Heavy construction or systems complete	February, year 7	April, year 7	(F) October, year 7	Likely delay, 6 months
First vehicles delivered	April, year 7	July, year 7	(F) November, year 7	Likely delay, 4 months
Integrated testing completed	July, year 7	September, year 7	(F) March, year 8	Likely delay, 6 months
Entry into revenue service	September, year 7	November, year 7	(F) May, year 8	Likely delay, 6 months

Note: Project milestones and dates are for illustrative purposes only and are not based on actual project data.

constructed underground, a critical-path schedule and Gantt chart visualization do not convey the geographic location where tunnel excavation begins and ends (Wonneberg and Drake 2012). For this reason, managers of tunnel projects often prepare geographic schedules to supplement the project's critical-path schedule. A geographic schedule builds on the functionality of a Gantt chart, while adding information about location. A geographic schedule is a listing of project activities and their duration, where the horizontal axis represents time (increasing from left to right) and the vertical axis presents the linear stationing (or geographic location) of the planned construction (as in figure 4.3). Together with the critical-path schedule, geographic schedules can help to explain and define the scope of work, communicate overall progress and schedule, evaluate what-if scenarios, and make key project decisions.



**FIGURE 4.3.** Illustrative Example of a Geographic Schedule, Including Linear and Nonlinear Elements



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## Risk Management

The risk management process allows project managers, partners, and decision makers to understand the project's risks as implementation proceeds. In addition, it provides a plan for mitigating and managing risks through various means, including the use of cost and schedule contingencies. A risk management program provides an analysis and assessment of risks to determine the maximum protection from risk and strategies for identifying and responding to risks at the earliest time in project development. Particular attention is given to high-magnitude cost elements and scheduled activities on or near the project's critical path. Risks originate at the earliest steps of project development and extend through design, construction, and operation. If not identified up-front, mitigated, and allocated appropriately in contracts, such risks can cause significant delays and may be exploited by construction companies for change orders

and cost increases from initial bid. As a project's complexity increases, more dimensions of risk emerge and should be analyzed for their potential impact on the project.

The development of a risk register helps to capture the risks associated with the project and to quantify the potential impacts of those risks to the project. The risk register should be developed at a meeting or workshop with staff and key stakeholders and updated regularly. The risk register identifies and describes each project risk, identifies the project activities potentially affected by the risk, provides the probability of occurrence, and identifies possible impacts on cost and schedule (Hillson 2002). The project management strategy should focus on risks of high occurrence and high impact; it is inefficient to pay attention to risks that are unlikely to occur and have low impact.

A risk management plan is a systematic process that identifies, analyzes, and responds to risk throughout all steps of project development. The plan, which includes a risk register and a mitigation plan, should be regularly updated since some risks are step-specific or evolve over time. Although some risks may be inevitable, risk evaluation assists in developing a program to avoid, reduce, transfer, or minimize their impacts (see chapter 7).

A risk management strategy should match the level of detail and needs of the project given its budget, schedule, and scope. All risk management strategies start by identifying risk. Identification can be top-down, in which case the most important risks are identified based on experiences in similar projects and environments. In more sophisticated bottom-up identification, every risk potentially affecting the project is registered and characterized in detail. This bottom-up identification represents a more precise picture of the situation, thus allowing project staff to collect information and make risk-informed decisions at the lowest level of an organization. However, because of its level of detail, bottom-up identification consumes more resources and may not be realistic if not enough comparable information from industry practice is available. Since most organizations cannot afford the resources necessary for a full bottom-up identification, modern strategies try to combine and find a balance between top-down and bottom-up risk identification. This balance enables executive-level project managers to perform a top-down risk assessment revealing the major risks to the project. Once these risks are identified, the project team, armed with more specific knowledge, can conduct a bottom-up assessment of the evolution of identified risks throughout the project development process and monitor the emergence of new risks.

A multidisciplinary team within the project-implementing agency should conduct a qualitative risk identification during preliminary design. This effort should be updated at different steps of project development. As design and

construction contracts are awarded, the risk management system set up within the project-implementing agency should expand to contractors, private partners, and any supervisory consultants with regular oversight. Risks inherent to all steps of the project development process should be identified. A quantitative value that measures the risks may be developed if suitable, but it is not always necessary. Alternative methods for mitigating risk should be analyzed, and a mix of risk-control practices and procedures should be selected. For additional information on risk analysis and management, see chapter 7 of this handbook.

### **Project Management Planning throughout the Project Development Process**

Project management planning is an important component of all steps of project development, with shifting emphasis as a project moves forward (see table 4.3).

As the project develops, certain designs are finalized and construction milestones are achieved. In general, project management planning prepares the project for the next step in the process. For example, project management planning in the corridor-level planning step sets up many of the procedures, financing, procurement, and staffing plans to prepare for project design and project delivery. As the project advances into the design step, project management planning efforts initiate planning for construction, including plans for construction oversight, inspections, and safety and security management. At the start of construction, emphasis is given to managing system and vehicle acquisition and to initial planning for testing, start-up, and revenue service. During this time, the emphasis of safety and security planning shifts from construction safety to safety and security of the system as a whole after revenue service begins.

Even after the project is complete, project managers and the implementing agency can benefit from continued monitoring and review of the system and its quality of service. An ex post review of the project development process from planning through initial revenue service can help implementing agencies to identify sources of uncertainty and risks that manifested throughout the project and to learn from these lessons for future projects. These ex post reviews should last at least five years, taking into account not just the delivery of construction works but also the efficiency of initial operations and maintenance of facilities. Taking into account the final operability of the system sheds light on any issues from the planning and design phases that affect the project only after construction is completed. These agencies can then learn how to mitigate these uncertainties and risks in future projects. Learning from the mistakes and successes of

**TABLE 4.3. Illustrative Areas of Emphasis for Project Management Planning throughout the Project Development Process**

PROJECT STEP	PROJECT MANAGEMENT PLANNING AREA OF EMPHASIS
Planning	<ul style="list-style-type: none"> <li>• Set-up of project management planning, including organizational structure, management, risk management, staffing, design control, quality assurance (QA)/ quality control (QC) process, and internal and external communications systems and strategies</li> <li>• Preliminary socioenvironmental planning, including investigation of cultural heritage sites</li> <li>• Land acquisition planning, utility relocation planning, and other legal services</li> <li>• Delivery and procurement planning</li> <li>• Financial planning</li> <li>• Geotechnical level of detail planning</li> </ul>
Preliminary and detailed design	<ul style="list-style-type: none"> <li>• Updating of all project management planning and all other relevant planning and design documents to prepare for next steps of project development</li> <li>• Project optimization (chapter 6)</li> <li>• Socioenvironmental impact assessment</li> <li>• Procurement plan implementation</li> <li>• Sequencing of civil works construction (chapter 11)</li> <li>• Systems and rolling stock acquisition planning</li> <li>• Safety and security management planning</li> <li>• Procedures for QA/QC and construction oversight and inspection</li> </ul>
Construction	<ul style="list-style-type: none"> <li>• Updating of all project management planning and all other relevant planning and design documents to prepare for next steps of project development</li> <li>• Oversight of construction</li> <li>• Planning for testing, start-up, and initial revenue service</li> </ul>
Start-up and testing	<ul style="list-style-type: none"> <li>• Oversight of start-up and testing</li> <li>• Preparing for revenue service</li> </ul>
Operations	<ul style="list-style-type: none"> <li>• Service quality review and optimization</li> <li>• Ex post analysis</li> </ul>

previous projects is especially important for large urban rail networks, which are often delivered one line or project at a time.

Project management planning for major urban rail projects includes many aspects. Well-developed project management planning should be reflected in a written document defining all tasks necessary to implement the project. This document should describe policies, practices, and procedures related to the management, design, and construction of the project as well as the staffing roles

**BOX 4.3.****Required Content for the U.S. FTA's New Starts Program Project Management Plan**

At a minimum, a project management plan should include the following:

- A description of adequate recipient staff organization, complete with well-defined reporting relationships, statements of functional responsibilities, job descriptions, and job qualifications
- A budget covering the project management organization, appropriate consultants, property acquisition, utility relocation, systems demonstration staff, audits, and such miscellaneous costs that the recipient is prepared to justify
- A construction schedule
- A document control procedure and record-keeping system
- A change-order procedure that includes a documented, systematic approach to handling construction change orders
- A description of organizational structures, managerial or technical skills, and staffing levels required throughout the construction phase
- Quality control and quality assurance programs that define functions, procedures, and responsibilities for construction and for installation and integration of system components
- Material testing policies and procedures
- Safety and security management
- Internal plan implementation and reporting requirements
- Criteria and procedures to be used for testing the operational system or its major components.

In addition to these components, the FTA also requires periodic updates of the plan, especially related to project budget and project schedule (completed monthly), financing, ridership estimates, and the status of local efforts to enhance ridership where ridership estimates depend partly on the success of those efforts. This periodic update is required because as a project advances through the development process, estimates of budget, schedule, and functionality become more precise.

Source: FTA 2016, 2–21.

and responsibilities to carry out each task. It should be written early in project development and updated regularly. The specificity of the document should be tailored to the step of project development, but details should always be included to address cost, schedule, risk, controls, monitoring and reporting procedures, and other content. The requirements of the U.S. FTA funding program for major capital investments known as New Starts illustrate the content that could be included in a project management plan (see box 4.3).

**Planning Management**

In the early planning steps of project development, multiple modal alternatives may still be under review (see chapter 3). During these steps, the

project-implementing agency has to decide whether to invest in the design of an urban rail project and what general horizontal and vertical alignment the system might take. These kinds of conceptual decisions can affect the success or failure of the project and should be analyzed from various points of view. It is especially important to involve representatives from all steps of project development (including design, construction, and operation) during planning—where decisions affect long-term “implementability” of the project.

During planning, project management emphasizes establishing adequate agency and consultant staff with well-defined reporting relationships, functional responsibilities, job descriptions, and job qualifications for the planning activities. In addition to organizational planning, risk management is also undertaken as early in the project development process as possible. This is because uncertainty and variability in the scope, schedule, and cost estimates are greatest at the beginning of a project.

Additionally, in preparation for design and implementation, project management planning needs to set up a design control process, including document control and record-keeping systems. Procedures to monitor and control project scope, budget and cost, and schedule using the fundamental project management planning tools discussed above need to be established. Furthermore, quality assurance (QA)/quality control (QC) procedures for the design should be developed, and right-of-way and land acquisition as well as utility relocation plans should begin.

### *Procurement Management*

An important component of project management planning during early planning is the development of procurement and land acquisition plans. A procurement plan is developed to provide the quickest and most cost-effective procurement and delivery process. The procurement plan details what project elements are to be included in each proposed contract as well as detailed scheduling for all internal and external approvals. It also details which procurement method will be used and why.

The procurement plan should be considered during the planning step, early in project development, because the level of detail of the project design and the role of the project-implementing agency in implementation are conditioned by the procurement scheme. For example, with a traditional design-bid-build project delivery method, the project-implementing agency plans and procures detailed design services followed by separate bidding and procurement for construction services from one or more contractors or equipment suppliers. However, with alternative project delivery methods that combine design and construction services into a single bid or that involve greater private sector

participation in project management, procurement planning will likely have a different structure. With alternative methods, the procurement plan may focus less on design details and more on procedures for oversight of contractor and project performance. Chapter 8 provides more information on the advantages and disadvantages of different project delivery methods.

### *Land Acquisition Management*

Land acquisition may be significant in urban rail projects and can lead to delays in the initiation of project construction (see chapter 11). Although some of these delays may be due to permitting and land rights, others may be due to social and environmental issues associated with land acquisition—such as archeological or paleontological remains and other issues of cultural heritage, decontamination of land, or protection of patrimonial or environmentally sensitive areas (see chapters 14 and 15). A land acquisition plan should be developed early in the design step, informed by social and environmental impact assessments, and executed well before the start of construction. This plan describes the roles and responsibilities of the various agencies that will be involved in land acquisition. A schedule for the acquisition of properties is included. The plan also describes the staffing of the lead land acquisition agency and establishes its authority for eminent domain. An early start of land acquisition and needed relocations is highly recommended so as not to impact the project's critical path schedule (see also chapter 11).

### **Design Management**

The design step of a project entails staff from many specialties. Design documentation is voluminous, and a document control system is a necessary component of this effort. The document control system stores draft design documents and any comments from the various reviewers, creating a record of changes to the design and inputs from multiple project stakeholders. New technology, such as BIM, can provide collaborative design platforms and project management tools for dealing with design input from multiple parties.

### *Building Information Modeling*

BIM is the process of designing civil engineering works collaboratively using one coherent system of computer models. BIM uses software suites that represent the physical and functional characteristics of engineering structures in digital form to manage changes throughout construction of the project and to provide up-to-date, shared information for project managers, contractors, and other key stakeholder groups. BIM offers enormous savings in cost and time, greater accuracy in estimation, improved project delivery, and fewer errors, alterations, and rework due to information loss (Crossrail Ltd. 2017) (see box 4.4).

**BOX 4.4.****Building Information Modeling in the United Kingdom and Mexico**

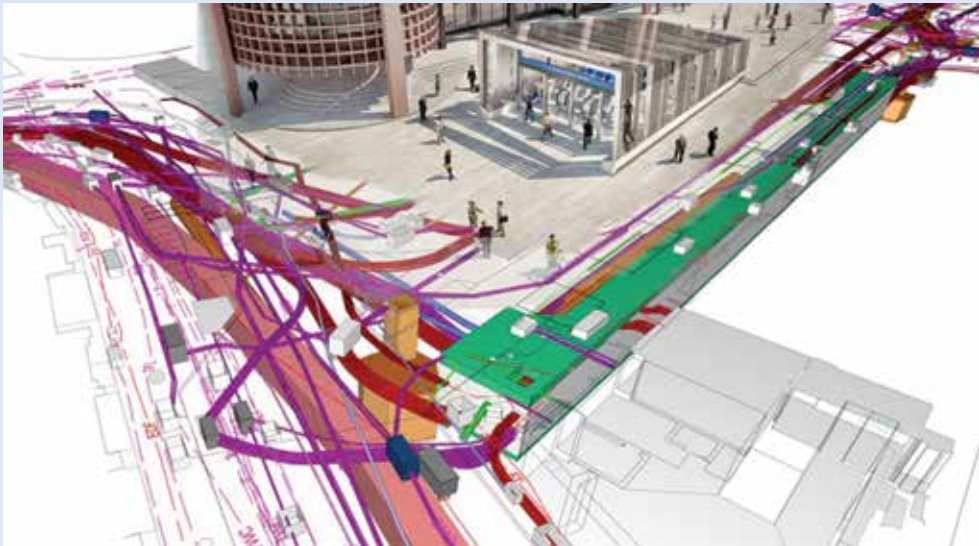
The U.K. government has recognized the value of the BIM paradigm, announcing in 2011 that it would require collaborative three-dimensional BIM (with all-electronic project and asset information, documentation, and data) at level 2 as a minimum standard for public construction projects by 2016 (Cabinet Office 2011). In 2015, the U.K. government reasserted its commitment to BIM, releasing the Digital Built Britain strategy toward implementation of BIM level 3 (Department for Business, Innovation, and Skills 2015).

Embracing the national strategic guidance, Crossrail was one of the first major transportation infrastructure projects to realize the BIM concept fully (see image B4.4.1). Crossrail

implemented BIM to streamline the 25 design contracts, 30 advanced works contracts, and more than 60 logistics and main works construction contracts involved in the project. Crossrail also plans to use BIM to realize long-term operational cost savings by providing accurate system design information to operators of the railway who will manage the structural assets after construction.

Although not yet mandatory, BIM also has been used successfully to reduce risks and costs in the design of urban rail projects in low- and middle-income countries. For example, BIM is being used in Mexico throughout the process of developing the third phase of the interurban train (Notimex 2017).

**IMAGE B4.4.1. BIM of the Utility Corridor Beneath Liverpool Street Ticket Hall: Crossrail, London**



Source: © Crossrail, Ltd. Reproduced with permission; further permission required for reuse.



Adopting BIM involves much more than simply changing the software used. In order to achieve all of the benefits it offers, everyone involved in the management, architecture, engineering, and construction of the project has to learn to work together in fundamentally new ways. BIM is a new paradigm that involves both new technology and new, multidisciplinary, and collaborative work processes.

Distinct milestones define different levels of collaboration (0–3) that imply increasing sophistication and reward (McPartland 2014):

- *Level 0.* At this level there is effectively no collaboration. Two-dimensional computer-aided design (CAD) drafting is used and is distributed via paper or electronic prints. The majority of the construction industry is already well ahead of this level.
- *Level 1.* This level of collaboration typically comprises a mixture of three-dimensional CAD for concept work and two-dimensional drafting of statutory approval documentation. A common standard is applied for all drawings, and data are shared electronically from a common data environment, often managed by the contractor, but models are not shared between project team members. Many organizations currently operate at this level.
- *Level 2.* At this level, all parties use their own three-dimensional CAD models and share design information through a common file format. This collaborative and standardized data sharing enables an organization to join data from other parties with its own in order to make a combined BIM and to test for compatibility of design and function.
- *Level 3.* Also known as “Open BIM,” level 3 represents full collaboration between all disciplines; a single, shared project model is held in a centralized repository. All parties can access and modify the same model. Doing so removes the risk of having conflicting information. In order to move to this highest level, copyright and liability issues have to be resolved by means of robust appointment documents and software-originator read-and-write permissions and shared-risk procurement routes such as partnering.

### *Quality Assurance/Quality Control*

As design is initiated, a QA/QC program is essential. QA emphasizes developing systematic activities necessary to provide confidence that the project conforms to specifications and will perform satisfactorily in service. QC refers to measuring, testing, and inspecting processes and products to ensure that they meet requirements. Together, QA/QC provides an effective system for ensuring that all project work is performed in accordance with requirements set by the project

management team. QA/QC is performed primarily during the design of the project, but continues through construction of infrastructure, acquisition of rolling stock, and operations.

During design, QA/QC actions focus primarily on reviewing engineering documentation and services. Procedures are needed to control and verify the design of the project to ensure that design criteria and other requirements are met. These procedures should stipulate that stringent reviews are made of all drawings and related specifications. Discrepancies of location, dimension, and function need to be rectified early before moving on to further steps in project development. In order to avoid conflicts of interest, it is important that QA/QC functions are performed by staff organizationally independent from those responsible for performing the work.

Project management teams may also want to allocate time and resources during design for project optimization. Several methodologies—including peer reviews, value analysis, value engineering, constructability reviews, and operability reviews—can be implemented during design to ensure a cost-effective project (discussed further in chapter 6).

### **Construction Management**

During construction, contractors build fixed facilities, install equipment, and integrate the facilities and equipment into a functioning system. Construction management entails the oversight of construction contracts to ensure that contract deliverables are on time and at the agreed cost and quality. The goal is to ensure that all work is conducted in the most efficient manner in full accordance with the contractual requirements.

Under a traditional design-bid-build project delivery method, the project-implementing agency is typically responsible for procuring and coordinating the activities of one or more construction contractors or equipment suppliers. It is responsible for functions such as construction safety and security oversight, designer interface, overall project schedule, and budget control and quality assurance. However, with proper monitoring, some construction functions, such as decontamination, can be delegated to the contractor who often has more specific technical knowledge and likely has practical experience with construction issues.

With alternative project delivery methods, such as design-build and the use of public-private partnerships (PPPs), many of the project-implementing agency's responsibilities are assigned to the contractor (see chapters 8 and 9). However, the project sponsor retains final authority over the project. The more contractual parties there are, the more interfaces are created. Roles and responsibilities among the different parties have to be designed and bounded carefully,

since any overlaps or gaps in responsibilities are sources of conflict that can cause delays or open up opportunities for parties to argue for more money.

Having a structured, adequately staffed, and experienced QA/QC organization during construction is essential. Typically, QA responsibility is maintained by the project-implementing agency, and QC responsibility is given to the contractor, with inspections carried out by an independent testing company. Project-implementing agencies have to pay special attention to any design optimizations proposed by contractors and to the quality of execution of the construction works—key areas where contractors may try to cut corners to recover money from their initial bid.

### **Start-Up, Testing, and Short-Term Operations**

As project implementation progresses, staff should plan for the start-up of operations and entry into revenue service. Advance planning should be done for this step to prevent delays to the start of operations after construction has been completed and to provide a smooth transition to operations. Commissioning is an important component of this step. Commissioning is a process for validating the project's equipment and systems in coordination with operating personnel and outside parties. Allocating adequate time and resources to commissioning minimizes the risks of delays, cost overruns, and underperforming mechanical and electrical support equipment.

An integrated testing and start-up program needs to be developed. Testing provides verification, validation, and documentation of system performance and its operational characteristics. Operating procedures are developed and documented in operations manuals. Operations and maintenance staff are trained based on these manuals and get hands-on experience of the system from simulated operations tests. For brownfield projects, different or new systems are often introduced into existing railway systems. This integration has to be considered carefully since new additions may have cascading effects on the system. It is highly advisable to have certified engineers focus on configuration management, including comprehensive hazards analysis of new components or technologies.

It is particularly important to include the perspective of a “shadow operator” in project management planning from preliminary design through start-up and testing to ensure agreement between the project-implementing agency's plan and the private operator's acquisition of rolling stock and implementation of service. If there is disagreement or nonconformity between the project executed and the operator's service planning, there may be delays in start-up, additional costs for asset modification, or increased operation and maintenance costs over the lifetime of service.

### **Medium- and Long-Term Operations and Maintenance**

Even when operations and maintenance are conceded to a private partner for many years, it is important for the project-implementing agency to monitor and periodically reevaluate operational and maintenance targets and performance. Having staff from the oversight agency who are familiar with the maintenance and operations of the infrastructure is critical when systems or capital assets reach the end of their useful life, rolling stock is renewed, or the urban rail system is upgraded or expanded. Furthermore, having staff acquire enough experience as time goes on is essential when the concession ends, and it must be decided whether to take back or to retender the operations and maintenance of the system.

### **Conclusions and Recommendations**

*The implementation of an urban rail project is an extremely complex undertaking and evidence suggests that many projects suffer from cost underestimation, budget overruns, and schedule slippage.* Good project management planning lowers the risk that, through unanticipated events, a project's implementation schedule will be delayed, cost overruns will develop, and scope adjustments will be needed. It is also a key tool for improving project accountability. In most low- and middle-income countries, urban rail projects may be among the largest megaprojects advanced in their modern history, making careful project management planning even more important. Since experience with megaproject management is often limited in these countries, project management planning principles may also be scarce, increasing project risk. This final section synthesizes the main conclusions and lessons learned when it comes to good project management planning for urban rail development.

*Control of project scope, budget, and schedule are basic ingredients for successful and reliable project implementation—this is the essence of project management planning.* Successful project delivery is constrained by three interrelated factors: project scope, budget, and schedule. Fundamental project management planning tools can help technical staff and key project decision makers to keep abreast of these three variables and to evaluate and manage project risks. Project management planning helps to inform and establish the organizational structure, design control, and risk mitigation processes that are critical for minimizing the occurrence of project change orders, budget overruns, and delays. As the project advances from initial planning through implementation, these tools can continually help to refine estimates and anticipate possible risks, delays, or additional costs. Without careful project management planning, significant risks and impacts are likely to materialize.

*Project management planning improves a project's credibility among partners and financiers.* Good project management planning builds trust with the agencies providing funds to the project by demonstrating that the right planning is being done up-front to prevent problems from developing during implementation. The project control structure provided by good project management planning practices—coupled with a solid project management team that is able to communicate effectively and demonstrate good judgment—lends confidence that the project is and will be managed properly.

*Serious project management planning is required from the beginning of the project and through all steps of the project development process.* Project management planning is a key element in all steps of project development, but the earlier that it begins, the better. Project management planning is a “living” approach, with varying areas of emphasis as the project advances through planning, design, construction, and operations. For each step in the project development process, project management planning is critical for implementing the current step and for proactively preparing for the next step.

*Stakeholder buy-in, careful and multidisciplinary staffing, and effective methods of communication at the technical and managerial levels are essential for successful projects.* A broad base of technical disciplines is needed to implement any complex project, including urban rail projects. However, multidisciplinary planning has to be balanced with decision-making expedience. Project management planning can help to synthesize the knowledge and recommendations of a multidisciplinary group of technical staff from all areas and components of an urban rail project and then communicate these recommendations to a core project management team. This project management team, with a direct line of communication to decision makers, can ensure that the project is implemented according to good practice in all domains (such as design, construction, systems, operations, finance, legal, and public relations). Good documentation, tracking, and monitoring are essential for managing the project and communicating the many managerial and technical aspects of the project among key internal and external stakeholders.

*If this is the first urban rail project for an agency, it is worthwhile to consider getting outside help, but essential to manage that support well.* For agencies undertaking an urban rail project for the first time, it may be vital to import international state-of-the-art experts in certain technical areas, but it is also imperative that internal staff oversee these consultants and work with them to build lasting knowledge and capacity within the project-implementing agency. Internal staff need to be trained to achieve a level of managerial and technical leadership that can ensure that the project is governed adequately.

*In terms of successful project delivery, good project management planning has high return on investment.* Project management planning is not a negligible investment of time and resources; however, international experience demonstrates that the value gained greatly outweighs the costs. Particularly for agencies with little experience in urban rail development, which is often the case in low- and middle-income countries, project management planning can help to identify and mitigate risks that could otherwise jeopardize the successful delivery of important infrastructure improvements or the reputation of the project-implementing agency.

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# 5

## DESIGNING AN URBAN RAIL PROJECT

Georges Darido, Joanna Moody, and Wenyu Jia

After deciding to proceed with an urban rail project for a particular high-demand corridor (see chapter 3) and undertaking project management planning (chapter 4), decision makers consider the design of the urban rail system. Urban rail projects of any size must be approached as a system that integrates many interconnected subsystems and design components, including infrastructure (such as guideways, stations, and maintenance and storage yards), rolling stock, traction power and electromechanical equipment, signaling and train control, telecommunication and operation support, ticketing, and passenger information.

The decision to develop an urban rail project is based on detailed feasibility studies and preliminary design, which can cost the project-implementing agency a few million U.S. dollars (see chapter 3). The technical studies and surveys, analysis of alternatives, and decision to pursue an urban rail project are important milestones that precede the detailed design of the system, which is an even more significant investment on the order of tens of millions of U.S. dollars, depending on the project. Careful investment in the detailed design, while costly, is of utmost importance for the project to be delivered on time and within budget.

The proposed design will most likely influence all subsequent steps of project development, including procurement, construction,

*Photo:* Washington Crossover, Loop "L," Chicago, Illinois, United States, 2012.  
*Source:* Chicago Transit Authority via Flickr (CC BY\_NC-ND).

and operations. The first and most critical decision is to determine the long-term service plan for the urban rail system or corridor (see chapter 13). Most design items and, therefore, their capital costs and operating costs will depend on the service plan and its associated design capacity. Careful estimates of construction costs are needed to determine the capital costs of the project, which must be adjusted in accordance with available budgets (chapter 10). Operating cost estimates are also needed to create a financial model for the system's operations over the long term (chapter 13). The design and its financial model have to ensure both short-term fiscal stability during construction and long-term affordability and sustainability during operations.

The design of any urban rail system needs to account for environmental, social, and economic impacts of the project, which should be reevaluated as the project advances through design. The level of detailed design and investment in technical, environmental, financial, and institutional studies to be completed by the project-implementing agency before bidding depends on the method of procurement used for the project. However, improving the technical capacity of the project-implementing agency to evaluate integrated design options is important for managing all procurement contracts and for understanding the operational capabilities and maintenance necessities of the system. Even for project-implementing agencies that procure detailed design services from other entities, it is important for agency staff to understand the major features and options for urban rail systems and their potential impacts on cost and performance. For less knowledgeable or experienced project-implementing agencies, internal capacity building is highly recommended throughout the management of preliminary and detailed design.

This chapter introduces the advantages and disadvantages of key urban rail design features and options, current recommended design practice, and how to perform corresponding cost estimates to a level of detail necessary for project implementation. It also presents trade-offs among features and costs during the design phase and discusses factors exogenous to the project design that will influence cost.

Although many of the design features discussed in this chapter apply to both metro and commuter rail systems on exclusive rights-of-way (collectively referred to as urban rail systems), certain features are distinct. For example, commuter or suburban rail systems (or even the periphery of metro systems outside the city center) often cater to longer-distance trips with greater spacing between stations. Thus, rolling stock can achieve higher maximum speeds between stops. Suburban rail systems may run at lower frequencies without the need for state-of-the-art signaling systems to reduce headways between trains. Unlike metro systems that are developed to serve dense urban cores where

existing development and land values often necessitate dedicated elevated or underground infrastructure, suburban rail systems are more likely to run at-grade and may share right-of-way with longer-distance passenger or freight rail services. Therefore, infrastructure, rolling stock specifications, and signaling and control systems may differ for these two types of systems. Where applicable, such differences are noted throughout the chapter.

## Key Challenges in Urban Rail Design

The design of urban rail systems is complex. Although many of these complexities are true for any urban transportation megaproject, certain design challenges—such as the lack of comprehensive design standards, the need to design for very long-term capacity and operational sustainability, trade-offs and interactions among design features, and the need for multimodal integration—are unique to the design of urban rail systems.

### Design Standards

No authoritative guidelines or comprehensive standards exist for the design of urban rail systems. For certain design components, such as track, engineering standards exist that define certain parameters, such as geometric design in terms of vertical and horizontal curves. In general, however, an urban rail system is built to respond to the unique conditions of the urban area it serves. Very few components can be purchased “off the shelf,” requiring customization, which can be resource intensive. Some components of urban rail systems have been subject to rapid technological advances in recent years. Much of this progress has outpaced traditional engineering standards, which evolve more slowly. As a result, some of the most useful guidance for system designers is continually evolving and dispersed across many sources, including professional experience with recent urban rail projects implementing some of these new technologies, papers in refereed journals, and presentations at technical conferences.

For any metropolitan region in the world, a regulatory context requires compliance with locally or nationally mandated standards. These standards include many of the generic elements of any heavy construction project, covering, for example, civil engineering works, electrical power, communication systems, fire prevention, and safety. Urban rail projects often involve specialized features that fall outside these compulsory norms, so it is common to see local project sponsors adapt standards from other jurisdictions. A typical specification for an urban rail project includes references to international standards or cites standards from certain countries that may be modified for international use (see table 5.1).

**TABLE 5.1. Relevant Design Standards for Certain Features of Urban Rail Systems**

INTERNATIONAL OR MULTINATIONAL STANDARDS	COMMONLY CITED NATIONAL STANDARDS
<ul style="list-style-type: none"> <li>• International Organization for Standardization (ISO)</li> <li>• Institute of Electrical and Electronics Engineers (IEEE)</li> <li>• International Railway Industry Standard (IRIS)</li> <li>• Union Internationale des Chemins de Fer (UIC) and Euronorms (EN)               <ul style="list-style-type: none"> <li>– Intergovernmental Organisation for International Carriage by Rail (OTIF)</li> <li>– Union of the European Railway Industries (UNIFE)</li> <li>– Community of European Railways (CER)</li> </ul> </li> <li>• International Association of Public Transport (UITP)</li> <li>• International Electrotechnical Commission (IEC)</li> <li>• International Commission on Illumination (CIE)</li> <li>• International Association for Bridge and Structural Engineering (IABSE)</li> <li>• International Telecommunication Union (ITU) and European Telecommunications Standards Institute (ETSI)</li> </ul>	<ul style="list-style-type: none"> <li>• Association of American Railroads (AAR)</li> <li>• American Public Transportation Association (APTA)</li> <li>• American Society for Testing and Materials (ASTM)</li> <li>• British Standards Institution (BSI)</li> <li>• Bureau of Indian Standards (BIS)</li> <li>• German National Standard (DIN)</li> <li>• Japanese Industrial Standards (JIS)</li> <li>• Chinese Code for the Design of Metros (GB 50157-2013)</li> </ul>

The use of one specific set of standards may often be biased by the availability of guidance in a country's native language—for example, standards in Latin America are highly influenced by standards in Spain.

### Designing for the Capacity Needed in the Long Term

Urban rail systems should be designed and built to serve the needs of the metropolitan region for at least 100 years, although most infrastructure components need to be rehabilitated or replaced within 50 years. The system's design capacity is a critical decision that has to account for projected growth of population and economic activity in the metropolitan region. However, it is difficult to forecast passenger demand and other requirements, such as resilience, with such a long-term horizon (see chapter 3).<sup>1</sup>

Implementing an urban rail system for a corridor that does not have the near-term demand to use the capacity designed (overdesigning) involves opportunity costs, such as the cost of operating and maintaining infrastructure and systems that are underutilized. At the same time, underdesigning capacity in a corridor with high current or future demand involves significant opportunity costs due to loss of potential economic activity due to unserved trips and because any changes after implementation are extremely costly.

Although some urban rail projects have had overly optimistic estimates of ridership demand, recent experience in Asia and Latin America suggests that demand can grow rapidly in mature public transport markets and that the opportunities to expand operational capacity are limited after a project is built. Projects should be designed and developed with an appropriate provision for future capacity expansion, particularly where opportunities exist to shape urban development around the urban rail infrastructure to generate even greater demand (see chapter 16).

Where future ridership is highly uncertain, the design needs to have some flexibility. At the outset, a marginal increase in capital cost can prepare the infrastructure to face unexpected changes in demand by building in options for future improvements (see chapter 6). If such flexibility (such as additional station capacity and land reserves for the expansion of depots) is not included a priori, capacity increases and other changes can become highly costly or practically impossible to add in the future. Once a system is built, it should be operated and maintained to maximize ridership according to its design capacity.

Urban rail is the urban transport solution with the highest and most reliable passenger-carrying capacity in return for a large capital investment. For corridors with estimated demand of 20,000–50,000 passengers per hour per direction, other urban transport solutions such as bus rapid transit (BRT) or light rail systems may provide similar levels of service at lower up-front capital costs but entail trade-offs with regard to marginal operating cost per passenger. For corridors with ridership projected beyond 50,000 passengers per hour per direction, no existing alternative to urban rail can safely and reliably accommodate such high volume of traffic (UN-Habitat 2013; Zhang 2009).

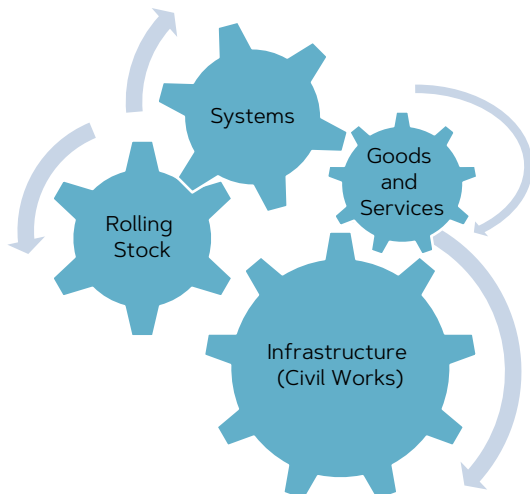
Due to concerns about initial capital cost, some urban rail systems in large cities with dense corridors are built with insufficient carrying capacity to support growth in population and economic activity. These systems quickly reach near-maximum capacity, experiencing associated deterioration of service quality, but they are difficult to expand or improve. For many of the design features described in detail in this chapter, it is much less costly to design for higher capacity and future expansion initially than to implement upgrades retroactively. Experience shows that retrofitting or upgrading rail solutions in a context of active operations can be significantly complex or, at times, impractical. Some features, such as wider trains, are virtually impossible to change after the system is operational. Other capacity upgrades, such as signaling and control systems, are feasible but extremely complicated and often take place only after previous equipment has reached the end of its useful life. Therefore, it is critical to design the system in a way that anticipates growth in population and economic activity in the host metropolitan region (World Bank and RTSC 2017).

### Trade-Offs and Interdependencies among Design Features

Each individual design feature has implications or trade-offs with regard to system capacity, operational flexibility, service performance, and cost. It is important to consider the project owner's priorities, customer preferences, and ultimate performance objectives during the design process. For example, the passenger-carrying capacity in the highest-demand sections of the line is one of the most critical parameters for design because it affects the number and type of trains needed, type and length of station platforms, shape of stations, number of station entrances and exits, and other dimensions of the system. It may also influence vertical alignment, choice of signaling and other subsystems, and service planning and maintenance (described in chapter 13).

On top of these trade-offs for individual design features, it is important to acknowledge the physical and temporal interdependencies among multiple features. The design of the system needs to consider carefully how the features interact and advance together (see figure 5.1). For example, advanced communications-based train control (CBTC) signaling systems can be installed to reduce spacing between trains and allow for more frequent service on a single track. However, the installation of turnouts, switches, and other elements of track geometry also have to support the efficient movement of trains at this higher frequency; otherwise, the improvement in service from the signaling upgrade cannot be fully realized. This is only one of many examples of how signaling

**FIGURE 5.1. Influence of Interdependencies among Design Features on Project Performance and Cost**



and infrastructure (civil works) features of an urban rail system have to be designed together for maximum benefit.

Given the trade-offs and interdependencies among design features, it is important to optimize project designs (see chapter 6). All detailed and final designs should be reviewed by appropriately qualified independent engineers or supervisory consultants who provide validation or certification of important features such as constructability and quality of infrastructure, operability and performance, and safety and security. Designs should be reviewed by the eventual system operator or a "shadow operator" to understand the long-term implications of features for service provision and maintenance. Roles and responsibilities should be allocated clearly among the project-implementing agency and its partners and contractors. Although the

allocation of responsibilities for project optimization and design interface management depends on the project delivery method adopted, in all cases, unclear or duplicated roles can lead to conflict and costly delays. As part of the design process, clear procedures are needed for review and approval of all documents, including alternative design proposals and contractual mechanisms to share costs or savings, if applicable (see chapter 4 for more details on technical oversight and quality assurance).

### **Multimodal Integration of Urban Rail Design**

Multimodal integration (including physical, operational, and fare integration) should be considered carefully in the design of urban rail systems. Maximum passenger demand and other positive effects such as economies of scale can only be exploited fully on a network of hierarchically integrated lines and services (see chapter 2). Urban rail systems do not, by nature, provide door-to-door service for passengers. Therefore, it is important to consider how people access and egress the system's stations when traveling from their origin to their final destination. The number of possible combinations of origins and destinations multiplies with the creation of a network of rail lines and complementary mobility options. For this reason, the design of an urban rail line should consider the integration points, terminals, and connections with all other existing and future transport infrastructure and services. In particular, it is important to integrate the urban rail line with other public transport and nonmotorized modes regarding physical layout, operations, and fare structure and technology.

Practice demonstrates that when design features related to multimodal integration are only considered as an afterthought, the project often suffers significant governance disruptions, increased costs, implementation delays, and risk of suboptimal operational performance. Good practice is to consider the design of the project and its integration with other modes and public space features from the outset (no later than during preliminary design). Addressing these features at final design or during construction is often detrimental to the value of the project.

Successful implementation of an urban rail project often requires supporting measures having to do with the rest of the public transport system and the urban transport system as specified in an integrated urban mobility strategy for the metropolitan region (chapter 3). These measures may involve additional or complementary investments; the reorganization of existing public and private transport services; changes in fare policy, parking policy, and other mobility regulations; the implementation of road use charges; and institutional reorganization. At the very least, design of the urban rail system should be complemented

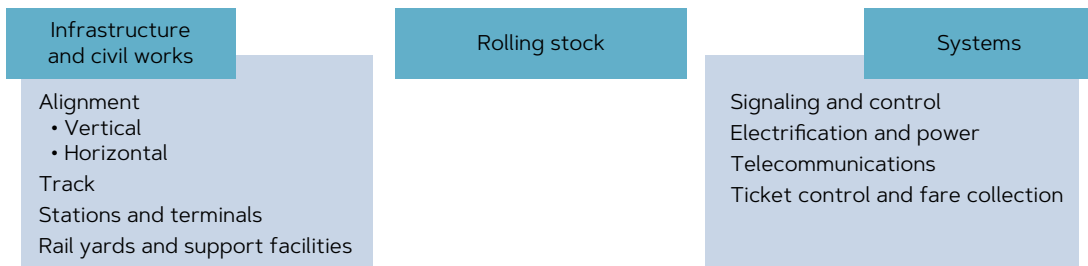
with a corridor transit service plan to integrate rail service with bus services and other modes of access. This complementarity often requires reorienting bus routes (both formal and informal) from offering competing services to providing feeder services to rail stations, building connected sidewalks and bicycle paths, and perhaps providing parking facilities at the end of suburban commuter rail lines (see chapter 16).

To avoid costly redesigns or retrofits later, it is important for urban rail system designs to reference the latest urban land use and transport strategies of the city (see chapter 3). Long-term commitments from metropolitan transport authorities and other relevant stakeholders regarding multimodal integration—as well as land use and transport planning, adequate governance, long-term political commitment, and stable funding frameworks—have to be obtained before the urban rail project is initiated.

### Design Features and Options

At a basic physical level, an urban rail project consists of infrastructure realized through civil works (such as guideways or stations), rolling stock, and number of systems (such as signaling or electrification). In the process of designing an urban rail project—whether a completely new system, an additional line of an existing system, or the extension of an existing line—the designers must choose among available options for a wide range of features that encompass infrastructure, rolling stock, and systems (see figure 5.2). There is no “standard” urban rail system since many of these options offer trade-offs or varying degrees of both up-front and ongoing costs and benefits. It is important to consider the advantages and disadvantages in the specific local context when choosing among the range of options.

**FIGURE 5.2.** Key Categories and Examples of Design Features for an Urban Rail System





The rest of this section presents the available options within each feature, summarizes the advantages and disadvantages of each option, and makes recommendations for choosing among those options.

**Infrastructure and Civil Works**

In broad terms, the infrastructure and civil works of an urban rail system consist of vertical and horizontal alignment, track, stations and terminals, and rail yards and support facilities.

*Alignment*

Alignment is one of the most critical planning and design categories of urban rail infrastructure. Metro and suburban rail systems have exclusive rights-of way, which require higher investment and land acquisition along their alignments but in return provide higher performance than other rapid transit alternatives that operate in mixed traffic. The category of alignment considers two main design features:

- *Vertical alignment.* The determination of which segments of the urban rail system will be constructed at-grade, elevated, or underground
- *Horizontal alignment.* The determination of the route that the rail line will take through the city

For vertical alignment, the choice among options is complex and depends on the topography and circumstances of the particular city (see table 5.2). For example, the higher initial cost of an underground rail system has to be balanced

**TABLE 5.2. Options for the Vertical Alignment Design Feature**

OPTIONS	ADVANTAGES	DISADVANTAGES
At-grade	<ul style="list-style-type: none"> <li>• Least expensive to construct</li> </ul>	<ul style="list-style-type: none"> <li>• May involve high land acquisition costs (depending on horizontal alignment)</li> <li>• Most disruptive to surface traffic (vehicles and pedestrians) both during and after construction period</li> <li>• Creates physical barriers between neighborhoods</li> <li>• Moderate noise, vibration, and visual impact</li> <li>• Requires the most land for operations</li> <li>• Potential hazards caused by intrusions onto right-of-way; requires fence</li> </ul>

(table continues next page)

**TABLE 5.2. Options for the Vertical Alignment Design Feature (Continued)**

OPTIONS	ADVANTAGES	DISADVANTAGES
Elevated	<ul style="list-style-type: none"> <li>Typically, costlier than surface construction, but less costly than tunneling</li> <li>Significantly less disruptive to surface traffic than at-grade</li> <li>Less vibration impact than either tunnel or at-grade</li> <li>Typically, lower land acquisition costs than at-grade</li> </ul>	<ul style="list-style-type: none"> <li>Vertical access costlier than at-grade (construction and passenger time and effort)</li> <li>Higher long-term capital maintenance costs due to faster asset deterioration from weather and environmental factors</li> <li>Worst visual and noise impact</li> <li>Moderate barrier effect between neighborhoods, particularly when under-structure space is poorly used (chapter 11)</li> </ul>
Underground	<ul style="list-style-type: none"> <li>Positive impact on urban form because it promotes dense, transit-oriented development around stations, leading to higher ridership and higher land values</li> <li>Does not create physical barriers between neighborhoods; no visual impact</li> <li>Lowest noise impact; moderate vibration impact</li> <li>May be perceived by the public as having higher quality</li> <li>Little to no impact on surface traffic after project delivery</li> <li>Protects infrastructure and passengers from weather</li> <li>Typically, lower land acquisition required than at-grade or elevated</li> </ul> <p><i>For deep (rather than shallow) tunnels</i></p> <ul style="list-style-type: none"> <li>May be advantageous for routes with irregular topography or crossing rivers and other barriers</li> <li>May be less costly in terms of initial construction costs, as there is less disruption to surface development and shallow utilities</li> </ul>	<ul style="list-style-type: none"> <li>Often highest cost for initial construction, more time required for construction, and greater cost for future expansion of capacity, compared with at-grade or elevated</li> <li>Extra cost for ventilation and climate control at stations</li> <li>Increased travel time and effort for passengers to move between station entrance and train platform</li> </ul> <p><i>For deep (rather than shallow) tunnels</i></p> <ul style="list-style-type: none"> <li>Often more expensive to operate due to the larger number of stairs, escalators, elevators, and lights that must be powered and maintained</li> <li>More time and effort required for passengers to move between train platforms and station entrance</li> </ul>

against the potentially greater long-term benefits to the urban and natural environment. In the central areas of older, dense cities, it is often necessary to develop an underground system to avoid the intense disruption to urban activities caused by construction and operation of surface or elevated lines (see chapter 11). In areas outside the city center, either an at-grade or an elevated rail system may be a practical way to provide more extensive coverage at less initial cost. In less-dense peripheral areas served by commuter rail service, one common approach is to construct the rail line within an existing public right-of-way, such as a highway median or along utility lines, which can substantially reduce land acquisition costs. In each case, it is important to account for both the initial capital cost and the long-term effects on system performance, the impact on urban development, and the environmental consequences before making a decision.

The number of design options for horizontal alignment is greater and specific to the city and corridor in which the urban rail system is being developed. In determining the horizontal alignment of the system, lines have to run as straight as possible and stations have to be located where the potential demand is greatest and future network extension is easiest. It is critical to consider carefully the location of entry and exit points of stations (including emergency exits) as well as ventilation and pump shafts. Local and universal accessibility should be addressed through the choice of location, number and type of entrances, placement of elevators and escalators, and other considerations. In determining horizontal alignment, it is best to make as much use of existing public land as possible to minimize expropriations. Available public lands may be parks or roadways, although construction along the road right-of-way often requires more traffic management during implementation. Horizontal alignments have to be drawn to minimize expropriation and resettlement (see chapter 14) and to avoid areas that may require substantial environmental mitigation (see chapter 15). For example, experience has shown that project alignments running through existing gas stations often require costly and time-consuming remediation of contaminated soils. Similarly, the tendency to use old garbage dumps for yards should be evaluated carefully because of the cost of soil treatments. However, if properly budgeted in terms of cost and time, these projects can provide an opportunity for the city to clean and repurpose contaminated sites.

### *Track*

When designing any urban rail system, it is important to consider carefully the track layout, including the track gauge or spacing of rails, the number and type of auxiliary tracks and their distribution throughout the system, and the type of track bed (see table 5.3). Widely accepted “good practice” exists for some of

these features of track design. For example, standard gauge is the preferred choice for track gauge, unless there is a specific need to maintain compatibility with preexisting track and equipment that runs on nonstandard gauge.

However, for many other decisions regarding track design, the advantages (value) and disadvantages (often costs) of the different options need to be weighed. For example, a collection of pocket tracks and passing tracks—which

**TABLE 5.3. Features and Options of Track Design**

FEATURE	OPTIONS	ADVANTAGES	DISADVANTAGES
Track gauge	Standard UIC gauge (1,435 millimeters)	<ul style="list-style-type: none"> <li>Used worldwide by all but a few urban rail lines</li> <li>Offers greater choice of off-the-shelf rolling stock and other equipment and hence much lower cost</li> </ul>	<ul style="list-style-type: none"> <li>None for greenfield projects (new developments)</li> </ul>
	Nonstandard gauge	<ul style="list-style-type: none"> <li>Required for expansion projects where there is a need for interoperability with existing infrastructure and rolling stock</li> </ul>	<ul style="list-style-type: none"> <li>Equipment is significantly more expensive than for standard gauge</li> <li>Maintenance vehicles may need adaptations, which makes maintenance much more expensive</li> </ul>
Auxiliary tracks	Pocket tracks	<ul style="list-style-type: none"> <li>Better matches rail system demand with operational capacity</li> <li>Provides flexibility to shift service around incidents and track work</li> <li>Offers staging of gap trains and temporary storage of disabled trains</li> <li>Reduces length and duration of deadhead train movements</li> </ul>	<ul style="list-style-type: none"> <li>Increases the cost of construction and operations</li> </ul>
	Passing tracks	<ul style="list-style-type: none"> <li>Allows trains to pass each other, making it possible to have local and express service without double tracks along the entire line</li> <li>Provides service flexibility for maintenance and response to disruptions</li> </ul>	<ul style="list-style-type: none"> <li>Increases the cost of the system and the risk of accidents</li> </ul>

*(table continues next page)*

**TABLE 5.3. Features and Options of Track Design (Continued)**

FEATURE	OPTIONS	ADVANTAGES	DISADVANTAGES
Track bed	Ballasted	<i>With wood sleepers</i> <ul style="list-style-type: none"> <li>• Lowest initial cost</li> </ul> <i>With concrete sleepers</i> <ul style="list-style-type: none"> <li>• Higher initial cost than wood sleepers</li> </ul>	<i>With wood sleepers</i> <ul style="list-style-type: none"> <li>• Highest maintenance cost</li> </ul> <i>With concrete sleepers</i> <ul style="list-style-type: none"> <li>• Lower maintenance cost</li> </ul>
	Fixed slab	<ul style="list-style-type: none"> <li>• Higher initial cost than either wood or concrete sleepers. In tunnels, requires smaller bore that reduces construction cost</li> <li>• Better vibration reduction</li> </ul>	<ul style="list-style-type: none"> <li>• Lower maintenance and life-cycle cost than ballasted track with sleepers</li> <li>• Provides safety path in emergency situations</li> </ul>
	Floating slab	<ul style="list-style-type: none"> <li>• Significantly less vibration than with fixed slab</li> </ul>	<ul style="list-style-type: none"> <li>• Higher initial cost than fixed slab or ballasted</li> </ul>

Note: UIC = Union Internationale des Chemins de Fer.

allow trains to pull off the main line to let others pass—should be designed according to the service plan for train operations and maintenance (taking into account targeted standards of performance and future network expansion). Well-placed pocket tracks and passing tracks throughout the system can greatly improve the network’s capacity and operational flexibility as well as its resilience to adverse events (that is, operational special events and climate hazards such as floods or fires) (see chapters 13 and 17). Using as many standard switches as possible helps to reduce maintenance and purchase costs.

In terms of track bed, a mixed solution is required, using different types at specific points along the line to address differences in operating speed, noise and vibration reduction, drainage and water encroachment, as well as considerations of emergency operation and evacuation. Ballasted track, due to its lower initial cost, is often used in depots where train speeds are low, but is often avoided on the main line due to maintenance requirements. Nonballasted track offers the lowest life-cycle cost and is generally preferred for its stability and durability and because it provides a safe path in the case of emergency evacuations. For locations near areas sensitive to noise and vibration, system designers may consider using floating rather than fixed slab or other methods to dampen vibrations (such as visco-elastic bedspreads).<sup>2</sup> The main way to reduce noise and vibration is to avoid placing at-grade or elevated sections near sensitive areas and to implement corresponding land use regulations.

In addition to these features, it is important to consider operational strategies when defining track layout. This effort involves careful calculation of the

operational capacity and flexibility at critical points along the alignment (such as terminals and crossovers) and a cost-value analysis of the number of switches, passing track redundancy for maintenance or express service, and turnaround capacity at the end station. Chapter 13 provides further discussion of the relationship between track layout and operations service planning.

*Stations and Terminals*

In addition to features of the alignment and track, the design of civil works and infrastructure for urban rail systems needs to consider many station features. Stations and terminals house operational, maintenance, and system equipment as well as passenger-facing amenities. Passenger-facing design features include platform layout, length, and width, presence and type of platform screen doors (PSDs), and vertical access (see table 5.4). The types of stations chosen should be consistent with the long-term design capacity of the system, the constraints

**TABLE 5.4 Features and Options of Station and Terminal Design**

FEATURE	OPTIONS	ADVANTAGES	DISADVANTAGES
Station platform layout	Center (or island) platform	<ul style="list-style-type: none"> <li>• Allows both directions to share the same vertical movement infrastructure (stairs, escalators, elevators)</li> <li>• Can simplify interline transfers</li> <li>• For cyclically unbalanced flows, can make better use of the common platform space</li> <li>• Is more convenient for passengers during periods of single-track operation</li> </ul>	<ul style="list-style-type: none"> <li>• For surface or cut-and-cover station, requires more right-of-way for lead-in tracks</li> <li>• For stations in tunnels, may require more costly construction</li> </ul>
	Side platforms	<ul style="list-style-type: none"> <li>• Separate directional passenger movements on the platform</li> </ul>	<ul style="list-style-type: none"> <li>• Additional space to facilitate movement of passengers (particularly when transferring between tracks)</li> </ul>
	Split platforms	<ul style="list-style-type: none"> <li>• Advantage when horizontal space is limited</li> <li>• Better solution for underground stations</li> </ul>	<ul style="list-style-type: none"> <li>• Second support slab needed for one of the rail lines, which greatly increases costs</li> </ul>
	Flow-through platforms <sup>a</sup>	<ul style="list-style-type: none"> <li>• Highest capacity and most appropriate at interchange stations with shared platforms</li> </ul>	<ul style="list-style-type: none"> <li>• Greatest construction cost</li> </ul>

*(table continues next page)*

**TABLE 5.4. Features and Options of Station and Terminal Design (Continued)**

FEATURE	OPTIONS	ADVANTAGES	DISADVANTAGES
Vertical access	Escalator	<ul style="list-style-type: none"> <li>• More cost efficient per person-movement</li> </ul>	<ul style="list-style-type: none"> <li>• More time required for passengers to go between surface and station</li> <li>• Need to run escalators at slower than maximum speeds due to safety concerns</li> </ul>
	Elevator	<ul style="list-style-type: none"> <li>• Provides faster access, especially for deep stations</li> <li>• Provides universal access for wheelchair-bound passengers</li> </ul>	<ul style="list-style-type: none"> <li>• Lower capacity</li> </ul>
Platform shape	Shorter platforms	<ul style="list-style-type: none"> <li>• Less costly to build than long platforms</li> </ul>	<ul style="list-style-type: none"> <li>• If platforms are sized to fit shorter trains, future expansion for higher capacity can be unnecessarily costly (especially for underground or elevated stations)<sup>b</sup></li> </ul>
	Longer platforms	<ul style="list-style-type: none"> <li>• Lower long-term cost since the need for costly future lengthening of platforms is eliminated</li> </ul>	<ul style="list-style-type: none"> <li>• Higher initial cost</li> </ul>
	Wider platforms	<ul style="list-style-type: none"> <li>• More capacity for passenger movements</li> </ul>	<ul style="list-style-type: none"> <li>• Higher initial cost and more space required to build the station</li> </ul>
Platform screen doors	Half-height	<ul style="list-style-type: none"> <li>• Prevents passengers from falling (or jumping) onto tracks</li> <li>• Improves security by controlling access to tracks</li> <li>• Prevents injuries caused by high-speed through and maintenance trains</li> <li>• Reduces discomfort from drafts underground</li> <li>• Less costly than full-height</li> <li>• Better than full-height for outdoor stations without climate control</li> </ul>	<ul style="list-style-type: none"> <li>• Provides less protection from intrusions on the track</li> <li>• Does not serve climate control function</li> </ul>

*(table continues next page)*

**TABLE 5.4. Features and Options of Station and Terminal Design** (Continued)

FEATURE	OPTIONS	ADVANTAGES	DISADVANTAGES
	Full-height	<ul style="list-style-type: none"> <li>Prevents accidents and improves security by controlling access to tracks</li> <li>Provides weather protection for outdoor stations; provides greater comfort for passengers for underground stations (less drafty)</li> <li>Can save significant money over the operating life of the system if stations are air-conditioned</li> <li>Improves acoustics for public address system</li> </ul>	<ul style="list-style-type: none"> <li>Costlier initial investment than half-height doors</li> <li>May not be supported by existing platform infrastructure</li> </ul>
Other activities at the stations	Joint development	<ul style="list-style-type: none"> <li>Potential for additional revenue</li> <li>May draw passenger traffic close to the station, increasing the number of transit users</li> <li>Potential to involve private sector in assuming a portion of operating (and even potentially construction) costs of the station</li> </ul>	<ul style="list-style-type: none"> <li>Adds to project complexity and cost-schedule risk</li> <li>Requires wider political and public support and greater level of effort to prepare legal and financial arrangements</li> <li>Potential danger for corruption or the perception of corruption</li> </ul>
	In-station commercial space	<ul style="list-style-type: none"> <li>Can offer convenient services to passengers using the station and provide an increased sense of security (due to more continuous activity)</li> </ul>	<ul style="list-style-type: none"> <li>Poorly designed arrangements can interfere with passenger flow</li> <li>Challenging to create inviting environment in tight and closed spaces</li> </ul>

a. One island platform and two sides.

b. In underground systems, tunnels can be built straight and wide for several meters on either end of the platform to allow for future expansion in length with a marginal increase in up-front cost.

of the vertical and horizontal alignment, and the type of construction method used (chapter 11). Since the design and size of stations and platforms are expensive to change, it is important to design these to meet maximum projected growth in demand from population and other regional demographic changes over the long lifetime of the system.

The design of turnbacks at terminal stations is particularly critical for the operational flexibility and maximum service frequency of the rail line (see chapter 13). With a front crossover, trains can be repositioned for service quickly as they pull into the assigned terminal platform before finishing the previous trip. In contrast,

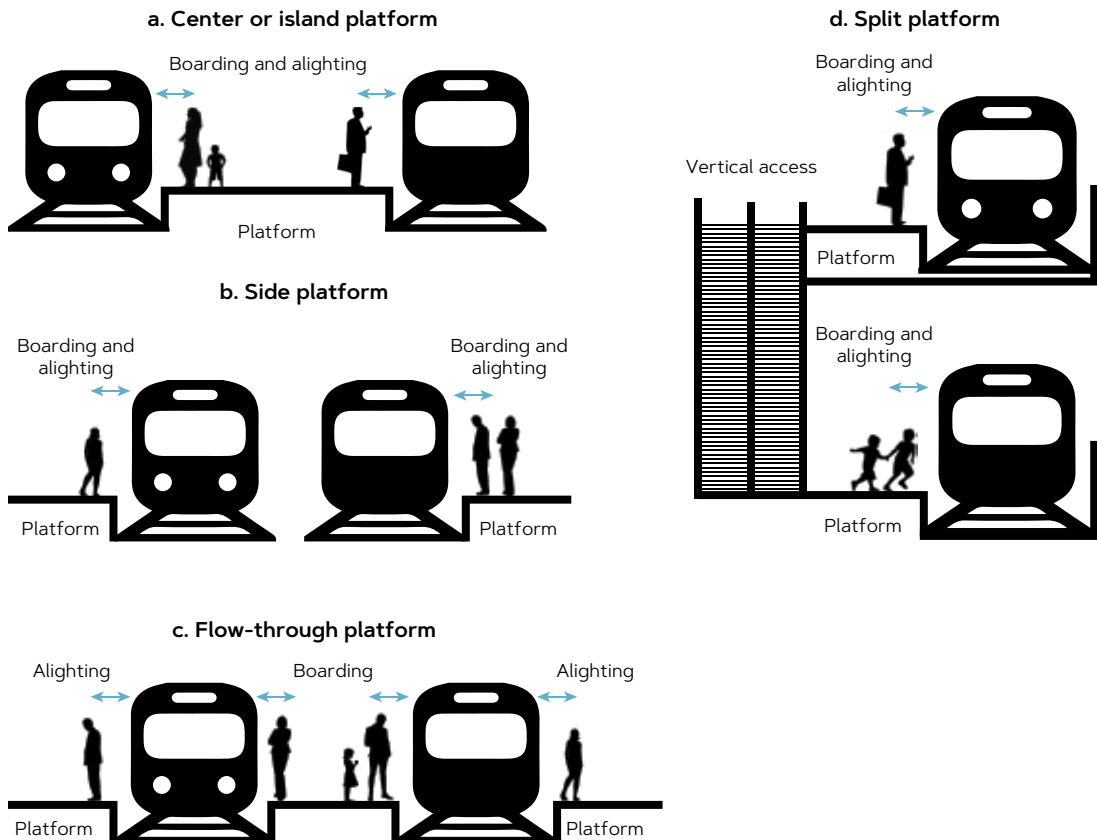


a back crossover requires trains to move to the crossover behind the station before returning to the platform for the next trip, increasing layover time.

With respect to the layout of station platforms, side and center (island) platforms are the most widely used (see figure 5.3). Center platforms are often better for stations projected to serve cyclically unbalanced passenger flows and for transfer stations because they allow passengers to alight and board from both sides of the train, reducing dwell times. Platform length and width and station capacity should be designed to accommodate the longest and widest trains that may be operated in the future.

There is a global tendency to implement PSDs for all greenfield projects due to their safety and other benefits, such as complementarity with driverless systems, platform acclimatization, vandalism control, and space for advertisement and information display. However, PSDs are not obligatory. Cheaper

**FIGURE 5.3. Schematics of Different Types of Station Platform Layouts**



Source: Adapted from Ministry of Railways 2009.

solutions—such as fences and automatic fall-detection systems—are available to prevent passengers from falling, but they do not provide as many other benefits. Therefore, the project budget and the full range of benefits of different solutions should be considered carefully before deciding whether to implement PSDs. Aboveground stations without climate control often implement half-height doors (see image 5.1), while underground, air-conditioned stations often use full-height doors, which can pay for themselves in long-term energy savings (see image 5.2). For older urban rail systems, platforms may not be able to take the weight of PSDs without significant investment to reinforce structures, so PSDs may be more expensive to implement on existing lines.

Most urban rail systems have some kind of vertical access in stations. Vertical access should be designed as part of a complete circulation, emergency evacuation, and universal accessibility plan that accounts for horizontal as well as passenger movements from entrance to exit. Continuity of capacity has to be maintained between all elements to avoid bottlenecks and to ensure the most cost-effective solution to provide the desired level of service. For complex stations, it is important to use simulation packages to understand passenger flows in normal operational conditions and emergency situations.

The design of any urban rail station needs to consider not only the rail terminal and platforms but also local accessibility at the front of the station. Station areas

**IMAGE 5.1. Half-Height Platform Screen (or Edge) Doors: Kwai Hing Station, Hong Kong MTR, Hong Kong SAR, China**



Source: Hokachung via Wikimedia Commons.

**IMAGE 5.2. Full-Height Platform Screen Doors: Raffles Place Station, Singapore**



Source: Calvin Teo via Wikimedia Commons.

and amenities should be designed carefully for pedestrians first, while still providing easy access by bicycle, bus, and other modes. To capitalize on these passenger flows through station space and to make use of any extra station capacity in the near term, it is worthwhile to consider incorporating other activities into station design, such as joint development or in-station commercial space. Incorporating other activities into the station is most feasible when part of a coordinated strategy to promote transit-oriented development across the entire system or as a means to defray some of the costs of complex multimodal terminals (see chapter 16). Commercial developers may be willing to contribute financial resources to construct the station in exchange for certain rights to develop adjacent areas. Although mixed-use development around stations can promote greater ridership and provide wider benefits to local communities, it is important to consider carefully the availability of land around the station and the possible need for any future system expansion before entering into long-term agreements with developers. Aerial development of stations may have a major impact on its structural elements such as foundations (and associated costs) and, therefore, must be decided early in design in order to ensure the appropriate supports are in place.

### *Rail Yards and Support Facilities*

All urban rail systems must have rail yards and adjacent maintenance facilities to accommodate servicing of rolling stock. For larger systems with multiple lines, it is recommended to locate multiple rail yards dispersed to serve different parts of the network. Having multiple rail yards and maintenance facilities costs more, but it can reduce deadheading of trains and improve service flexibility in response to disruptions (see box 5.1). The amount of land needed for yards and facilities is not trivial and needs to be well planned up-front, especially if there are system considerations (such as a single facility catering to more than one urban rail line). Once again, the location and design of these facilities have to take into account future network development. Experience shows that the location, environmental impacts, and resilience to climate hazards of these facilities need to be

#### **BOX 5.1.**

### **The Importance of Maintenance Yards for Urban Rail System Design**

Urban rail maintenance and parking yards require a large area that needs to be planned early in the project and that can have a high urban impact if not treated properly. These yards include space and facilities for parking and maintenance of rail cars; storage for auxiliary vehicles; loading, unloading, and storage of materials; and system control rooms and office buildings. All of these functions require a large space that can support industrial use. For example, Metro de Madrid uses the following benchmarks: 700 square meters of building space and 2,100 square meters of total surface area per rail car that is 2.4 meters wide and 90 meters long or 800 square meters of building space; and 2,400 square meters of total surface area per rail car that is 2.8 meters wide and 115 meters long.

Because of the noise, vibrations, traffic, and other negative externalities associated with yard activities, it is convenient to locate rail yards far from residential areas. When this is not possible, the rail yard can be protected with barriers or strips of green areas (for example, parks or gardens) around the

perimeter or be constructed underground. Sometimes an advantageous location with cheaper land can entail substantially higher operational costs, making it critical to assess the life-cycle costs of the location of the yards. To avoid affecting the operational expenses and financial sustainability of the overall system, this assessment would consider the nonrevenue costs for the foreseeable service plan. If the location is in a very dense area, underground facilities could allow for above-ground space that can be repurposed as commercial space, public space, or other land use needs (see image B5.1.1).

The location and design of railway maintenance and parking yards need to account for the long lifespan of the system assets and future growth of the city and its urban development. As cities grow, the semi-industrial yards may be surrounded by residential development, which can later generate difficult and costly conflicts (see image B5.1.2). Therefore, the project-implementing agency has to be sufficiently cautious in the location and design of these

*(box continues next page)*

**BOX 5.1.****The Importance of Maintenance Yards for Urban Rail System Design** *(Continued)*

facilities from the beginning of the project. In addition to accounting for city growth, the design and location of rail yards should also account for future growth of the urban rail network and fleet required for scaled-up operations. In most cases, it is cheaper and

less disruptive to reserve space for future expansion of the maintenance and storage facilities during construction of the first rail line rather than have to locate and design new or extended facilities as the network expands.

**IMAGE B5.1.1. Current Surface-Level Storage Area (left) and Model of Future Surface Restitution after Burial (right) for Cuatro Caminos: Lines 1 and 2, Metro de Madrid, Spain**

Source: © Metro de Madrid. Reproduced with permission from Metro de Madrid; further permission required for reuse.

**IMAGE B5.1.2. Space Reserved for the Possible Future Expansion of the Villaverde Storage Area: Line 3, Metro de Madrid, Spain**

Source: © Metro de Madrid. Reproduced with permission from Metro de Madrid; further permission required for reuse.

considered during early system planning and preliminary design, accounting for the operational service and maintenance plans. Otherwise, the construction and equipping of these facilities can affect the project delivery schedule. Poorly planned support facilities can also result in suboptimal operations with unnecessary nonrevenue kilometers for the trains and a negative impact on operating expenses and financial sustainability of the system.

### Rolling Stock

When designing the rolling stock for an urban rail system, many important features need to be considered (see table 5.5). For some of these features, there are strong recommendations or global trends toward a “standard.” For example, most new urban rail systems use gangway-style trains. Steel wheels are considered more efficient than tires, except where the system must be designed with vertical grades of more than 3 percent. Furthermore, although regenerative brakes are not yet standard, the global trend is toward their use due to their reduction of energy costs during operations.

For other features, careful consideration of the rolling stock’s interrelations with infrastructure, system capacity, performance requirements, and life-cycle costs will determine the best option. It is critical to specify the rolling stock to cater to an operational service plan. For example, the choice of door width

**TABLE 5.5. Features and Options of Rolling Stock Design**

FEATURE	OPTIONS	ADVANTAGES	DISADVANTAGES
Car width	Wider cars (3.2 meters)	<ul style="list-style-type: none"> <li>• Can increase floor space for standing passengers by 40%</li> </ul>	<ul style="list-style-type: none"> <li>• Depending on train configuration, may have higher unit cost (20% more), but trains could carry the same loads with fewer cars</li> <li>• Require larger, more costly tunnel bores</li> <li>• More price competition than for narrower cars</li> <li>• May increase boarding time depending on the door design</li> </ul>
Number of cars per train	Greater number of cars per train	<ul style="list-style-type: none"> <li>• Increases total capacity of line</li> </ul>	<ul style="list-style-type: none"> <li>• Longer platforms required at all stations and higher output power capability at system level, which carries significant additional cost</li> </ul>
Doors	Wider doors	<ul style="list-style-type: none"> <li>• Reduces dwell time by allowing for more efficient pattern of access and egress</li> </ul>	<ul style="list-style-type: none"> <li>• Less seating capacity</li> </ul>

*(table continues next page)*

**TABLE 5.5. Features and Options of Rolling Stock Design (Continued)**

FEATURE	OPTIONS	ADVANTAGES	DISADVANTAGES
Type of connection between cars	Gangway or continuous corridor	<ul style="list-style-type: none"> <li>Increases train capacity by allowing equalization of crowding between cars</li> <li>Reduces dwell time by avoiding overcrowding and distributing entering and exiting passengers more evenly among available doors</li> <li>Improves ability of passengers to move through train to exit the “best door”</li> <li>Increases safety from crime and hazardous conditions as a result of open design</li> </ul>	<ul style="list-style-type: none"> <li>Higher cost for maintenance of articulated couplings</li> <li>More difficult to remove individual cars for maintenance</li> </ul>
Climate control	Air-conditioning and heating	<ul style="list-style-type: none"> <li>Provides greater comfort for passengers</li> <li>Is considered a standard option</li> </ul>	<ul style="list-style-type: none"> <li>Higher initial and operating costs</li> </ul>
Propulsion systems and regenerative brakes	Regenerative brakes	<ul style="list-style-type: none"> <li>Consumes less energy than normal brakes</li> <li>Lower carbon dioxide emissions</li> </ul>	<ul style="list-style-type: none"> <li>Higher installation costs than normal brakes</li> <li>Requires three-phase alternating current induction motors</li> </ul>
	Power accumulation systems	<ul style="list-style-type: none"> <li>Can store (either on board the train or in electrical substations) energy obtained by regenerative brakes so that it does not have to be used immediately</li> </ul>	<ul style="list-style-type: none"> <li>Relatively new technology</li> <li>Expensive up-front cost, but costs are likely to decrease as cheaper batteries are being developed</li> </ul>
Front-end design	Aerodynamic front end	<ul style="list-style-type: none"> <li>Energy savings from aerodynamic shape</li> <li>More aesthetically attractive and modern look</li> </ul>	<ul style="list-style-type: none"> <li>Higher procurement cost</li> <li>Reduces space available for carrying passengers, so may adversely affect capacity (entire train length must stop next to platform)</li> </ul>
Car frame materials	Stainless steel	<ul style="list-style-type: none"> <li>More resilient in collisions</li> <li>Less expensive</li> </ul>	<ul style="list-style-type: none"> <li>Greater unsprung weight of cars, leading to more power consumption and higher maintenance costs for track</li> </ul>
	Aluminum	<ul style="list-style-type: none"> <li>Lower power consumption due to lighter weight</li> </ul>	<ul style="list-style-type: none"> <li>Not as strong</li> <li>More expensive</li> </ul>

*(table continues next page)*

**TABLE 5.5. Features and Options of Rolling Stock Design (Continued)**

FEATURE	OPTIONS	ADVANTAGES	DISADVANTAGES
Maximum speed and acceleration <sup>a</sup>	80–100 kilometers per hour	<ul style="list-style-type: none"> <li>• Most common specification for off-the-shelf cars; adequate for lines with station spacing of 600–800 meters (for metros)</li> <li>• Requires smaller motor than for higher speed, therefore, lower initial and operating costs</li> </ul>	<ul style="list-style-type: none"> <li>• Less efficient if station spacing is greater than 800 meters, leads to longer travel times (for commuter rail)</li> </ul>
	100–110 kilometers per hour	<ul style="list-style-type: none"> <li>• Lower travel time for line with station spacing greater than 800 meters (commuter rail)</li> </ul>	<ul style="list-style-type: none"> <li>• More powerful electric motors required and higher manufacturing cost</li> </ul>
Wheels	Rubber tires	<ul style="list-style-type: none"> <li>• Less vibration resulting in smoother ride</li> <li>• Better traction enabling faster acceleration, ability to climb steeper grades</li> <li>• Less noise in open air</li> </ul>	<ul style="list-style-type: none"> <li>• Higher energy consumption</li> <li>• More frequent tire replacement cycle resulting in higher maintenance cost and less availability of cars</li> <li>• Debris and air pollution from tire decay and failure</li> <li>• Higher in-tunnel noise than for steel</li> <li>• Tire blowout risk</li> </ul>
	Steel wheels	<ul style="list-style-type: none"> <li>• Less initial cost and lower maintenance cost</li> <li>• More (energy) efficient</li> </ul>	<ul style="list-style-type: none"> <li>• Track gradient limited to 3%</li> </ul>
Advanced monitoring and maintenance systems	Train Control and Monitoring System	<ul style="list-style-type: none"> <li>• Better levels of maintenance (at the predictive level)</li> <li>• Real-time monitoring of vehicle condition</li> <li>• Increased train reliability and availability</li> </ul>	<ul style="list-style-type: none"> <li>• Installation and operation costs</li> </ul>

Note: a. Maximum acceleration should not exceed 1.3 meters per second squared.

affects the station dwell time during saturated (peak hour) operations. For the structure of the car body, stainless steel, aluminum, and composite materials are viable options, and the choice should be made based on life-cycle cost studies. Similarly, although Train Control and Monitoring Systems (TCMSs) are not standard equipment for all train manufacturers and, therefore, can entail high initial investment, TCMSs should be strongly considered because of their influence on operation and maintenance (O&M) costs.



The decision regarding car width should conservatively consider the operational service plan and peak passenger capacity that will be required in the future, not only the opening year. Furthermore, the density of passengers per square meter must also be considered from the perspective of passenger comfort. Many decisions regarding rolling stock—such as the gangway style of cars, number of car doors, and length of trains—can be optimized throughout the lifetime of the system through vehicle renewal. However, the width of vehicles is constrained by the physical infrastructure, such as the width of underground tunnel sections and the space between track and station platforms.

Cars between 2.7 and 3.2 meters wide are usually available “off the shelf,” which has brought down the cost of designing systems with wider cars. In large cities (such as Hong Kong SAR, China; Rio de Janeiro; and Singapore), cars between 3.1 and 3.2 meters wide are used; in medium-size cities or older systems, cars between 2.6 and 2.9 meters wide are used. Although the seating capacity of most rail cars is fixed by their layout, as vehicle width increases, cars have more standing room and, therefore, more capacity. According to urban rail operators, the wider the vehicle, the better, but this operational consideration must be balanced with the comfort of passengers. When considering operational efficiencies and improved capacity for the lifetime of the urban rail system, building the system to accommodate wider trains may be well worth the initial investment. However, the installation of more advanced signaling systems that reduce headways may increase capacity in a less expensive manner than the use of wider cars (which require wider tunnels).

The size and number of doors per rail car are other important elements of rolling stock design. These choices affect the time required for passengers to exit and board the train, which is the greatest determinant of dwell time in station and therefore of service headways. Less critical considerations include the length and number of cars. The length of cars is not as influential as the length of the entire train, which must match the length and capacity of station platforms. Similarly, the number of cars can be increased later as long as platform lengths, system power supply, and train couplings are designed to accommodate this eventual increase.

In the design and procurement of rail cars, it is important to balance operational efficiency and cost with the comfort of users. Design considerations that may be most important for users of the system include seat distribution, air conditioning, space for disabled persons, and on-board facilities (such as wi-fi, battery chargers, traveler information, and advertising).

## **Systems**

All systems supporting an urban rail project are interrelated and have to be designed to work with and reinforce one another. A centralized control system is necessary to facilitate communication and data sharing among

the many subsystems, which include the traffic control and signaling system, the power or electrification control system, communications system, passenger-flow system, and system of auxiliary equipment (including the monitoring and control of station equipment, such as ventilation, pumps, air-conditioning, and fire detection).

### *Signaling and Control*

Signaling and control systems play a significant role in determining the design capacity of the system (see table 5.6), but there is a difference between the capabilities of an urban rail line and how it is operated. As global populations continue to gather in cities, urban rail operators—particularly operators of metro systems—are increasing service to the limit of their existing signaling and control capabilities to meet peak demand. For busy lines in large, dense metropolitan areas, metro rail systems should be designed to run at least 30 trains per hour.<sup>3</sup> To provide such high-frequency service, any new metro rail system (greenfield project) should implement signaling systems such as communications-based train control (CBTC). CBTC systems can reduce the required spacing between trains and allow more trains per hour to run safely on a single track. Such state-of-the-art signaling may not be needed for suburban or commuter rail lines that operate less frequently.

For new urban rail lines, even those that will only run 20–24 trains per hour at initial start-up, it is important to build in flexibility for operational improvements and midterm increases in service frequency before the signaling system has to be replaced (approximately 30 years). Initial investment in higher-quality signaling can save costs in operations, maintenance, and safety over the lifetime of the project. For existing systems, the conversion to CBTC can increase system capacity, but is very complex to implement since it affects many other aspects of operations. Therefore, although CBTC is an emerging standard for new urban rail development, its implementation on existing systems (brownfield projects) requires careful consideration of interoperability, up-front disruptions and costs, and long-term benefits.

For new or upgraded urban rail systems implementing CBTC, the design should consider the grade of automation (GoA) in the system (see box 5.2 for a definition of GoA levels). All CBTC signaling systems are software ready to provide support for GoA, but additional up-front expense will be needed to upgrade rolling stock and telecommunication technology. For greenfield projects, GoA4 level 4 with fully automated, unattended operations should be highly considered. Unattended automated operations can save money over the operational life of the system, provide greater flexibility in scheduling and service disruption, and allow staff to serve critical functions other than driving (such as security or customer service) (see chapter 13).

**TABLE 5.6. Features and Options of Signaling and Control System Design**

FEATURE	OPTIONS	ADVANTAGES	DISADVANTAGES
Signaling	Fixed block	<ul style="list-style-type: none"> <li>Legacy technology used on many existing systems</li> </ul>	<ul style="list-style-type: none"> <li>Creates artificial separation between trains, constraining track capacity and frequency of service</li> <li>Can mitigate capacity constraints somewhat by shortening block lengths</li> </ul>
	Moving block, communications-based signaling; CBTC	<ul style="list-style-type: none"> <li>More efficient use of track capacity, providing higher frequency of service, while ensuring safety</li> </ul>	<ul style="list-style-type: none"> <li>More complex to operate (requires control system with tighter tolerances)</li> <li>High cost and significant disruption for conversion of existing lines</li> <li>Requires more sophisticated and reliable maintenance</li> </ul>
Grade of automation	Level 1	<ul style="list-style-type: none"> <li>Provides crash protection (ATP or ATC)</li> </ul>	<ul style="list-style-type: none"> <li>Increases the initial cost for acquisition of higher-grade rolling stock, telecommunications technology, and platform edge protection (PSD recommended for GoA2 or higher)</li> <li>Requires greater attention to maintenance than traditional methods</li> <li>Difficult to convert existing lines</li> </ul>
	Levels 2 and 3	<ul style="list-style-type: none"> <li>Provides reliability bonus beyond ATP, which is particularly important for high-frequency operations</li> </ul>	<p><i>Same as above, plus</i></p> <ul style="list-style-type: none"> <li>GoA3 (and GoA4) require an operation control center responsible for automatic train supervision</li> </ul>
	Level 4	<p><i>With unattended operations:</i></p> <ul style="list-style-type: none"> <li>Better safety records</li> <li>Can operate with shorter headways, giving higher capacity</li> <li>Greater operational efficiency given the ability to schedule vehicles and staff separately</li> </ul>	<p><i>With unattended operations:</i></p> <ul style="list-style-type: none"> <li>Can be a source of labor disputes and may require restructuring of institutions or staffing</li> </ul>

*Note:* ATC = automatic train control; ATO = automatic train operation; ATP = automatic train protection; CBT = communications-based train control; GoA = grade of automation; PSD = platform screen door.

**BOX 5.2.**  
**Levels of Unattended Automated Operations**

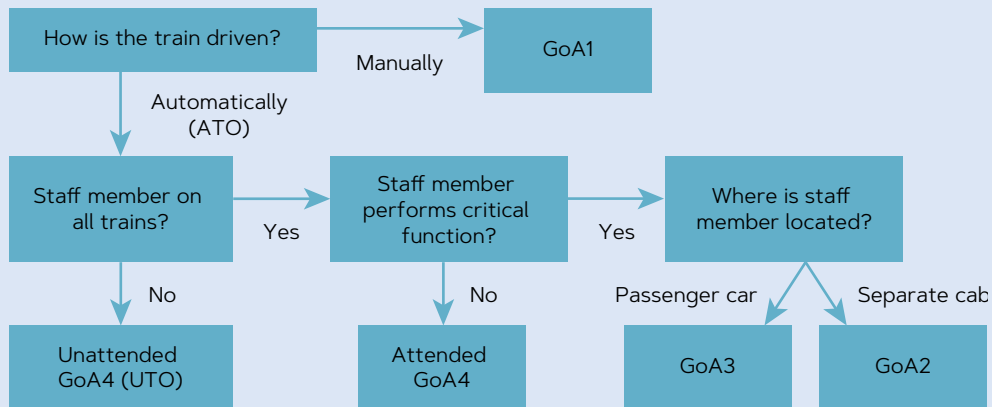
The International Electrotechnical Commission standard IEC-62290-1 (IEC 2006) has defined clear terminology to classify the grade of automation (GoA1-4) of an urban rail system (see figure B5.2.1 for a flowchart):

- GoA1 has automatic train protection (ATP), with a driver in a cab who manually controls the train movement. ATP prevents unsafe movements but does not otherwise control the train.
- GoA2 has automatic train operation (ATO), with a driver in a cab who does not manually control the train movement but does

perform critical functions, such as closing doors and setting the train in motion.

- GoA3 has ATO and a train attendant in the passenger car who performs a critical function, such as supervising safe door closure.
- GoA4 is capable of unattended train operation (UTO), meaning that trains can operate without fixed staff in either trains or stations. At this level, the operator may still choose to put someone on the train to handle customer service or emergency response.

**FIGURE B5.2.1. Grade of Automation Level Flowchart**



Sources: Adapted from Cohen et al. 2015; UITP n.d.  
Note: ATO = automatic train operation; GoA = grade of automation; UTO = unattended train operation.

*Electrification and Power*

Electrification and power systems are also important design considerations (see table 5.7). It is fundamental to carry out an in-depth study of the electricity needs of the system (for example, higher accelerations, higher speeds, and air-conditioning or heating may require more energy) and the characteristics of

**TABLE 5.7. Features and Options of Electrification Design**

FEATURE	OPTIONS	ADVANTAGES	DISADVANTAGES
Electrification	Overhead wires	<ul style="list-style-type: none"> <li>• Allows for higher voltage leading to lower transmission losses</li> <li>• Enables more dense train operations and hence higher passenger flows due to higher voltage</li> <li>• Enables track maintenance work to occur without shutting down power</li> <li>• Safer in the case of train failure that forces passengers to descend to the rail level</li> </ul>	<ul style="list-style-type: none"> <li>• Higher initial cost and ongoing maintenance cost</li> <li>• Greater visual impact from overhead lines</li> <li>• Depending on design, can require larger bore for underground tunnels due to greater distance between catenary and track-platform edge</li> </ul>
	Third rail	<ul style="list-style-type: none"> <li>• Longer life, much lower maintenance cost</li> <li>• Lower initial cost</li> <li>• Allows smaller tunnel diameter, but may need additional walkways in tunnel</li> </ul>	<ul style="list-style-type: none"> <li>• A hazard for passengers falling onto tracks and during emergency evacuations</li> <li>• Loss of time during track or roadbed maintenance, due to shut-down and power-up</li> </ul>
Power	AC motor (three-phase induction)	<ul style="list-style-type: none"> <li>• Inherent regenerative braking compatibility</li> <li>• Low cost-to-power ratio</li> <li>• Lower maintenance, higher reliability</li> </ul>	
	DC motor	<ul style="list-style-type: none"> <li>• Compatible with legacy systems</li> </ul>	

Note: AC = alternating current; DC = direct current.

power generation, transmission, and distribution that exist to ensure that the electric power supply for the urban rail system is reliable (no blackouts).

Power generation and transmission infrastructure requires significant space, especially along the right-of-way and in facility areas of stations and depots. The option of setting up one or more dedicated power generation plant or substation for the system should be considered carefully, along with the possibility of installing new regenerative technologies at these facilities. Discussions with municipal utilities are required to decide whether existing power generation and transmission infrastructure has the capability to supply the future rail line or whether additional power generation and substations are required. The electrical substations and transmission infrastructure needed to connect them with the urban rail line require significant space that must be accommodated within the right-of-way and station areas.

Additional negotiation with energy providers will be needed with regard to the rate at which electricity is charged at peak hour because electricity can be a very expensive item of operating costs in some low- and middle-income countries. Even if the urban rail line will be operated by a private concessionaire, the government will need to be involved in proactively securing an appropriate discounted rate for electricity at peak hour prior to completion of the project. Securing the appropriate discounted rate is essential since peak-hour electricity consumption may coincide with peak-hour urban rail service.

When considering the electrification option of the urban rail system (catenary versus third rail), no option is clearly superior (see table 5.7). For either option, the most widely used power solution is direct current (DC)—at 750 volts for third rail and 1,500 volts for overhead—through inverters that convert it into three-phase alternating current (AC) for induction motors.

#### *Telecommunications*

Telecommunications is a significant design feature of urban rail systems. Many telecommunication options are obligatory because they are critical for operations or safety and security. These options include communications and cabling systems among facilities and equipment, announcement and sound systems, as well as security cameras. Other telecommunication options—such as the presence of wi-fi, cellular telephone service, or on-board entertainment systems for passengers—are not essential to the operations and safety of the system, but can improve the passenger experience (see table 5.8). These options are often implemented as part of a leasing or concession contract with private companies and, therefore, have potential as additional sources of revenue. Furthermore, passenger-facing amenities may improve customer satisfaction and increase

**TABLE 5.8. Options for Telecommunications Design**

OPTIONS	ADVANTAGES	DISADVANTAGES
Wi-fi	<ul style="list-style-type: none"> <li>Convenience for passengers</li> </ul>	<ul style="list-style-type: none"> <li>Costlier to size wi-fi network for passenger use (on top of necessary operational support)</li> </ul>
Cellular telephone network	<ul style="list-style-type: none"> <li>Convenience for passengers</li> <li>Ability to recover costs by charging fees or leasing equipment to cellular providers</li> </ul>	<ul style="list-style-type: none"> <li>Significant infrastructure costs (antennas, switches, access points, repeaters)</li> </ul>
On-board entertainment systems	<ul style="list-style-type: none"> <li>Ability to recover initial costs with advertising revenue</li> <li>Improved passenger experience due to perception of shorter in-vehicle travel time</li> </ul>	<ul style="list-style-type: none"> <li>Additional maintenance</li> </ul>

ridership throughout the lifetime of the system. Therefore, wi-fi, cellular service, and on-board entertainment systems deserve evaluation for all new urban rail projects.

*Ticket Control and Fare Collection*

Automated ticketing with smartcard is the recommended practice for any new or existing urban rail system that is considering upgrading its ticketing control and fare collection. Furthermore, greenfield systems that are not constrained by compatibility with legacy systems should strongly consider the use of smart-phone or app-based payment. For a new urban rail system, a tap-in/tap-out automated ticketing system is a must. Automated ticketing collects real-time fare transaction data that can be processed quickly into origin (and destination) data for reporting ridership and revenue. In addition, such data are valuable for assessing service and revenue options. For new systems, tap-in/tap-out ticketing provides data that are invaluable for operational scheduling and service planning purposes and provides greater fare policy flexibility by laying the foundation for distance-based fares.

For traditional fare collection systems, gates must be installed at each entrance and exit at each station along with ticketing and top-up machines. For urban rail systems in low- and middle-income countries, many riders cannot afford to load their cards with a lot of money up-front, requiring frequent recharge or top-up of fare amounts. Unless the ticketing system allows for mobile recharge, frequent recharge can create long queues at fare and ticketing machines.

Most new urban rail systems use barrier fare collection with contactless ticketing capabilities to improve the capacity of stations. However, capacity should not be the overwhelming factor when making this choice, and the disadvantages should also be considered. Barrier-free systems without fare collection gates are prone to fraud and fare evasion if poorly enforced, which can undermine the revenue stream of the operator. More effective ways to improve capacity exist and have to be addressed consistently across the system, avoiding bottlenecks (table 5.9).

**TABLE 5.9. Options for the Ticket Control and Fare Collection Design Feature**

OPTIONS	ADVANTAGES	DISADVANTAGES
Barrier-free design	<ul style="list-style-type: none"> <li>• Increases passenger-flow capacity</li> </ul>	<ul style="list-style-type: none"> <li>• Has greater potential for fare avoidance</li> <li>• Requires enforcement system and promotional or educational campaign</li> </ul>
Tap-in/tap-out	<ul style="list-style-type: none"> <li>• Provides origin-destination data very useful for service planning</li> <li>• Enables distance-based fares</li> </ul>	<ul style="list-style-type: none"> <li>• Creates problems when passenger tap-out fails</li> <li>• Reduces exit capacity at stations</li> </ul>

## Capital Cost Estimation

The history of large-scale infrastructure projects in the past century, and urban rail projects in particular, has shown that preconstruction cost estimates are highly unreliable predictors of the actual cost of implementation, with the final cost typically much higher than the predicted one. Nevertheless, a reasonable forecast of financial costs for construction and operation is important throughout the project development process.

For any urban rail project, two types of costs need to be estimated: the initial cost for construction and start-up (capital costs) and the recurring cost of operations, maintenance, and capital rehabilitation and renewal.<sup>4</sup> The estimation of capital and recurring costs is necessary for the economic evaluation of project costs and benefits and for financial and fiscal analysis of the project (chapter 3). Sound cost estimation is also critical to convince decision makers, financiers, and the public that the project is credible. The cost estimates provide essential input for comparative evaluation of planning alternatives (chapter 3), project optimization (chapter 6), preparation of bidding documents (chapters 8 and 9), financing and funding (chapter 10), construction (chapter 11), and the long-term financial sustainability of the operations and maintenance of the system (chapter 13).

This section provides an overview of capital costs for urban rail systems (see chapter 13 for a complementary discussion of recurring costs), highlights the importance of preparing disaggregated, bottom-up cost estimates based on detailed project design, and discusses how to mitigate the impacts of exogenous factors beyond the control of the project design.

### Key Drivers of Capital Costs

Initial capital costs are fixed, one-time expenses incurred for the purchase of land; construction of stations, facilities, and track; procurement of rolling stock; mitigation of social and environmental issues; and implementation of systems (such as electromechanical, signaling, and ticketing) necessary for the start of urban rail service. Capital costs also include financing and structuring costs (such as debt service reserve accounts), particularly when a project involves a private investor or operator. In other words, capital costs represent the total cost needed to bring an urban rail project from planning to a commercially operable status.

For estimation purposes, capital costs need to be broken down into standard categories (and detailed subcategories) that avoid omissions and double counting. In the United States, the Federal Transit Administration (FTA) has



**BOX 5.3.****An Example of Capital Cost Categories, Including Professional Services, for Urban Rail Projects**

- Guideway and track elements
- Stations, stops, terminals, and intermodal transfers
- Support facilities: yards, shops, and administrative buildings
- Site work and special conditions
- Systems
- Right-of-way, land acquisition, and existing improvements
- Social mitigations (resettlement and compensation of economic displacement)
- Environmental mitigation
- Vehicles
- Finance charges
- Professional services
  - Preliminary and final design
  - Project management for design and construction
  - Construction administration and management
  - Professional liability and other nonconstruction insurance
  - Public outreach
  - Legal, permit, and review fees
  - Surveys, testing, investigation, and inspection
  - Start-up
- Unallocated contingency

Sources: FTA 2005; TCRP 2010.

established a standard framework for estimating and comparing capital costs, given in box 5.3.

An often overlooked, but important component of capital costs are the costs for professional services or “soft costs.” Soft costs are the expenditures necessary to plan, design, and manage the project during construction and start-up.<sup>5</sup> They typically include project management, preliminary engineering, final design, construction management and administrative expenses, permitting and review fees, nonconstruction insurance, surveys and testing, and some start-up costs (see box 5.3). Planning and preliminary engineering services can easily account for 3 percent of the construction cost (hard cost) of the project; additional soft costs can amount to as much as 20 percent of total capital expenditure (TCRP 2010). Therefore, soft costs represent a significant proportion of the overall cost of any urban rail project and cannot be overlooked during cost estimation and budgeting. Soft costs are likely to be quite consistent among different types of civil works projects within a given country, but they vary enormously among countries. The best source for estimating soft costs are knowledgeable civil engineers in the subject city.

## Methods for Cost Estimation

Two methods are used for estimating urban rail project costs; each is used at a different step of the project development process. During the early decision-making and planning step of an urban rail project, costs are often estimated by analogy, using broadly aggregated categories of costs derived from comparable projects as a benchmark. These benchmarks provide rough estimates of the order of magnitude of project costs helpful for evaluating the economic, financial, and fiscal impact of a potential project (see chapter 3). During design, bottom-up cost estimates are calculated from individual design options disaggregated to a point where the unit costs can be derived more credibly from experience in specific construction markets and adjusted for local conditions.

### *Benchmarking*

During the planning phase, very little information is available about a project beyond its most basic characteristics. The quantities typically available are horizontal alignment of the route, a general estimate of the amount of additional public right-of-way that must be acquired, route-kilometers for each of the three types of vertical alignment (underground, elevated, at-grade), number of stations and rail yards, maximum capacity expressed as passengers per hour per direction, and some indication of the amount of rolling stock needed. Therefore, preliminary cost estimates use analogies to comparable urban rail systems to identify the cost of these categories.

The first task is to select the most relevant cases. Comparative benchmarks have to be chosen carefully, beginning with a full consideration of context. The best sources of applicable experience are always those closest to home—the same city, same country, same region, or same legal and fiscal regime. Any city pursuing a new urban rail project will necessarily be of significant size. It should have prior experience implementing and managing large infrastructure projects. Even if this experience does not include urban rail projects, this local experience will be the most reliable guide to many cost components, such as the cost and timing of land acquisition, the cost of labor and materials, and the estimation of soft costs for design, construction management, and project supervision. If the city already has an urban rail line, that rail line should be the primary benchmark.

In choosing a benchmark, project-implementing agencies should favor more recent projects in addition to those close to home. Given technological advancements and increasing competition in the manufacture and supply of certain features of urban rail systems—most notably, rolling stock—prices have fallen

dramatically over the past decade. Changes in markets need to be borne explicitly in mind when using historic benchmarks for early cost estimations.

If using a different urban rail project for benchmarking purposes, the first step would be to make adjustments based on differences in scope and project design features, accounting method, availability and price of material and systems supply, local context, and project-implementing agency capacity between the benchmark project and the project of interest.

### *Bottom-Up Estimation*

An engineering estimate is a bottom-up model of project cost, based on a detailed bill of quantities derived from project design. Capital cost estimates include the physical design of the fixed infrastructure and the specifications for equipment and systems. Typically, engineering estimates are prepared for preliminary engineering and again for final design using a unit-cost-based approach:

$$\sum_i (\text{quantity}) \times (\text{unit cost}) \times (\text{adjustment factors}). \quad (5.1)$$

Unit costs are estimated based on several sources. In most high-income countries, construction cost databases are the first point of reference.<sup>6</sup> Recent bids for similar work are another important source of unit costs. The final bid cost is often sensitive to the perceived level of competition by bidders, as well as the general demand for large construction projects compared with the availability of qualified contractors. However, it is often difficult to predict the contractor and supplier market and potential bidder premiums, especially for large urban rail projects. It is common practice to conduct a “market sounding” at some point by seeking feedback from a panel of qualified contractors and vendors to determine the level of interest (and probable price competition) and to identify other factors for adjusting the unit costs.

Bottom-up engineering estimates are based on predicted costs with a certain degree of uncertainty. This uncertainty is quantified as a contingency reserve. Depending on the level of detail in the design, the contingency factor would typically be 30–35 percent for conceptual design, 15 percent for preliminary engineering, and 10 percent for final design. For underground construction, the contingency for civil works would be higher and would vary with the quality of geotechnical surveys on which the design is based as well as the bidders’ familiarity with underground construction in local conditions. The consequences of unforeseen events or circumstances can fall to the project-implementing agency, contractors, vendors, or other parties (see chapter 7). Although the distribution of these costs depends largely on the language of the contract and local law, in all cases, unforeseen events and contingencies increase project costs.

For these reasons, it is very important to budget contingency factors considering the relevant sections of the contract and local experience with other large projects. Beyond the engineering stage, contractual arrangements and legal processes for adjusting the contract budget throughout the development process generally are among the most important factors influencing the costs of almost any large construction project (see chapters 8, 9, and 10).

In summary, the best way to obtain a reliable understanding of the total cost of the project is to break it into its component parts and to look at the ways in which the individual quantities and unit costs are derived. This exercise should be done by someone with extensive experience with urban rail system accounts and operations, preferably from the same country as the project.

### **Allocation of Cost Estimation Responsibilities**

In traditional design-bid-build project delivery, the public project-implementing agency must complete bottom-up cost estimates based on the detailed project design to control cost uncertainties before going to bid. For projects in which detailed design and construction are tendered together as a fixed-price or lump-sum contract, bottom-up cost estimates may be based on the preliminary design (see chapter 8).

What varies between bottom-up cost estimates during preliminary and final design is the precision of the line items and their quantity estimates, the source and reliability of unit costs, and the uncertainty represented by the adjustment factors. As the design and specifications become more detailed, so do the quantity estimates and unit costs used for procurement and construction of the project. This is also true for the adjustment factors, which are determined largely by the design features, project management plan, details of contractual arrangements, and operational plan for the completed urban rail system. The more disaggregated (granular) the basis for the project design estimates, the more credible it becomes.

The preparation of any project cost estimates should be entrusted to qualified professional engineers and practitioners with specialized training and experience. If using a traditional design-bid-build project delivery method, it is advisable for the project management unit to have the specialized knowledge needed to ensure the quality of the estimates—either using its own staff or bringing in specialized expertise (see chapter 4). As described in chapter 6, it is also critical to conduct periodic optimization exercises during project design. Although alternative project delivery approaches may change the sequence and responsibility for updating and refining cost estimates (particularly in fixed-price contracts), regardless of the procurement method chosen, the project-implementing agency should understand and approve all project cost estimates.

## Variability of Capital Costs

Research has shown that comparing projects on a combination of aggregate parameters—such as global costs per kilometer, number of stations, and percentage of the route that is underground—is of limited value without careful consideration of all of the design features and other endogenous and exogenous cost drivers associated with the project, location, and context. Initial estimates of capital (and recurring) costs for urban rail systems have proven to be poor predictors of actual costs and performance. This high variability makes cost benchmarking using broadly aggregated costs derived from “comparable” projects in the planning stages extremely difficult. It emphasizes the need for careful bottom-up estimation of costs based on the final design of all features and options.

The reported capital cost per route-kilometer varies widely between projects (Flyvbjerg, Bruzelius, and van Wee 2008). Some of this variation is due to errors or differences in scope and accounting methods of the reports or specific design attributes of the system (such as the alignment, station spacing, percentage underground, or density of passenger demand). The greatest sources of variation, however, may be less tangible factors.

In terms of scope and accounting methods, each system categorizes and accounts for costs differently, and it is always difficult to identify all costs incurred by a megaproject such as urban rail. For example, it is common for portions of an urban rail line to use existing public right-of-way that was previously acquired, sometimes for a different purpose. Although there may be no direct acquisition cost when using existing public land, this land still represents an economic value that could be used for another development or purpose. This loss of potential land value is often most reported as part of a project’s cost estimate. Furthermore, each estimate is based on a different source, often from a different year and using different ways to adjust for cost inflation.

With careful accounting and adjustments, many of these differences in scope and methods can be corrected to produce comparable costs for like-designed systems. However, even then, real costs can vary significantly based on the local context and capacity of the project-implementing agency. For example, the cultural, legal, and fiscal environment of the city can greatly affect the system cost. Perspective and procedures for executing construction projects are deeply embedded in the engineering culture and rules of a particular location, and there are important differences among countries. Taxes should be itemized in cost estimates as they may vary widely and are sometimes a large factor in the overall budget. Public agencies are allowed differing degrees of exemption from taxes and workplace liability. This can have a big impact on costs, especially in countries with strict protectionist tariffs and local-content rules.

Finally, the quality and type of contract structuring, financing, and packaging and project management can affect the cost of the project. Virtually no project is ever built and operated for the originally estimated price. There are always adjustments in scope, quality, schedule, and, therefore, price. For projects with weak direct supervision by the project-implementing agency, the difference between actual and booked quantities is often large. Therefore, careful attention should be paid to project management planning (see chapter 4) and optimization of project features and their costs (see chapter 6).

### **Exogenous Cost Drivers**

Careful design and optimization of an urban rail system's features and their integration is where the project-implementing agency can exert the most control or leverage for reducing costs and getting the best value for money from the system. However, many factors that influence the cost of system implementation are beyond the control of the project-implementing agency. These exogenous factors differ based on the local context of the system, but often include rules, standards, and regulations; geotechnical conditions; availability and price of land; need for social and environmental mitigation (see chapters 14 and 15); and enabling industry, institutional, and political environments. Project-implementing agencies need to invest properly in prerequisite studies to understand these exogenous factors and the risks and constraints associated with them (see chapter 7) and then to incorporate this understanding into planning and design. Investing in detailed studies and surveys to investigate these exogenous cost factors almost always pays off in the end.

Geotechnical conditions can affect the choice of horizontal and vertical alignment and the cost of construction, particularly of underground segments. Careful study of the hydrogeological and geotechnical characteristics of the land is necessary to design the appropriate level of structural support and to estimate accurately the cost of construction (see chapter 11). These studies also inform the seismic and other natural risks that the project may face as well as the design of appropriate resilience and mitigation measures (chapter 17). This again highlights the importance of allocating enough money for complete surveys during the early planning stage of the project. Since underground segments are often the key driver of up-front costs and can present the highest uncertainties during construction, it is imperative to investigate soil conditions and geotechnical risk at a level of detail necessary to cost them properly in the procurement contract.

When designing the horizontal alignment of the urban rail system, the track and station areas should be built on existing public land wherever possible. When public land is not available, it is important to consider the availability of land,

the price of different parcels, and how land acquisition may affect the implementation schedule of the project. Delays due to the lack of timely resettlement and expropriation can negatively affect implementation; accordingly, social impact assessment and land acquisition and resettlement planning have to be timed properly with the design and construction of the project. The location, condition, and use of all buildings on and adjacent to the land to be used for urban rail development should be inventoried and measures taken to reduce the impact of the project on current residents and abutters (chapter 14). In addition to this inventory of surface economic and social activity, it is important to have a detailed survey of the utility networks that may run through the alignment so that they can be relocated or avoided during construction. Delays due to improper identification and relocation of utilities prior to the scheduled start of construction can be significant (chapter 11).

The local enabling environment, in terms of local costs of doing business and construction and institutional set-ups, can also affect the cost and value of a given urban rail project. Cost estimates at any level should consider exchange rates for foreign capital, interest rates for local financing, and local labor costs and labor regulations. In addition to these costs of doing business, the technical capacity of the project-implementing agency, the state of development of the in-country engineering and construction industry, local levels of coordination among institutions, and the time necessary for permitting and approval can affect the project budget (and schedule) (chapter 4).

## Conclusions and Recommendations

*There is no single “gold standard” urban rail system design; it is crucial to invest in a design that customizes the system to the unique conditions of the local area it serves and to the operational service plan for which it is designed.* Urban rail systems are complex and require the design of many interdependent features. Infrastructure, rolling stock, and systems should be designed to cater to a long-term operational service plan identified up-front. Although international standards exist for certain features, no single design works for all contexts. The most successful urban rail systems are designed and built for the unique conditions of the urban areas they serve. This customization of design is critical and requires time and resources early in project planning and preliminary design to assess the transportation-specific needs of the urban region and rail corridor, as well as exogenous factors such as soil conditions and the financial and technical capacity constraints of the project-implementing agency. Planning and design studies, careful selection and integration of design options, and

external review and optimization of these integrated designs represent a significant fraction of project costs, but they have high return on every dollar spent.

***Design for the long-term capacity of the system.*** Urban rail systems have the highest potential passenger-carrying capacity and reliability of any rapid transit alternative in return for a large capital investment. Research shows that urban rail systems usually have higher fixed than variable costs and have strong “returns to density” (World Bank and RTSC 2017). Maximizing the design capacity helps to make the most of expensive urban rail infrastructure. Even if demand is lower in initial years, mistakes in designing for capacity that is too low for the long term can be impossible or prohibitively costly to fix. Therefore, considering a long design horizon and designing systems with the flexibility to run longer, wider, and more frequent trains in the future to meet growth in demand is recommended. If the underlying demand justifies urban rail investments, the benefits of additional up-front capacity improvements may substantially outweigh the costs.

***Urban rail design should consider trade-offs with respect to system capacity, operational flexibility, and costs of individual features and the interdependencies among them.*** This chapter presents the general advantages and disadvantages of design features and options in three broad categories: infrastructure and civil works, rolling stock, and systems. Although it is important to consider trade-offs for individual design options, project design requires taking a systems approach that acknowledges the physical and temporal interdependencies among multiple features (World Bank and RTSC 2017). It is essential to consider carefully how the design features interact and advance together, as well as the implications of these interrelations for both capital and recurring costs.

***Urban rail systems need to be designed as part of an integrated public transport system facilitating accessibility and transferability among urban transport modes.*** Multimodal integration is a critical element of urban rail design. An urban rail project often requires supporting measures to improve access to and from station areas via public transport and nonmotorized forms of transport, such as walking and bicycling. Therefore, design and cost estimates should account for the implementation of complementary investments in other public transport services, traffic management, and other initiatives and should reference the latest urban transport strategy of the city (see chapter 3). It is critical to identify and define these considerations during planning and preliminary design rather than waiting until final design or construction, when the impacts to the project may be irreversible.

***Cost estimation during the design phase of an urban rail project should use bottom-up techniques to reflect individual design features.***



Due to differences in cost accounting practices and local conditions, capital and recurring costs vary significantly from one urban rail project to another. As a result, benchmark cost estimation based on aggregate cost categories often involves large margins of error. Although it is often necessary to make such comparative estimates during initial planning, once the project enters the design phase, it is best to employ bottom-up techniques to reflect the unit costs of individual design features within the local market. The more detailed the level of design, the more certain are the estimates of both capital and operations costs.

## Notes

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1. Anticipating transit system ridership and commuter willingness to switch modes with any accuracy is difficult, particularly in low- and middle-income countries, which lack a track record of such systems. Ridership levels depend on a host of factors—such as feeder services, ease of transfers, and demand management policies—whose pace of implementation is difficult to predict *ex ante* (see chapter 3).
2. Asphaltic materials usually come from organic, petroleum-based materials, which can have a shorter life cycle (30 years) than other infrastructure components. Therefore, synthetic bedspreads may be more appropriate than asphaltic bedspreads in some situations.
3. At least one-third of urban rail systems in the Nova metro benchmarking group are running at or above this level, while others would like to but are constrained by their signaling systems (Cohen et al. 2015). Operational headway can go down to 80 seconds and even 60 seconds, as for the VAL in Lille, France.
4. The recurring cost of capital rehabilitation and renewal is often included in an operator's annual or multiyear capital expenditures (see chapter 13).
5. Soft costs also relate to the institutions and administration needed to operate and maintain the rail system when considering the recurring costs of the system.
6. For example, the FTA maintains the Capital Cost Database (<https://www.transit.dot.gov/capital-cost-database>) and the National Transit Database (<https://www.transit.dot.gov/ntd>).

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# 6

## PROJECT OPTIMIZATION

Edward Fleischman, Ramon Munoz-Raskin,  
and Joanna Moody

Funding and political implications are at stake as an urban rail project proceeds through planning and design. Various stakeholders with different goals are involved in the decision-making process, influencing the design of the project and, consequently, its costs, schedule, risks, and inherent value as a public transport solution. Project optimization supports project decisions that may have significant impacts on resources or the short- and long-term performance of the project. These project decisions should be reanalyzed and validated as the project evolves. Project optimization is thus the ongoing process of increasing the value of a project to both the project sponsors and the end users. Project value comes in many forms. For the project-implementing agency, value is added by reducing project risk, shortening the delivery schedule, or lowering costs. For users, project value comes from low fares, improved accessibility from faster and more direct routes, and improved frequency and reliability, as well as improved sustainability, comfort, and safety.

The principles of project optimization should be applied to all projects, and optimization should be a fundamental goal of any project development team. Considering the magnitude and complexity of urban rail projects, their high capital and operating costs, and

*Photo: Dom Luís I Bridge, Porto, Portugal, 2017. Source: J. P. Rosa via Flickr (CC BY-NC-ND 2.0).*

their wide-ranging impacts on the urban landscape, economy, and society, minimizing their life-cycle costs and optimizing their benefits are particularly important. Since urban rail projects are extremely complicated, have high costs, and require the expertise of many disciplines, a greater opportunity exists to optimize cost and effectiveness.

Project optimization helps to identify nonbinding opportunities to reduce costs, time, and risks with the goal of increasing overall project value. The implementation of these opportunities is subject to management decision. Project optimization methodologies are powerful tools for making projects more robust and valuable to their stakeholders. They are particularly invaluable when resources, such as funding or technical expertise, are constrained. Project optimization should be considered as an opportunity and not an auditing exercise; it finds and documents possibilities for improvement, instead of highlighting deficiencies. As staff from project-implementing agencies actively participate in the preparation and management of optimization activities, these activities can be opportunities to build internal capacity, knowledge, and experience that can benefit other projects in the future.

Although project optimization can add value at all stages of project development and delivery, the more upstream in the process these tools are used, the greater potential there is for added value. Emphasis should be placed on performing optimization throughout the planning and design steps, in preparation for construction and implementation. Analysis should be ongoing and continue through construction as the project moves toward completion. Although it is never too late to consider opportunities to add value, implementing changes or interventions later is sometimes too complex or costly.

This chapter discusses various methods of project optimization, ranging from value analysis by internal project staff to the use of outside experts for peer reviews, value engineering (VE), constructability reviews, and operability reviews. In value analysis, project staff optimize the design and implementation of the project. This internal effort considers the cost-effectiveness of each individual design component, identifying ways to reduce cost or increase performance. It compares the cost of the project and each individual design component with the effectiveness of the project and each individual component. Value analysis of the cost-effectiveness of each component incorporates risk analysis and life-cycle cost analysis. Risk analysis helps decision makers to identify and manage risk to the project's scope, budget, or schedule (see chapter 7). Life-cycle cost analysis characterizes the trade-offs between up-front, short-term, and long-term costs for sustained system operation. Optimization from an asset life-cycle (both capital and operating) perspective should always be considered, since a strategy that reduces initial capital costs may increase operation and maintenance (O&M) costs. Value analysis is thus an important optimization tool to be used by the project team throughout the development of a project.

The project staff's value analysis efforts should be complemented using outside experts. External experts provide an unbiased and fresh point of view; they can also contribute a breadth and depth of knowledge and experience not available within agencies that have not implemented large urban rail projects. This chapter discusses project optimization methods involving external experts, particularly peer reviews, VE, constructability reviews, and operability reviews. Peer reviews employ experienced personnel who have worked on similar projects. Value engineering is a formal approach to optimizing the value of each project component. Constructability reviews require input from construction experts to assist in optimizing a project's construction cost and schedule. Similarly, operability reviews require input from operations experts to consider the project's long-term operational flexibility and maintenance costs.

The optimization methods discussed in this chapter can apply to most urban rail projects, no matter the method of project delivery. In some cases, alternative project delivery and contracting strategies—such as design-build and public-private partnerships (PPPs)—can assist in further optimizing a project, as discussed later in this chapter. Although these methods have different levels of sophistication, if carefully structured, they could have a very good return on investment for the project sponsor by allowing more flexibility in optimization throughout project development.

There are different methods for project optimization. Each has distinct advantages, disadvantages, and applicability to certain steps of the project development process. However, they all provide benefit through a formalized process of optimization. Having a formal process gives national and local governments, financiers, and other project sponsors more confidence in the cost-effectiveness of the project design. Involving external reviews to complement value analysis efforts by internal staff further incentivizes the design team to be creative and flexible, realizing schedule efficiencies, lowering costs, and mitigating risks. External reviews should be performed in coordination with internal staff to get the most value from the project optimization process. Project staff and key decision makers need to be well briefed on the process and how they can best contribute to its value. Only with up-front buy-in and full involvement of technical and management staff can project optimization methods, either internal or external, provide the greatest savings.

## **Project Optimization through the Project Development Process**

Project optimization is an important strategic process throughout the development of a project, but its impact is greatest when applied early in project

planning and design. During planning, an analysis of alternatives—including different rapid transit modes and alignments—should be undertaken (see chapter 3). This analysis of alternatives uses criteria (for example, cost-effectiveness) to assist decision makers in determining the project alternative that is of greatest value for the specific city and corridor under consideration. Analysis of alternatives provides an opportunity to optimize the value of a project since it compares options and gives technical and management staff a lot of information relevant to optimized project decision making.

After a preferred project alternative is selected, its details are defined in the iterative design step (see chapter 5). At this stage, optimization methodologies are used to analyze each component of the project for its cost-effectiveness and value. Table 6.1 lists illustrative components of a typical urban rail project for which there is significant opportunity for optimizing value within the planning and design steps. In addition to analyzing these project components, optimization methodologies should include a review of potential construction methods, delivery schedules, performance outcomes, and risks as well as risk mitigation.

In addition to optimizing particular details of planning and design, it is also useful to implement a cost-effectiveness approach to the implementation

**TABLE 6.1. Illustrative Components Where Value Can Be Optimized throughout the Steps of the Project Development Process**

STEP OF PROJECT DEVELOPMENT PROCESS	ILLUSTRATIVE COMPONENTS FOR OPTIMIZATION
Corridor planning (alternatives analysis)	<ul style="list-style-type: none"> <li>• Mode</li> <li>• Horizontal alignment (right-of-way)</li> <li>• Interconnectivity and integration with the entire metropolitan or regional transportation system</li> <li>• Vertical alignment (tunnel vs. elevated structure vs. at-grade)</li> <li>• Location of depots, workshops, and maintenance yards</li> <li>• Land acquisition or resettlements</li> <li>• Environmental impacts</li> </ul>
Preliminary design	<ul style="list-style-type: none"> <li>• Right-of-way width</li> <li>• Adjustments to alignment</li> <li>• Number, location, and size, shape, and construction method of stations</li> <li>• Number, type, and size of vehicles to be procured</li> <li>• Operational speed</li> </ul>
Detailed design	<ul style="list-style-type: none"> <li>• Electrical systems</li> <li>• Architectural finishes</li> <li>• Construction method</li> </ul>



schedule of a project. When the vision for a project is ambitious, but existing resources are constrained, project optimization may consider phased implementation in which a fully functional initial phase of the project is designed to support future expansion and extension of the urban rail system in subsequent phases or projects (see box 6.1).

### **BOX 6.1.**

#### **Phased Implementation and Real Options Analysis**

When the vision for a project is ambitious, but resources are constrained, one way to optimize the project is to adopt a phased implementation approach. A phased implementation approach involves constructing an initial, self-contained part of the project in a first phase, allowing more time to mobilize funding, financing, and political support to design, bid, and construct additional phases of the project. This first operable part has to have independent utility; in other words, it has to operate and provide benefit on its own prior to the construction of additional parts. For implementing agencies with little experience with complex urban rail projects, the first phase can provide an opportunity for institutional capacity building before embarking on additional expansion. Lessons learned from the first operable part can be applied to parts built later. The implementation of a metro network with extensions to existing lines or new lines is almost always a continual, phased process that accompanies city growth and development.

A phased implementation approach needs to be studied carefully so as not to limit the long-term potential of the project. Careful application of schedule optimization is needed to ensure that the first segment is of enough value to society to garner adequate ridership and political consensus to support successive segments. While phased implementation can be useful in cutting up-front costs and fitting project delivery

into a tight window of political and economic opportunity, it can also delay benefits, particularly to neighborhoods not yet connected to the system. Therefore, savings in immediate expenditure must be weighed against the cost of delaying additional phases, in terms of both inflation on future capital expenditure and future discounted benefits.

If considering phased implementation, it is particularly important to design the initial phases with expansion or extension in mind. It is crucial that initial infrastructure and systems are able to support increased demand and service that may come with future phases of the project and future adaptation to technological evolution in the sector (open systems). The literature on business investment and systems planning provides a useful theoretical and analytical tool for quantifying the return on investment of design choices that provide for future flexibility: real options analysis. A real option is an alternative or choice (such as the opportunity to expand projects if certain conditions arise) that becomes available with an investment (Mun 2006). It is referred to as “real” because it usually pertains to tangible assets, such as infrastructure or technological improvements, rather than to financial instruments. For example, the implementing agency may choose to build stations and platforms with greater space than is

*(box continues next page)*

**BOX 6.1.****Phased Implementation and Real Options Analysis** *(Continued)*

necessary merely to meet projected near-future ridership. Although this decision costs more capital up-front, it accommodates future population growth and provides the option of expanding the system without needing to retrofit existing stations, which would be more expensive in the long-term.

In Lisbon, Portugal, authorities built in the option of urban rail system expansion when planning other metropolitan transportation projects. The first bridge across the Tagus River was constructed to bear additional weight beyond what was projected for automobile and truck traffic on the surface highway. This was done so that a lower platform could be added in the future to carry trains. While this rail capacity was not needed at the time, by building a stronger bridge and incorporating a real

option, the public authority gained the flexibility to create a metropolitan rail line across the river whenever the political, financial, and social environment made it expedient and prudent to do so. In 1999, a rail deck was added below the highway lanes, costing a fraction of the price of an entirely new bridge structure (de Neufville 2003; see image B6.1.1).

Incorporating these real options can greatly affect the valuation of potential investments because, despite their greater up-front cost and risk of overbuilding, they can greatly reduce the cost of future improvements to the system (Mun 2006). Therefore, real options analysis (in conjunction with more traditional discounted cash-flow analyses) can be a useful instrument in the application of project optimization methods.

**IMAGE B6.1.1. Highway and Rail Bridge across the Tagus River, Portugal**

Source: Ribeiro Simões via Flickr Commons.

## Optimization by Project Staff: Value Analysis

In value analysis, staff within the project-implementing agency seek to improve the overall value of the project (by cutting cost, reducing risk, or adding benefit) without compromising the function and performance of the system in the long-term. Value is defined as “the reliable performance of functions to meet customer needs at the lowest overall cost,” where maximum value for a project is achieved through the optimum balance among function, performance, quality, safety, and cost (SAVE International 2016). Every dollar to be expended is reviewed.

Project optimization through internal value analysis is conducted throughout planning, design, construction, and O&M; it is an integral part of project development. In the planning step of project development, optimization methods can be incorporated into the analysis of alternatives, including the choice of mode and general alignment. In the design step, the focus of project optimization shifts to the cost-effectiveness and value of specific design components.

The value analysis of design components should make use of the multidisciplinary expertise within the project-implementing agency. To this end, periodic meetings of the entire project staff should be held to discuss cost-value trade-offs among design components. By considering project optimization as a group, internal staff can capitalize on the greater level of creativity and problem solving fostered by interdisciplinary team dynamics and reinforce existing institutional knowledge and capacity.

## Risk Analysis

Risk analysis is a process that helps project staff to identify and manage potential problems that could undermine development of the rail project. For each potential problem identified, risk analysis determines the likelihood of its occurrence, as well as the magnitude of its impact on cost and schedule. These factors are tabulated in a “risk register” that is monitored and shared among agency staff.

The sophistication of risk analysis varies with the scale of the project and depends on the step of development in which it is applied. In the early planning stages, a simple qualitative approach can be used to understand the risks involved in different alternatives before deciding on a particular alternative. A top-down qualitative approach characterizes the overall severity of each risk as low, medium, or high, based on its relative probability and impact (Behr 2016). Qualitative approaches are also useful when quantitative information about costing is scarce. When the design components of a project are better defined later in the project development process and enough industry information is

available—sometimes unlikely in low- and middle-income countries—a more detailed bottom-up quantitative approach is used to estimate numerical (monetary) values for the probability distribution of impact for each risk category and to run Monte Carlo or other simulation techniques to quantify, price, and transfer risk in the bidding and contract steps (Behr 2016). Chapter 7 discusses the specific methodologies and tools available for identifying and analyzing risk and the management processes that employ this analysis.

Risk analysis and management helps to identify risks, encourages proactive and early planning for mitigating potential problems, and controls costs through the development of targeted-response strategies for anticipated risks. In addition, the use of risk analysis and management tools demonstrates due diligence on the part of project-implementing agency staff. Rigorous risk analysis and management help to ensure transparency, integrity, and accountability throughout project development and build confidence and credibility in the project's plans and estimates for financiers and other stakeholders (Behr 2016). Risk analysis is a project optimization tool that can and should be applied throughout project development. It should be done in conjunction with other optimization tools, such as VE, constructability reviews, and operability reviews.

### **Life-Cycle Cost Analysis**

It is tempting for decision makers and elected officials to focus primarily on short-term considerations when making funding decisions under constrained budgets. High importance is placed on up-front costs, while little attention is given to costs or compromises in functionality occurring later (ASCE 2014). However, because urban rail projects serve as key high-capacity corridors of transportation systems that develop over more than 100 years, many costs are not involved up-front (see box 6.2).

In order to improve long-term decision making, planners and policy makers need to think more strategically about how to build and maintain transportation assets and networks. Life-cycle cost analysis is a data-driven tool that provides a detailed account of the total costs of a project over its expected life. A holistic life-cycle cost analysis calculates up-front development, capital, and financing costs, discounted O&M costs, and end-of-life (material disposal and recycling) costs associated with each specific project component. Life-cycle cost can also factor in uncertainty, risk, and environmental and equity considerations. When performed correctly, life-cycle cost analysis enables a more accurate and less biased comparison of transportation projects and alternatives, which can help decision makers to get the best value for their money over the long term. This useful tool can be incorporated into VE or other project optimization frameworks.

**BOX 6.2.****Construction versus O&M Budgets: Metro de Madrid, Spain**

Metro de Madrid illustrates the magnitude of construction versus operation and maintenance (O&M) costs for urban rail systems. Between 1995 and 2015, Metro de Madrid spent almost €10.6 billion to build around 200 kilometers of new urban rail. Although this capital expenditure is large, it is small compared with the cost of operating and maintaining the system in the

future. Metro de Madrid's annual O&M budget for the whole urban rail system (with a total length of 293 kilometers) is approximately €1 billion. Considering that this type of investment is needed each year to keep the network running for 100 years, it clearly is important to keep operating costs in mind even during initial planning and design of capital works.

**Optimization Involving External Experts**

Urban rail projects are expensive and complex and can involve significant risk. Accordingly, ample justification exists for bringing the expertise and opinions of outside experts into the optimization process. This is particularly important for project-implementing agencies inexperienced in urban rail projects or lacking the technical capacity to carry out detailed internal value analysis. However, both inexperienced and experienced agencies alike can benefit from an independent, honest opinion of the project. Therefore, the use of external experts is recommended and critical for optimization of any urban rail project.

In addition to providing detailed knowledge and applicable experience, external experts also provide an unbiased and fresh view of the project. This objectivity is important to maintain the credibility of the project planning and design and to keep project decision makers focused on seeking the best solutions. Although a single individual expert can be sufficient for a small-scale review, most optimization methods call for groups of external experts in order to benefit from interdisciplinary teamwork and collective problem solving.

Although external experts can be of great help, it is important to research their credentials and select them carefully. In some countries, certain certifications are required to corroborate that experts have the necessary knowledge and experience to be of value. Furthermore, any project optimization method that involves external experts needs to be well managed by the project-implementing agency to ensure that the experts make recommendations in line with the scope and goals of the project. Project optimization with external experts always requires the involvement of staff at every level within the project-implementing agency, including high-level decision makers.

A specific approach should be tailored to the project management resources available and the project circumstances to ensure that the review is adequate for the project's size and complexity. Of the many ways to obtain external input for project optimization, four approaches are commonly used: peer reviews, VE panels, constructability reviews, and operability reviews. These reviews are nonbinding; their recommendations are implemented at the discretion of the executing agency. Consequently, they should be embraced as an opportunity to inform decision making rather than feared as an audit of the project. Agencies with seasoned experience in implementing urban rail megaprojects often include these reviews in their mandatory procedures for project preparation.

### **Peer Reviews**

A peer review is a study of part of a project (for example, plan, design, budget, or construction timeline) conducted by an outside individual or panel of experienced personnel from other construction and operating agencies. Peer reviews are often focused on evaluating (rather than improving) project plans or designs for compliance with prevailing codes, standards, and performance goals. Peer reviews add an external perspective to enhance the functionality of the planning, design, construction, and operation of a project (FTA Research 2012). These reviews can be conducted in any step of project development, but they can have particularly strong impact and value when implemented early in project planning and design.

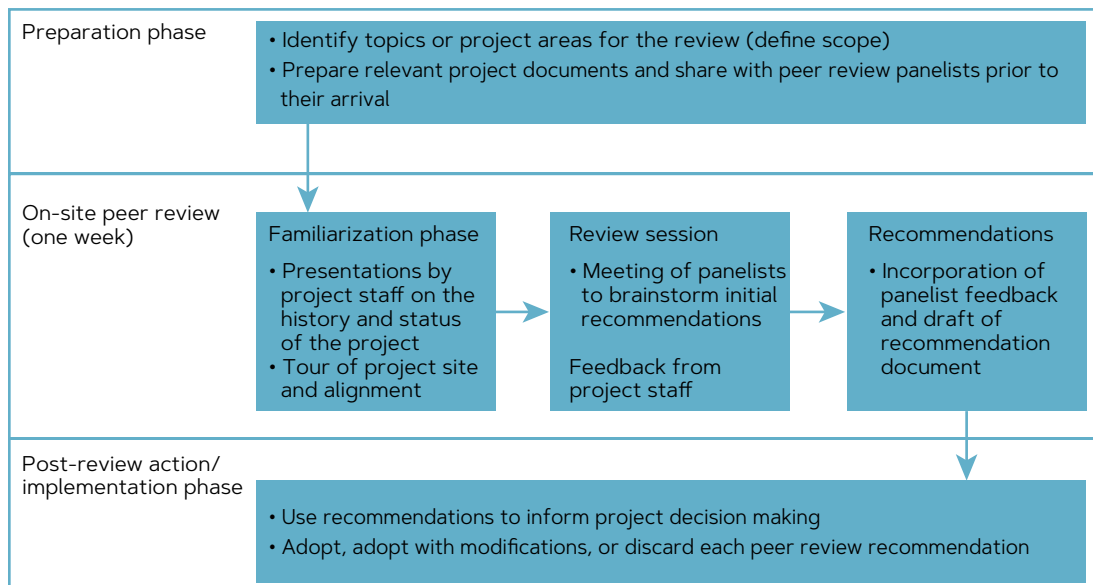
Panelists are often experts who have done similar review work in the past. The exact size of the team and expertise of the individuals involved should be tailored to the precise objectives, needs, and scope of a given review. Even if the project sponsor and its consultants have previous experience with major urban rail transit projects, contacting additional experts with experience from other projects can assist in optimizing a project with respect to both capital and operating costs. The peer review provides project sponsors with an independent, unbiased review of a project and its organizational structure, technical approach, policies and procedures, and other topics. However, external peer reviewers may not have the same depth of understanding of the local context and stake in the project as the actual project team and partners. Peer review panel members should be selected based on their experience, knowledge, and problem-solving ability; the transferability of this knowledge and experience to the local context; and references from other agencies that have used their services to find savings opportunities in the past. Recommendations from a peer review can help the sponsoring agency to

strengthen and enhance the project design, minimize capital costs and duration of construction, reduce risks, and strengthen operational effectiveness, efficiency, and safety. However, the peer review process should be managed carefully by the project-implementing agency so that the outcomes are compatible with the local context.

Before a peer review panel is convened, project staff define the scope of the review and prepare and disseminate project materials to panel members so that they are familiar with the general history and status of the project (as illustrated in figure 6.1). Panel members then meet on-site for the review. The duration of the review depends on its scope but is typically about one week. The on-site review begins with presentations by project staff that focus on specific topic areas identified by the project-implementing agency. These topic areas should be appropriate to the current step of project development (see table 6.1); for example:

- During project planning, alternatives and broad alignment decisions may be reviewed.
- During design, specific alignment adjustments, construction methodology, and equipment issues may be reviewed.

**FIGURE 6.1. Phases of the Peer Review Process**



- During construction, the sequence of civil works, key delivery milestones, and quality assurance and quality control procedures may be reviewed.

An on-site meeting is recommended to allow panel members to tour the project alignment and discuss the project with key personnel in charge of technical and managerial decision making. This on-site visit can help to build knowledge about the physical area and local context of the project among panel members and can help transfer expertise from external panelists to internal staff.

After the familiarization phase of the peer review process, the peer review panel meets to develop draft recommendations. These recommendations are shared with appropriate technical project staff members for early feedback. The recommendations are then refined and presented to the project sponsor and staff in a briefing and discussion meeting. After the meeting, a final peer review report is prepared to document the nonbinding recommendations. The project sponsor and staff can then choose to adopt, adopt with modifications, or discard each peer review recommendation.

### **Value Engineering**

VE is a formalized, systematic multidisciplinary approach to optimizing the value of each dollar spent on a project. VE seeks to satisfy the required function at the lowest total cost over the life of the project consistent with the requirements of performance, reliability, maintainability, safety and security, and aesthetics (FTA 2016). The lowest total cost incorporates capital and O&M costs for the life cycle of the project. A formal VE study calls for an independent external panel of subject matter experts to identify and analyze the function of each element of a project. Unlike peer reviews, VE studies focus on actively improving project plans or structural designs to optimize their life-cycle cost-effectiveness. VE studies are most often proposed and coordinated by the project-implementing agency during project planning or preliminary design. However, some contracts allow contractors to propose VE during bidding and construction and to share any gains with the project-implementing agency.

A formal VE study is performed early in the design process before major decisions have been incorporated into the design (FTA Research 2012). Early VE seeks to address planning and design issues that would otherwise result in costly redesign of project elements (such as structures, systems, and architectural elements) and schedule delays. It also assists in identifying options to minimize land acquisition or resettlements and disruption to local utilities and urban service networks, which are often critical-path items for



the project (see chapter 11). Since developing a major urban rail project is a lengthy and complex process, a two-tier approach to VE is often needed, with one review conducted at the completion of planning and another conducted during design.

VE may be a new undertaking for many agencies with little experience managing and implementing urban rail megaprojects. In such cases, it is prudent to train some internal staff and project decision makers on the benefits and procedures involved in a VE study. An agency may want to host a certified VE instructor to train key personnel; alternatively, the agency could send representatives to a VE conference for a standard introductory module.

Similar to peer reviews, the multidisciplinary panel of professionals who participate in a VE study should not be composed of internal project staff, but rather of outside experts with experience on similar projects. The exact form of this panel should be considered on a case-by-case basis. It typically includes a project leader, a facilitator, and five or six technical specialists from different, relevant fields, such as electrical, mechanical, civil, structural, or construction engineering, architecture, cost estimation, construction management, and transit operation and maintenance. It should contain members with international experience as well as members with knowledge of the local labor market and construction contractors.

The project-implementing agency also plays an important role in the VE process. To realize value from the process, project staff should coordinate workshop logistics, disseminate materials, and review recommendations and documents. It is also critical to foster institutional understanding and buy-in among technical personnel and key decision makers up-front, prior to the external review, so that internal staff can work with the experts to optimize the project creatively and realistically. Having this blend of external experts and internal staff participate in the VE study not only ensures that the project will benefit from an independent review; it also expands in-house knowledge, which will be needed in the future.

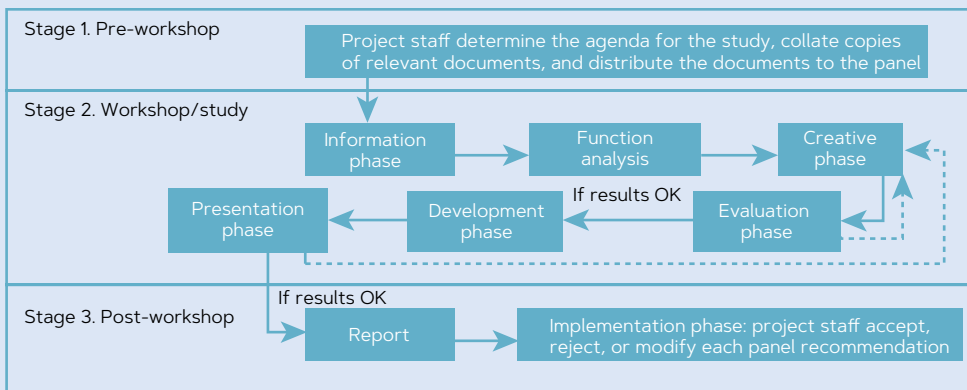
Several organizations have published recommended methodologies for VE. For example, SAVE International (2015) has published a standard for VE referred to as the Value Methodology Standard. This standard provides a three-stage, six-phase process for applying the principles of VE in a consistent manner (see box 6.3). Most VE standards suggest that the VE panel should meet on-site for three to five days for an intensive workshop (SAVE International 2015). In the week prior to the workshop, project staff should obtain, copy, and distribute relevant project documents to the panel. Doing so will allow panel members to become familiar with the project in advance of the workshop and allow project staff to set the agenda and manage the outcomes of discussion.

**BOX 6.3.****SAVE International Value Methodology Standard**

The SAVE International Value Methodology Standard (SAVE International 2015) outlines the following six-phase process for value engineering. The logical flow of this six-phase process is illustrated in figure B6.3.1.

1. *Information phase.* Project staff inform the VE panel about the current conditions of the project and identify the scope and goals of the study.
2. *Function analysis phase.* The panel defines the project functions using a two-word active verb-measurable noun context. The panel reviews these functions to determine which need improvement, elimination, or creation to meet the project's goals.
3. *Creative phase.* The panel employs creative techniques to identify other ways to perform the project's functions.
4. *Evaluation phase.* The panel follows a structured evaluation process to select those ideas that offer the highest potential for value improvement, while still properly delivering the project's functions within performance requirements and resource limits.
5. *Development phase.* The panel develops the selected ideas into alternatives or proposals with a sufficient level of documentation to allow decision makers to determine if the alternative should be implemented.
6. *Presentation phase.* The panel leader produces a report or presentation conveying the alternatives developed by the VE panel and the value improvement opportunity associated with each of them.

**FIGURE B6.3.1. Illustration of the Six-Phase Value Engineering Process**



Source: Adapted from SAVE International 2015, 5.

The workshop week starts with an information phase in which project staff give a presentation and conduct a site visit. Design decisions, weighing cost and performance for individual project elements, are discussed. Next, during the function analysis phase, the VE panel identifies the functions (purposes) of the project and allocates resources, such as cost and time, to these functions. Based on the analysis, the VE panel prioritizes the functions with the most potential for value improvement. The VE panel then individually and collectively brainstorms a list of ideas for achieving the prioritized functions. This brainstorming should make use of the creativity and collaborative thinking of the panel; it should also be constrained within the project and study parameters (such as budget and required performance) set by the project staff. Initial evaluation of these ideas screens out those with less promise.

The best ideas are then developed further and subjected to a more detailed life-cycle cost analysis. Discussions are held among panelists and staff from the project-implementing agency to ensure that the ideas are valid within the local context of the project and underlying assumptions are verified. At the end of the week, the panel presents its findings and alternatives for a preliminary review by project staff. Typically, this exercise results in a final list of 15–20 value options (as well as synergetic packages of these options) that are presented to decision makers for consideration. This final list of value options usually represents life-cycle cost savings and performance improvements that total 5–15 percent of estimated project costs.

Following the workshop, a draft report is prepared with a summary of recommendations, including their estimated life-cycle costs (capital and operating), schedule, and other important implications. The project staff reviews the recommendations and decides to accept, reject, modify, or further study each of them. A final VE report is prepared by the panel taking into consideration the project staff's comments on the draft report. This report is a nonbinding, valuable tool for informed decision making.

Some countries, including the United States, have institutionalized these methods, specifically in the context of the development and optimization of urban rail projects. The U.S. Federal Transit Administration (FTA) has expanded the SAVE International process in its *Construction Management Handbook* (FTA Research 2012). The detailed process laid out by the FTA puts greater emphasis on preworkshop efforts to bring key decision makers into the discussion at the onset of the process (FTA Research 2012, 55). In the United States, VE is required for major transit investments over US\$100 million and recommended for all projects whose estimated construction costs exceed US\$2 million (FTA Research 2012). This requirement reflects VE's potential for major cost savings (see box 6.4).

**BOX 6.4.****Using Value Engineering to Optimize a Project: Metra Grade Crossing Flyover, Chicago, Illinois, United States**

This case study illustrates a successful value engineering (VE) study. An at-grade crossing of two rail lines—the Metra Rock Island District commuter line and the Norfolk Southern Railroad’s Chicago freight line—was a major bottleneck in the rail network of Chicago, Illinois. A project was developed to eliminate the at-grade crossing by creating a flyover for the Metra Rock Island commuter rail line tracks to minimize delays and operational difficulties for both Metra and the Norfolk Southern Railroad at this location. The construction costs for the project were estimated at US\$117.5 million based on 2008 prices, with construction lasting 24 months starting in 2010. With careful application of the VE methodology, the VE panel was able to identify potential cost savings of more than US\$10.4 million (or 10 percent of estimated total project cost) for consideration by decision makers. In the end, the project-implementing agency decided to carry forward value options that reduced the total cost (capital, operation and maintenance [O&M], and management) by 4.3 percent and came away with additional ideas for cost savings.

As recommended by the SAVE methodology, a multidisciplinary panel of experts, independent of the project development team, was convened to ensure maximum objectivity in identifying alternative designs. Constraints established for the study included a project budget (available funding), a two-year construction period, the prohibition of service outages that affected rail schedules during construction, and the requirement that

the project be implemented using existing rights-of-way.

A five-day (40-hour) workshop was held in Chicago, on March 22–26, 2010. Following standard SAVE methodology (box 6.3), the workshop began with an information phase consisting of presentations by project staff to provide background information on the project and a site visit. During the function analysis phase, the team reviewed the purpose of the project—to improve service for Amtrak, Metra, and Norfolk Southern by reducing delays caused by grade-crossing conflicts—and the current design to raise the Metra tracks over the Norfolk Southern tracks. The VE panel then transitioned to the creative phase of the workshop, generating 82 ideas for potential changes to the design. Based on the panel’s professional expertise and input from the project design team (during the evaluation phase), 15 of these ideas were selected and developed further into “value alternatives,” as described in table B6.4.1.

During the presentation phase on April 12, 2010, VE panelists met with key project decision makers and technical personnel to discuss each suggestion, answer questions, and help the design team to decide what changes to make to the project. The estimated capital and life-cycle cost savings immediately accepted by the design team totaled US\$5.2 million, with an additional savings of almost US\$5.3 million possible pending further study by the design team. Thus, VE found significant cost savings in the design of the project without reducing its functionality. Investing in a VE study as a form of project optimization created significant returns for the project-implementing agency.

*(box continues next page)*

**BOX 6.4.****Using Value Engineering to Optimize a Project: Metra Grade Crossing Flyover, Chicago, Illinois, United States** *(Continued)***TABLE B6.4.1. Select List of Value Alternatives Developed and Their Potential Cost Savings***US\$, unless otherwise noted*

ALTERNATIVE	UP-FRONT COST SAVINGS	PRESENT WORTH O&M SAVINGS	LIFE-CYCLE COST SAVINGS	SCHEDULE SAVINGS (MONTHS)	DECISION
Reuse 66th Street Bridge at 67th Street	364,000	0	364,000	0	Reject
Reuse the 60th Street girders at 61st Street	495,000	0	845,000	0	Reject
Use a truss bridge to span the Dan Ryan Expressway	(10,599,000)	997,000	(9,602,000)	3	Reject
Use tied parallel retaining walls, gabions, sheet pile bin, or performance spec instead of cast-in-place wall	3,751,000	0	3,751,000	22	Accept, with modification
Use retaining walls instead of flyover bridge	4,564,000	840,000	5,404,000	1	Reject
Use a straddle bent to avoid signal bungalow	2,020,000	0	2,020,000	0	Accept
Use precast concrete substructure and steel piles for flyover approaches	5,255,000	0	5,255,000	3	Further study

Source: SVS Inc. 2010, 1-8.

Note: O&amp;M = operation and maintenance.

VE studies cost time and resources to undertake, but there is ample evidence to suggest that this investment more than pays for itself in terms of added institutional and project knowledge and identification of potential project cost savings. Although the cost of a specific VE exercise depends on the scope of the review and the number of international experts involved, VE studies typically cost between US\$75,000 and US\$100,000, excluding some additional expenses for travel, accommodations, and interpreting services. In low- and middle-income countries, given limited local experience and expertise, costs are likely on the higher end of that range due to the need to hire experts from other countries. If applied in early steps of the project development process, VE often finds savings equivalent to 5–15 percent of total estimated project costs. For small-scale projects, this can be a 10:1 return on the investment. The return on investment can be even higher for projects, such as urban rail projects, with larger size and budget (Kirk 2016). Therefore, for large-scale, complex urban rail projects—especially in low- and middle-income countries where both cost savings and additional institutional knowledge and capacity can be gained—VE is a highly recommended use of time and resources in optimizing the project (see box 6.5).

Although formal VE studies are typically conducted early in planning or design of a project, opportunities for VE also arise later in the project development process. During bidding, proposal requirements can be structured to allow contractors to review project designs and suggest changes that reduce construction time or save money over the life cycle of the system, while still complying with all engineering specifications. Recommendations from contractors, unlike those from an independent VE panel, may have a bias toward saving up-front costs at the expense of longer-term operating costs or project performance and thus should be reviewed even more carefully by all project staff and decision makers. Yet with careful management of these contractual arrangements and review of resulting recommendations from a life-cycle cost perspective, much can be gained by leveraging the competition among highly experienced bidders.

### **Constructability Reviews**

Constructability reviews of project design documents ascertain whether what is depicted on the drawings, technical specifications, and construction bid documents can actually be built without major problems. These reviews optimize the project through early identification and elimination of construction requirements that are impossible or impractical to build. They are especially important in low- and middle-income countries, where the construction market may be underdeveloped and materials and experienced labor may be scarce.

**BOX 6.5.****Using Value Engineering in a Middle-Income Country Context:  
Metro Line 1, Bogotá, Colombia**

The city of Bogotá contracted advanced engineering studies for a first metro line with support from a World Bank loan. The proposed solution included 27 kilometers of underground metro line with 25 stations, two terminals, and one train depot and workshop. The project was designed for a peak capacity of 80,000 passengers per hour per direction and daily ridership of up to 900,000. The project had a pre-value engineering (VE) capital expenditure estimate of US\$7.1 billion, including rolling stock, based on 2013 prices and exchange rates. An updated cost estimate at the final-design level was significantly above the original estimate and the foreseeable funding envelope to be provided by national and local government budget appropriations. This merited a profound discussion of the project's affordability and the credibility of the cost estimates.

In 2015, following World Bank recommendations on project optimization for megaprojects, the public sponsor of the project—Financiera de Desarrollo Nacional (FDN)—competitively procured a consulting firm to carry out a VE study following the SAVE methodology outlined in box 6.2. The VE exercise generated 49 possible changes to the advanced engineering designs, identifying potential capital cost savings of nearly 24 percent of estimated total project capital expenses (US\$1.7 billion), as well as significant operational expense savings (SENER 2015). Of these options, approximately 80 percent of the project capital cost savings could come from three broad themes: reducing the number of stations, replacing underground segments with at-grade or elevated segments, and reducing the total length of the line. After the VE dissemination workshop with key decision makers, FDN carried forward 27 of the proposals, with combined potential savings of

8 percent of total project capital expenses (US\$554 million). The VE study also assisted in identifying specific options for minimizing tax duties.

The following are some key takeaways from the Bogotá Metro Line 1 VE experience:

- Since this was the first VE study implemented in the transport sector in Colombia, a key ingredient for success was the investment of initial time and effort in informing relevant stakeholders of the VE methodology and its applicability to the project. The VE consulting firm, the project sponsor, and the World Bank partnered to build stakeholder capacity and buy-in prior to the start of the workshop.
- Key decision makers understood that the VE options proposed by the consulting firm were nonbinding and embraced them as an opportunity for adding value to the project. A sensitive topic was the differentiation between a nonbinding VE study and a technical review or audit (a more traditional approach in the Colombian context, which would require due action by the project sponsor based on possible findings).
- The VE study increased the credibility of the project's engineering assumptions and cost estimates and strengthened the public and political perception of the project.

In Colombia, this VE study was a seminal exercise which, beyond identifying significant capital and operating cost savings for the project, established the VE practice in the preparation of transport infrastructure projects. Other rapid transit projects, including the Medellín Ayacucho light rail transit line sponsored by FDN, followed suit and made use of VE studies.

Constructability reviews are an integral part of the internal design process and the value analysis conducted by project staff. In addition, the use of an independent team of individuals who know urban rail construction and routinely work with relevant contractors is an important addition to the design process. Participants in these external constructability reviews should not be allowed to bid on the project because this could give them an unfair advantage in the bidding process and represent a conflict of interest. External participants should be experienced field engineers who have worked closely with contractors and construction documents during the various steps of construction (including bid, construction, and closeout) but who will not be involved in a bid for the project. The quality and applicability of the review depend on the choice of reviewers and the management of the review process; it can be difficult to identify external experts whose experience is compatible with the local context but who will not be bidding on the final project. Therefore, the project-implementing agency should spend adequate resources vetting, recruiting, and informing these experts about the unique features of the metropolitan region and the urban rail project.

In the detailed design step of project development, constructability reviews are performed as part of the design review. Constructability reviews consider the availability and suitability of materials and the capability of labor resources (FTA 2016). Constructability reviews make certain that designs can be constructed using methods, materials, and equipment common to the local or global construction industry, so that competition and market forces keep costs in check. Constructability reviews are particularly beneficial given the complex nature of urban rail construction, particularly when it requires tunneling in an urban environment (see chapter 11). Experts with experience in underground and urban rail station construction can provide valuable insight on the optimum construction methodology to use in a particular case.

Constructability reviews can recommend design modifications or suggest alternative contracting methods that streamline construction or mitigate risk, resulting in cost savings. Recommendations from these reviews can be developed, refined, and then included in bid documents. The process can be similar to a peer review or VE study, with information, analysis, evaluation, and presentation phases.

Although constructability reviews held during detailed design should not employ construction contractors who may be potential bidders, constructability reviews and other project optimization proposals can be used effectively as part of the bid process. Bid documents can be structured to allow the inclusion of alternative design or construction strategies that could reduce construction costs, speed up project delivery, and improve the short- and long-term function



of one part of the project without increasing the budget. Bidding contractors are sometimes in a better position to analyze constructability issues and to propose alternative construction methods than the design team itself. Tender designs and drawings used to seek bids for rail projects, particularly in low- and middle-income countries without a strong domestic construction industry, should incorporate the maximum flexibility possible to allow the winning bidder to propose detailed design solutions, as long as these solutions meet the project's capital and O&M budgets, design criteria, and performance standards. If properly applied, this approach can help to achieve significant reductions in bid prices, without compromising the quality of the built facility. Similar bidding arrangements that allow for project optimization proposals may also exist between the contractors and their specialist subcontractors, encouraging innovation and project optimization to meet specified engineering targets.

However, the project-implementing agency must be careful to structure incentives and oversight so that proposed optimizations are not simply ways to cut corners and costs in the delivery of civil works. The project-implementing agency (with support from a "shadow operator" when available) needs to review and approve any suggestions from the contractor to ensure that changes in design made to reduce the initial capital cost of the project do not compromise the long-term operability of the system. Furthermore, contracts should specify that any cost savings resulting from optimizations proposed by the contractor will be shared with the project-implementing agency. Opportunities for design and construction optimization should be treated in such a way that, without detriment to the life-cycle cost or performance of the project, both the project-implementing agency and the contractor work together as win-win partners.

While constructability reviews require time and resources from the project-implementing agency to set up, manage, and approve, they also can provide significant value to complex urban rail projects. Therefore, during design and construction, feedback from construction contractors should be sought, either formally or informally, on strategies to reduce project costs or improve materials or construction methods, optimizing the project.

### **Operability Reviews**

Operability reviews are performed in the preliminary and detailed design steps of project development. These reviews involve a "shadow operator" or other external operational specialists who can help to identify ways to maximize the long-term operational flexibility and reduce the lifetime maintenance costs of assets. Operability reviews are important complements to constructability reviews: they ensure that design and construction choices for the delivery of civil works also support the long-term operation and maintenance of the system.

Similar to constructability reviews, the quality of the results depends on the choice of reviewers and careful management of the process by project-implementing agency staff.

## Alternative Contracting Strategies

The effort to optimize a complex project should extend to the type and method of contracting. Procurement decisions are a very important aspect of project optimization. Therefore, the project-implementing agency needs to consider carefully the impact of contract structuring and packaging on overall project costs (see chapter 8).

Although not a panacea, various procurement strategies offer the potential to involve external expertise in the implementation process with considerable benefit. The traditional approach to project delivery is a design-bid-build process in which an engineering firm is retained to prepare plans, specifications, and estimates for a project. Once completed, the project engineering documents are used to solicit bids for construction. The lowest responsible bidder is then selected. This project delivery process disconnects project design from construction by using separate design and construction teams. Even with the contracting agency assuming the coordinating role between the two teams, this arrangement provides fewer opportunities for joint value analysis and collaborative review among design and construction professionals without the implementation of formal project optimization tools. Although this remains a preferred method of delivering major rapid transit projects, many recent projects have used alternative methods. Chapter 8 discusses the advantages and disadvantages of many alternative delivery methods.

This section highlights the possibilities for additional project optimization afforded by two of these alternative delivery methods: design-build and public-private partnerships. Analysis of the advantages and disadvantages of different delivery methods is highly dependent on the local context and needs to consider, for example, the state of development and structure of the local engineering and construction industry, the interest and likely level of participation of international bidders, the management capacity of the project-implementing agency, and the risks of greater political interference in one type of process over another.

### Design-Build

Under a design-build arrangement, one entity performs both design and construction under a single contract. The design-build delivery method has several

advantages over the traditional design-bid-build method that can help to optimize the project's schedule and cost. One of the biggest advantages is that the design and construction steps of the project overlap, fast-tracking the project development schedule. In addition, integration of the design and construction teams allows construction efficiencies to be incorporated more easily into project design through continual use of constructability and other reviews. However, it is important to ensure that such a focus on optimizing the constructability of the project does not compromise the long-term operability and maintainability of the system.

Design-build contracting has some disadvantages, including the undermining of inherent checks and balances between the design and construction teams; in design-build arrangements, the design team is no longer independent of the construction contractor. In addition, design-build may reduce competition for design and construction services by favoring large national and international engineering and construction firms because the contracts involved are too big for smaller and less experienced local or regional firms to pursue. Furthermore, if the process is poorly managed by the project-implementing agency, the unchecked incentives for the contractor to optimize its own up-front costs can seriously affect the life-cycle value of the project.

A project-specific analysis needs to be completed before a procurement process is selected. The potential advantages of the design-build process in optimizing a project need to be weighed against the disadvantages. As with any procurement method, design-build has to be well managed. Given the size of some international design-build teams and their profit motive, the project-implementing agency has to provide strong and active oversight in the implementation and optimization of complex urban rail projects. Thus, design-build should be exercised with caution, and project-implementing agencies should be prepared to manage the process actively. For more experienced project-implementing agencies that want more control over the design and construction of the project, a range of hybrid solutions other than complete design-build is possible; in these, the project-implementing agency provides a certain level of outline design and asks bidders to compete by providing detailed design-build offers.

### **Public-Private Partnerships**

Public-private partnerships are another type of procurement that may be appropriate in certain circumstances. The PPP method can enable the public sector to harness the expertise, efficiencies, and financial resources of the private sector for the delivery of facilities and services traditionally procured and delivered by the public sector (see chapter 9).

For PPP arrangements that extend through operation of the project, the PPP team has an incentive to optimize the project through both its construction and its operation. As with design-build, this method is not a panacea; appropriate incentives and safeguards need to be put in place as part of the contract to ensure that the private partner maximizes benefits for system users and the wider public along with its profit. Effective oversight of the private partner has to be maintained through the life of the arrangement, which requires building appropriate capacity within the project-implementing agency.

PPP arrangements also have some disadvantages. PPPs take much longer to process than regular contracts, so they must be considered carefully with regard to project delivery schedule. Furthermore, the more risk and responsibilities that are transferred to the private partner, the less control the project-implementing agency has over the design, construction, and, potentially, operations of the system and the higher the premiums paid to the partner for adopting these risks (see chapter 9).

## Conclusions and Recommendations

Considering the magnitude, complexity, and uncertainty of urban rail projects, their high capital and operating costs, and their wide-ranging impacts on the urban landscape, economy, and society, optimization should always be an integral component of their development. Project optimization can help to balance up-front capital costs with savings over the operating lifetime, maximize the benefits, and mitigate the risks of these megaprojects. This chapter has presented in detail three basic project optimization tools that internal staff should conduct continuously throughout the project development process: value analysis, risk analysis, and life-cycle cost analysis. These internal efforts are complemented by the periodic involvement of external experts in formal peer reviews, value engineering, constructability reviews, and operability reviews (usually during the design or prebid steps of project development). In addition, two alternative project delivery methods are discussed that, if properly implemented, may lead to further optimization.

The specific optimization approaches that a project-implementing agency uses should be tailored to the management resources available and local circumstances to ensure that the review is adequate for the size and complexity of the project in question. Although many of these project optimization methods involve the use of external experts, all require the active participation and buy-in of key decision makers and technical staff within the project-implementing agency. The principles of project optimization should be applied to all projects,

and optimization should be a fundamental goal of project development. Different methodologies have different levels of sophistication and formality, but all of the methods provide a good return on investment (see table 6.2).

***Project optimization yields higher returns when applied early and as an ongoing process in project development.*** The earlier that project optimization tools are used, the greater is their potential for increasing savings and value. Emphasis should be placed on optimization during project planning and design, when changes are less costly or disruptive to implement. Techniques such as value, risk, and life-cycle cost analyses should be applied for all projects undertaken by the project-implementing agency as an ongoing process beginning in the very early planning stage. These ongoing internal efforts should be complemented by periodic studies and reviews involving external experts at critical milestones in early planning and design. However, opportunities for optimization show up in all stages of project development; the components of the project that are the focus of optimization and the methods used evolve throughout the project development process. Project optimization is a process rather than a one-time task.

***Buy-in from key stakeholders and project staff is required to leverage the knowledge and experience of external experts.*** Up-front buy-in from key stakeholders and full involvement of the project-implementing agencies' technical and managerial staff are not only critical to achieving the most savings; they are also germane to the wider impact of any optimization tool. Decision makers should be aware of the importance of project optimization methodologies in building internal capacity and institutional knowledge, as well as identifying opportunities to reduce cost, save time, increase project value, and reduce project risk. Internal project staff should undertake their own value analysis

**TABLE 6.2. Summary of Optimization Methodologies**

TYPE	CONDUCTED BY	ADDITIONAL PROJECT RESOURCES REQUIRED	WHEN (DURING PROJECT DEVELOPMENT)
Value analysis	Project staff	None	Ongoing
Risk analysis	Project staff	None	Ongoing
Life-cycle cost analysis	Project staff	None	Planning and design
Peer reviews	Outside panel or individual	Few	Planning and design
Value engineering	Outside panel	Moderate	Design
Constructability reviews	Outside panel	Moderate	Design

throughout development of the project. The efforts of project staff should be complemented by the use of outside experts through peer reviews, value engineering, constructability reviews, and operability reviews. These external experts not only provide an unbiased and fresh point of view; they also contribute a breadth and depth of knowledge greater than that available within many less experienced project-implementing agencies. Involving external review to complement internal value analysis further incentivizes the project team to be creative and flexible in its design, realizing schedule efficiencies, lowering costs, and mitigating risks.

***Project optimization recommendations are nonbinding; project optimization constitutes an opportunity, not an auditing exercise.*** Each optimization method produces nonbinding recommendations that can be an invaluable source of information for project decision makers. Decision makers in the project-implementing agency review all recommendations (from either internal staff or outside experts) and decide to accept, reject, modify, or further study each proposal. Therefore, project optimization is an opportunity to identify possible ways to improve the value of the project and to consider the trade-offs and feasibility of these ways, given the political, institutional, and financial environments. The knowledge gained throughout this process makes it a worthwhile investment of time and effort, even if only some of the recommendations identified are actually implemented.

***Project optimization builds project credibility and is particularly important when resources are constrained.*** Establishing a formalized process of project optimization can give national governments, financiers, and other project sponsors more confidence in the cost-effectiveness of the project design. For political administrations whose timeline is shorter than the typical implementation period of an urban rail megaproject, project optimization may enable a phased approach to implementation that delivers key project milestones and capitalizes on existing political economies. When resources are limited, phased implementation, incorporating appropriate analysis and planning of real options, can allow project-implementing agencies to reduce up-front capital costs and speed up construction of a self-sustaining, stand-alone initial part of the project without sacrificing the project's long-term viability.

***Some alternative methods of project delivery can provide greater opportunity and flexibility in project optimization.*** While project optimization methods are applicable to any project regardless of the procurement strategy and delivery method used, some alternative delivery methods (such as design-build or PPP) may provide greater opportunity and flexibility in optimization throughout the life cycle of the project. If properly structured, these arrangements can expedite the schedule of the project and encourage collaboration

among the design, construction, and O&M teams, resulting in better optimization. However, careful analysis of advantages and disadvantages should be undertaken before choosing any project delivery method (see chapter 8).

## Note

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03

# 7

## MANAGING RISKS

Daniel Pulido and Ramiro Alberto Ríos

Although all infrastructure projects face risks, urban rail projects are considered particularly risky. An estimated 75 percent of urban rail projects have final project costs that are at least 33 percent higher and initial ridership that is, on average, 51 percent lower than forecasted (Flyvbjerg 2007). Risks arise during all steps of the project development process. In the haste to move projects forward, implementing agencies often fail to identify all risks—frequently concentrating only on risks in the construction phase—do not appropriately assess their likelihood and impact. The development of strong risk management procedures is fundamental for project-implementing agencies embarking on urban rail projects.

Risk management includes identifying, assessing, and then addressing risks (HM Treasury 2013). Risks are addressed by designing and implementing measures aimed at diminishing the probability and severity of negative events, including transferring or allocating risks to a third party, accepting and retaining the risk, or even rejecting (or redefining) a project to reduce risk. This chapter provides guidance to project decision makers on how to better manage potential undesired events that can negatively affect project implementation and reduce the project's socioeconomic benefits. This chapter delineates the rationale and dynamics of the risk management process for urban rail projects and highlights some of the most common risks they face.

*Photo:* ViaQuatro Trains on São Paulo Metro Line 4, 2010. *Source:* Milton Jung via Flickr (CC BY 2.0).

The nature of urban rail megaprojects creates added levels of risk (see table 7.1). In general, larger projects with longer implementation periods are riskier than smaller projects with shorter implementation times. Such projects could span the course of two different administrations that may see the project differently. For example, an incoming administration, citing economic difficulties, might not see existing budgetary commitments to a project developed during a previous administration as a priority. The cost of labor and materials may also increase as the project is

**TABLE 7.1. Key Characteristics That May Influence Risk Levels for Urban Rail Projects**

RISK CHARACTERISTIC	DESCRIPTION
Size and scope	Difficulty in building and maintaining political consensus or commitment and raising necessary funding for large projects involving investments of billions of US\$ that may be subject to scope adjustments and cost increases
Duration	Difficulty in maintaining political commitment and funding for long-term projects with lengthy construction periods that may be subject to completion delays and cost escalation
Location	When done for the first time (in a country or jurisdiction), may be carried out in uncertain or underdeveloped regulatory environments  Uncertainty in geological conditions, interference with existing utility networks, negative impacts on buildings and archeological findings, particularly when underground
Interfaces	
Internal	A high degree of integration and coordination between relevant public entities (that is, national and subnational governments) and between these entities and multiple private companies (that is, project contractors and equipment suppliers)
External	Interconnection with existing public transport modes and neighboring property or facilities
Technology	May involve the use of new technologies or require the adaptation or upgrade of outdated technologies when involving the expansion of a project with legacy systems for which in-house or in-country expertise and experience may be limited
Financing	Large cost and limited cost recovery, fixed budgets and limited funding sources, insufficient and uncertain farebox revenues
Market	Limited availability of qualified contractors and in-country engineering expertise and supply chain constraints
Delivery	Complexity of procurement process and inflexible schedules
Management	Decision makers without real decision-making power and without coordination among them

Source: Adapted from Smith 2015.

implemented as a result of higher global demand (as was the case during the first decade of the twenty-first century due to high consumption by China).

This chapter discusses ways to manage the financial manifestation of risks. In addition to financial risks, project-implementing agencies are exposed to other uncertainties and risks during the life of the project that may not necessarily generate a direct financial impact but will affect the image and long-term viability of the urban rail service. Although not discussed in detail in this chapter, examples of these nonfinancial risks include commissioning delays, reputational risks, or poor quality of the service not duly compensated for by penalties or payment abatements (ADB et al. 2016). Managing these risks includes handling public perceptions and communications, which are also critical for project success (ADB et al. 2016).

This chapter provides guidance on how project-implementing agencies can develop a risk management strategy, focusing on the key tasks and steps involved. It also describes the main risks associated with implementing an urban rail project and provides guidance on how to mitigate these risks.<sup>1</sup> Finally, it introduces risk allocation under public-private partnership (PPP) projects, a topic that is explored further in chapter 9. Large private construction companies and infrastructure operators have sophisticated risk management processes and know how to arbitrate between risks (higher costs) and opportunities (higher profits). In order for public implementing agencies to manage PPP contracts adequately, they need to develop similar capacity to assess risks.<sup>2</sup>

## Managing Risks in Urban Rail Projects

All of the characteristics mentioned in table 7.1 contribute to the level of risk to which an urban rail project is exposed. To manage such a broad range of complex characteristics effectively, project-implementing agencies should consider developing a risk management strategy that encompasses six essential steps: (1) identification, (2) assessment, (3) mitigation, (4) allocation, (5) treatment for risks retained, and (6) monitoring. Table 7.2 describes each of these steps in more detail. It is critical to develop a risk management strategy early in the project concept stage and to update it throughout project implementation and operation. This task is crucial to establish existing constraints and develop appropriate cost estimates, as well as to focus the project manager's attention on minimizing risks (Ward, Chapman, and Curtis 1991). Poor risk management during planning and preliminary design may lead to suboptimal

**TABLE 7.2. Six Essential Steps to Develop a Risk Management Strategy**

RISK MANAGEMENT STEP	DESCRIPTION
1. Identification	Identify and describe all possible risks and understand their impact
2. Assessment	Examine possible impacts of risks and categorize risks using both qualitative and quantitative methods <sup>a</sup>
3. Mitigation	Devise measures that reduce the likelihood and impact of risks if they materialize (or to reduce perceived risk by reducing uncertainty)
4. Allocation	Assign financial consequences to the stakeholder best positioned to deal with them
5. Treatment	Deal with accepted or retained risks under different strategies—such as self-insurance, contingency funding, and insurance—or simply react to consequences
6. Monitoring	Conduct risk oversight so as to be prepared to act promptly and effectively, establish concrete mitigation measures for risks that suffer an increase in likelihood, reassess risks, identify or incorporate new risks, change prioritization, and permanently update the risk-control systems and strategies depending on changes in context and evolution of the project

Sources: Adapted from Smith 2015; World Bank 2014.

a. Several analytical methods use complex mathematical models and even specialized computer software to quantify risks. These methods are not covered in this handbook.

project procurement and financial structuring, which, in turn, may result in underperformance (Beckers and Stegemann 2013). Impartial risk identification during planning may even lead decision makers to scrap the proposed project and look for alternatives (see chapter 3).

### Risk Identification

Risk identification refers to defining a comprehensive list of risk events, usually grouped in different categories, and clearly determining how those risks will affect the project outcome if they materialize (World Bank 2014). Such a comprehensive list of all risks associated with the project is referred to as a “risk register” or a “risk matrix” (see box 7.1; World Bank 2014).

These lists are often developed during risk identification workshops. In the case of Metro Line 1 in Bogotá, Colombia, public authorities conducted a risk identification and allocation workshop early during project conception. This helped to focus attention beyond the engineering aspects associated with construction to the consideration of other project risks such as financial risks.

Decision makers took a holistic approach to all project stages through a risk management lens (see box 7.2).

Although it is important to identify risks early, it is also important to revisit these lists often. Risk management is an ongoing effort that should continue throughout the life of the project—as the project-implementing agency takes an urban rail project from concept to operations, different circumstances and risks can materialize.

### **Risk Assessment**

Once project risks have been identified properly, the next step in the risk management process is to assess those risks. In simple terms, risk assessment is

#### **BOX 7.1.**

#### **The Importance of a Risk Register**

It is good practice to develop risk registers during project planning. Risk registers are essentially information logs where the details of all risks identified throughout project development are kept. The following is the main information included in a risk register:

- Risk identification number
- Description of each risk
- Description of how each risk affects the project
- Assessment of the likelihood and impact of each risk
- Classification of risk
- Party responsible for managing the risk
- Proposed mitigation measures
- Cost impact and responsibility for each measure

A risk register not only lists identified risks, but also categorizes them. This can help to avoid blind spots and to keep track of risks that overlap. The detailed risk register

is used to conduct an orderly quantitative risk assessment, usually in the context of appraisal exercises such as cost assessments or estimates to build the budget and base case. However, for allocating risk (especially in the context of a public-private partnership [PPP]), a simpler list is built using a risk allocation matrix.

Risk registers are useful for closely monitoring and, where possible, reducing potential risks and documenting responsibilities and mitigation actions during the life of the project. Before developing a risk register, project-implementing agencies need to have considerable knowledge and understanding of the project, its stakeholders, and potential mitigation strategies (including early mitigation). Table B7.1.1 provides a sample risk register that can help project-implementing agencies to develop their own risk register for an urban rail project.

*(box continues next page)*

**BOX 7.1.**  
**The Importance of a Risk Register** (Continued)

**TABLE B7.1.1.** Example of a Risk Register for an Urban Rail Project in a Public-Private Partnership Context

IDENTIFICATION NUMBER	RISK CATEGORY	DESCRIPTION OF THE RISK IDENTIFIED	IMPACT ON PROJECT (IF RISK IS NOT MITIGATED)	RISK ASSESSMENT			RISK ALLOCATION			MITIGATION TIMELINE	COST (US\$)
				P	I	C	R	PUBLIC	PRIVATE		
1	Site	Inability of project owner to acquire all land needed	Cost increase; delays	2	2	4	Medium	<input checked="" type="checkbox"/>		Purchase land required before starting the project	\$62M
2	Operations	Underestimated passenger demand	Need for larger subsidies	2	3	6	High	<input checked="" type="checkbox"/>		Implement fare and physical construction integration	\$35M

Note: For risk assessment, P = risk probability; I = risk impact; C = risk classification; R = risk rating. Risk classification is calculated by multiplying the probability rating by the impact rating; risk rating values are 1-2 = low, 3-5 = medium, 6-9 = high. Cost amounts do not correspond to real projects and are provided for indicative purposes only.



**BOX 7.2.****Early Risk Identification in Risk Management Workshop: Metro Line 1, Bogotá, Colombia**

In 2014, the World Bank provided assistance to the government of Bogotá with the preliminary evaluation of business models to deliver the first line of the Bogotá metro. The World Bank, with support from the Public-Private Infrastructure Advisory Facility, executed a technical assistance project that explored the advantages and disadvantages of different procurement and financing options using a risk-based approach.

The first task in this technical assistance project consisted of evaluating international case studies, focusing on the risks and mitigation measures adopted in those cases. This was followed by a preliminary risk workshop in which the relevant stakeholders evaluated the project from a risk management perspective. They looked at all potential risks, not just those emanating from the engineering studies. The workshop was attended by representatives from all of the public agencies involved in the project, including city and national governments, the consulting firm in charge of project design, and representatives from international financial institutions.

As a preliminary evaluation, this exercise was intended to lay the foundation for an expert panel, bringing in independent experts with experience on similar projects. This panel was scheduled to take place during the project structuring phase.

The workshop started with a presentation on the main risks relevant to urban rail projects and was followed by a preliminary identification of the most significant risks specific to the project. This identification was based on the project parameters available at the time and assumed that implementation would take place under the business model that had originally been considered by Bogotá's public works agency—Instituto de Desarrollo Urbano—the entity in charge of the project at the time. Participants were then asked to indicate their opinion regarding the likelihood and potential impact of the risks identified. Finally, participants weighed in on the most desirable allocation of risks from the perspective of the project-implementing agency and established a preliminary risk matrix for the project.

the process of estimating the level of each risk identified in the project with respect to its “expected value” (probability multiplied by impact). By considering the level of detail and object of the analysis, there are two broad types of assessment: qualitative (or semiquantitative) and quantitative.

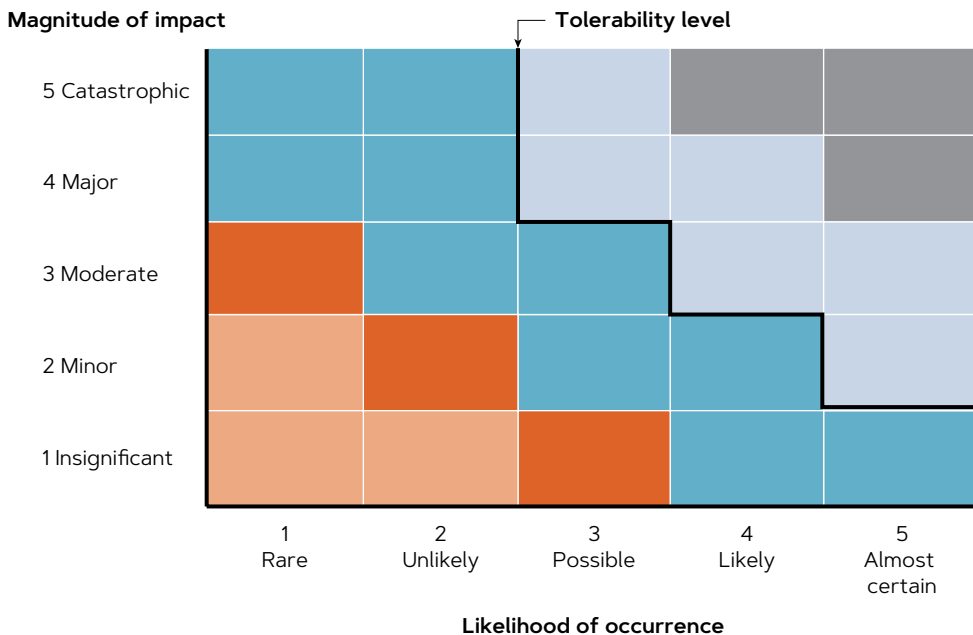
***Qualitative Assessment***

The objective of a qualitative assessment is to understand the most significant risks to the project in order to prioritize risks and decide which deserve special attention. This attention can be in the form of additional research and surveys (for example, geotechnical studies or demand analysis), detailed quantitative

assessment, early mitigation measures, and, above all, a strategy to assign or allocate risks to stakeholders in the best position to manage them.

In the United Kingdom, a good practice is to use a risk matrix—or tolerability matrix—similar to the one shown in figure 7.1. This matrix is important not necessarily to determine the absolute value of each risk, but instead to determine whether the risk is tolerable for the party in charge of managing it (HM Treasury 2013). It is important to base the assessment on unbiased independent evidence, to consider the views of all possible stakeholders, and to avoid confusing objective assessment of the risk with judgment about the acceptability of the risk (HM Treasury 2013). Figure 7.1 presents a graphical representation of a simple risk tolerability matrix that can be used to assess the magnitude of impact and likelihood of occurrence for all risks of an urban rail project. Table 7.3 provides an example of how to document each risk, the impact and probability rating of each risk, and any mitigation or follow-up actions needed for an actual urban rail project.

**FIGURE 7.1. Simple Risk Tolerability Matrix for an Urban Rail Project**



Source: Adapted from HM Treasury 2004.

**TABLE 7.3. Example of Risk Identification and Assessment Matrix for an Urban Rail Project: Metro Line 2, Lima, Peru**

RISK	PROBABILITY RATING	IMPACT RATING	RISK CLASSIFICATION	MITIGATION ACTION	FOLLOW-UP INDICATOR
Unexpected negative impacts on cultural findings	2	2	Medium	Cultural heritage evaluation and management plan	Follow-up and risk monitoring report
Lower than expected demand due to lack of integration with other modes	2	3	High	Create a provisional agency with representatives of all levels of government in the metropolitan region	Number of bus lines feeding the project Number of parallel lines eliminated
Delays in land acquisition	2	3	High	Strengthen implementing agency capacity	Project implementation indicators: planned versus actual

Note: Risk classification is calculated by multiplying the probability rating by the impact rating. Impact ratings are 1–2 = low, 3–5 = medium, 6–9 = high.

Although several tools and techniques exist, qualitative risk assessment is still a subjective process based on decision makers' judgment. It is also an intricate and iterative process that needs to handle differences of opinion and imperfect information.

### *Quantitative Assessment*

The objective of a quantitative assessment is to produce an estimate of the expected value of the risk. This is necessary for calculating risk-adjusted costs, which will serve as the basis for determining the upper limit for the project budget, assessing whether the project is affordable, and carrying out other exercises related to project appraisal (for example, value for money [VfM] analysis in a PPP context).

Different methodologies are often used to quantify risks. In general, two risk quantification approaches are commonly used:

1. *Scenario analysis* applies values to discrete scenarios to understand what would happen in each of the scenarios (best, worst, or most likely scenario).
2. *Probabilistic analysis* (such as Monte Carlo simulations) shows the outcome of each event and how likely it is to occur (probability). Such a probabilistic

analysis can adopt a parametric approach—if the risk probability distribution responds to a known distribution, such as normal or triangular (often used for cost overruns)—or a stochastic approach, if the risk probability distribution responds to a Brownian aleatory (random) behavior (for example, interest rates or demand).

### **Risk Mitigation**

Once risks have been identified and assessed, project stakeholders can begin to proactively mitigate these risks. Risk mitigation can take different forms. From the perspective of the procuring authority, for example, the ultimate solution may be to transfer the risk to a third party by allocating the financial consequences of the event through the contract (with the contractor or private partner in a PPP) or selling it to an insurer. Accordingly, the concept of mitigation may include “risk allocation” or “risk treatment”; however, for the purpose of this handbook, we treat these as separate steps in a risk management strategy. Therefore, risk mitigation in this handbook is defined as any measure or initiative that can reduce the likelihood or impact of a risk over a project’s lifetime. As such, risk mitigation is irrespective of who or which part of the project is assuming the financial consequences of the risk.

Several approaches and mechanisms are available for implementing effective risk mitigation strategies and actions, including the following:

- Early mitigation measures
- Proper qualification and selection process
- Proper planning and hiring of a project management oversight consultant (PMOC) to manage risks throughout implementation
- Involvement of other relevant public stakeholders in the consequences of negative events that occur or in the management of or reaction to these consequences

Early mitigation focuses mainly on assessment and research, which includes robust investigations that provide meaningful information about risks (and thus reduce uncertainty), such as geotechnical assessments; traffic, demand, and revenue studies; archeological maps; utility network maps; and assessments of the condition of surrounding buildings (see chapter 11). Early mitigation is closely related to the concept of appraisal and preparation of projects and is independent of who finally assumes the risk according to the risk allocation exercise. Most project failures result from poor preparation. Therefore, early mitigation is critical.

Aside from proper research and assessment, early mitigation also entails securing agreements with other stakeholders—such as levels and units of government different from the project-implementing agency and community associations—to ensure that they accept the project or provide insights in advance. Another example of early mitigation is developing communication campaigns with the goal of increasing public acceptance of the project, especially among opposition groups. Finally, developing a risk register and introducing a transfer strategy is also considered an early mitigation measure. This subject is discussed in detail in the next section.

In many cases, urban rail projects administered by a project-implementing agency running several bidding processes run into complications and delays. Some of these problems are due to poor performance of contractors in critical aspects, and others are due to inefficiencies in the administration of the project. In theory, these cost and delay risks could be potentially minimized if the project were procured using a single, turnkey contract in which the contractor is responsible for all components.<sup>3</sup> However, in practice, the project-implementing agency may still have a critical role in approving the as-built designs and a supervisory role in guaranteeing that construction standards are being respected. The turnkey contract must be designed in a way that ensures proper integration between infrastructure and systems and supports the operational sustainability of the system in the long term.

While only one example, this helps illustrate how critical it is to consider the choice of project delivery models and procurement strategy for the project as a form of risk mitigation. In particular, project-implementing agencies should set up proper qualification and selection processes for contractors and consider hiring a project management oversight consultant to manage retained risks and monitor or supervise the management of transferred risks. Chapter 8 of this handbook provides additional discussion of the risk management implications of different project delivery models, including those based on turnkey contracts.

### **Risk Allocation or Transfer**

Risk allocation is one of the most important exercises in the process of preparing an urban rail project (World Bank 2014). When dealing with a multimillion-dollar (often multibillion-dollar) complex project, it is extremely important for the project-implementing agency to allocate risks effectively and efficiently among project stakeholders. This is an essential step for increasing the likelihood of a project's success and decreasing the possibility of losses.

Project-implementing agencies should consider making an informed decision on which stakeholder will ultimately be responsible for avoiding or minimizing any given risk and internalizing the financial impact associated with its possible occurrence. In this context, one of the most relevant principles in risk management emerges: every risk must be allocated to the party in the best position to manage it. This means the party that is best able both to avoid risks when possible and to manage them when they occur. It also means that the risk is borne by the party that is able to bear it at the lowest cost. The lowest cost refers not only to the ability of a stakeholder to reduce the financial impact of the risk that materializes, but also to assume the risk at the smallest risk premium. The decision to allocate a risk to a given party is based on this party's technical expertise, as well as financial capacity (Stambrook 2005).

The promotion of effective risk allocation in urban rail projects is essentially based on subjective expert judgment. Nonetheless, it is important to define some criteria—including stakeholders' technical expertise, financial capacity, and previous experience with similar projects—and to account for the fact that parties use disparities in information to their own advantage. According to Ng and Loosemore (2007), risks should only be allocated to a stakeholder who

- Has been made fully aware of the risks it is taking,
- Has the greater capacity (expertise and authority) to manage the risk effectively and efficiently at the lowest risk premium,
- Has the capability and resources to cope with the risk occurring,
- Has the necessary appetite to assume the risk, and
- Has been given the chance to charge an appropriate premium for taking the risk.

Transferring risks comes at a price. Where a contractor is aware that it will be required to bear a given type of risk, professional fees and tender prices will include a premium to reflect the expected value of this risk, a contingency sum in most cases, and a fee for the risk-bearing service. The client may not be aware of the size of this premium, which may represent a significant portion of the bid price (Ward, Chapman, and Curtis 1991).

Furthermore, effective risk transfer from the public to the private sector requires more than a contractual arrangement establishing that a certain risk is assigned to a private party. Knowledge of a risk—its likelihood and potential impact on the project—is essential to allow a reasonable estimation of the risk

premium with a view to achieving an adequate contractual balance between risks and rewards.

An appropriate security package needs to be included in each contract to ensure that any risks transferred to a private contractor are appropriately backed up with the necessary guarantees. This need increases the importance of preparatory studies, such as preliminary geological tests, demand analyses, and others. Such investments in analyses are reflected in lower project uncertainties and the need to pay lower premiums to transfer remaining risks. In several recent projects, poor engineering preparation and inadequate geotechnical surveys led to surprises that delayed the projects and ultimately resulted in higher costs.

### **Treatment of Retained Risks**

Once risks are allocated, each party must treat their retained risks. For the purpose of this handbook, treatment of retained risks refers to the management of risks that have been retained by the project owner or project-implementing agency because it was not efficient to transfer them to the private partner or contractor. In such cases, the project-implementing agency has two options: self-insure the risk or buy commercial insurance. When self-insuring the risk, the project-implementing agency assumes the consequences and proactively creates a contingency fund or relies on future budget availability to cover any costs should the risk materialize. Alternatively, the project owner can obtain insurance against the specific risk or even use a hedge instrument for some financial or economic risks (for example, an interest rate swap for a variable interest loan). These activities provide an alternative to relying on reactive management when a risk materializes and reduce the potential for contingent liabilities.

### **Risk Monitoring**

Risks identified in urban rail projects are characterized by a dynamic context marked by constant change. After risks have been identified, assessed, allocated, and treated, risk monitoring is the next step in the risk management process. The main purpose is to regularly update the types of risks, their likelihood of occurring, and the magnitude of their consequences and to adjust the management framework accordingly as the project advances. The risk monitoring process should not only monitor the likelihood and consequences of a risk occurring, but also the “effectiveness and adequacy of existing controls, risk treatment plans, and the process for managing their implementation” (ISO 2009).

To manage the risks of urban rail projects effectively, it is important to monitor every single risk using the register, being aware that the likelihood and

impact of these risks may change as the project progresses. The project-implementing agency should consider monitoring not only the risks that have been retained, but also the risks that have been transferred to the private sector or other partners. This monitoring is an important feature of the supervision reports required by the World Bank in ongoing urban rail projects.

### **Key Potential Risks in Urban Rail Projects**

Although there are many ways to categorize risks of urban rail projects, a convenient way to identify and organize them is to associate them with the step of project development in which they are expected to occur. This section presents the most relevant potential risks involved in the development and implementation of urban rail projects using the following risk categories:

- Multistep risks
- Precontractual risks
- Site-related risks
- Design, construction, and commissioning-related risks
- Operations-related risks (see figure 7.2)

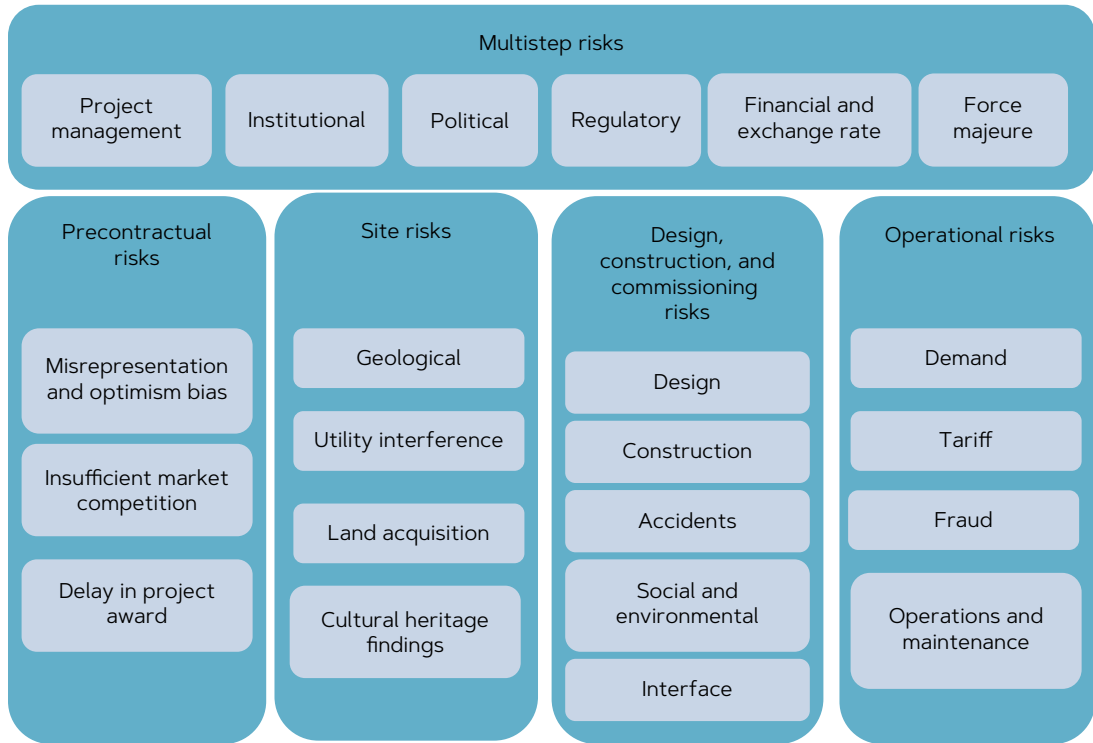
#### **Multistep Risks**

Important risks can arise along the different steps of urban rail project development. In many instances, these risks do not affect or may be ascribed to a specific project development step and hence may require permanent attention and appropriate management. These risks include lack of proper project management as well as institutional, political, regulatory, force majeure, and financial and exchange rate risks.

#### *Project Management Risks*

Understanding the potential project management risks during any given step of the project and having the essential tools and qualified personnel to manage those risks are essential for successful project development. Project-implementing agencies can mitigate these risks by engaging a qualified PMOC that provides strategic management services above and beyond the services provided by a contract supervision consultant and by establishing adequate control of the project's scope, budget, and schedule throughout implementation (see chapter 4).



**FIGURE 7.2. Risk Categorization for Urban Rail Projects**

### *Institutional Risks*

Risks can be generated or exacerbated by ineffective or fragmented institutional arrangements that are not adequate for the development and implementation of a large-scale project. No matter how the project is delivered or the level of private participation, a strong project-implementing agency with the capacity to plan, procure, and monitor project implementation and operations and a mandate that goes beyond the management of civil works is required. Ideally, project-implementing agencies should be able to manage aspects that are outside the scope of the project, but critical to its success (such as physical, operational, and fare integration with other modes, land use changes, and urban development).

Institutional capacity and coordination become even more critical in the context of projects that involve multiple levels of government (national, provincial or state, and municipal). When project-implementing agencies do not have a wider mandate and multiple levels of government are involved, the existence of an

entity responsible for coordinating the various service providers and for planning and regulating transport for the metropolitan region becomes a critical factor for success (see chapter 12). The Regional Transport Consortium of Madrid, which brings together more than 170 municipalities, regional and national governments, trade unions, consumers, and other relevant stakeholders, is a good example of a coordination authority with power over factors that are critical to the success of an urban rail project that is part of a multimodal, hierarchically integrated transport system.

### *Political Risks*

Political risks are the risks associated with a government action (or inaction) that can negatively affect implementation of the project. Although political events may also affect the implementation of projects developed under public procurement, this type of risk is most relevant for projects developed via a PPP, where the private partner is exposed to government actions that can impede its operations or affect its profits, including unfair contract termination, payment default, failure to honor contractual obligations, expropriation or confiscation of assets, and limitations on foreign exchange convertibility or transferability. An example of failure to honor a contractual obligation is when a noncompeting clause is included in an operation contract for an urban rail line, but the government authorizes another transport operator to provide a competing service—for example, bus rapid transit along the project route—that erodes rail ridership. Another example is where the government fails to implement feeder bus services that are part of the agreed transportation plan and are essential to build rail ridership to targeted levels.

The risk of adverse political decisions increases with changes in government. Given the fact that urban rail projects span multiple administrations, government authorities and project-implementing agencies need to ensure broad support from different political parties and to enshrine government commitments in long-term budgets or through ratification of project agreements by the relevant legislatures.

Multilateral development banks often assume an important role in urban rail projects that goes beyond financing. A private partner may have valid reasons for doubting the ability of the public partner, particularly one implementing an urban rail project for the first time, to live up to its contractual obligations. The World Bank Group can provide guarantees to cover specified risks arising from nonperformance of government obligations or certain political events. During project preparation, the project-implementing agency should consider assessing the potential availability of these instruments and other contract credit enhancements (see chapter 10). To the extent that certain projects are financed

commercially, the implementing agencies can also improve the prospects of reaching financial close by including appropriate termination clauses in the PPP agreement that protect lenders' rights in case of political risks and make the project more bankable (see chapter 10).

Political risk overlaps country risk to some extent, which expands the definition to encompass other factors that may, in some instances, also be the result of political decisions. These factors include adverse economic downturns, unfavorable business climate, and security-related events, such as civil disturbances and war (also considered force majeure, which is discussed later).

### *Regulatory Risks*

Regulatory risks originate in changes in the legal and regulatory frameworks on which the project was originally structured. Such changes may negatively affect the project's implementation. One example of such regulatory changes is a modification in the form and periodicity of fare or tariff adjustments that prevents operators from raising fares to cover costs. Another example may involve the imposition of new technical or safety standards that slow down operations or increase their cost. Governments need to be aware of the private sector's aversion to regulatory (as well as political) risks and provide stable legal frameworks. It is good practice for the public sector to retain these risks and for contracts to include protections to shield private partners from these changes.

### *Force Majeure Risks*

Force majeure risks (or "acts of god") are risks associated with the occurrence of events that no project stakeholder can avoid or control. Examples include earthquakes, storms, floods, external accidents (for example, failure of other infrastructure that affects the project), and other natural and man-made events. In a PPP context, potential mitigation measures include contractually defining obligations for each project stakeholder in case such a risk materializes. This measure prevents legal battles that could translate into higher costs and delays. Another mitigation measure is to involve insurance companies in the project. For example, after Superstorm Sandy hit the U.S. coastal cities in New York and New Jersey in 2012, New York's Metropolitan Transportation Authority acquired US\$200 million of insurance protection for future storm-related events (see chapter 17).

### *Financial and Exchange Rate Risks*

Financial risk refers to the ability to obtain adequate or expected financing, or to fluctuations in the cost of financing (interest rate) during the life of the project. Exchange rate risk or currency risk refers to the risk of variations in the currency

exchange rate. Such variations may affect the project in two ways: (1) by changing the final costs of materials or price of equipment or (2) by changing the interest rate in real terms—that is, the real cost of financing in local currency terms, which is affected not only by the variation in the original interest rate (for example, interest rate in U.S. dollars) but also by the variation in the currency exchange rate.

From the private investment or financing perspective of a partner in a PPP, the most common problem in many low- and middle-income economies is that fares are in local currency and the debt assumed by the private sector concessionaire is usually in foreign currency (in many cases, U.S. dollars or euros). When the local financial market is poorly developed for significant long-term financing in the local currency, to make a project bankable (in a currency that is not likely to depreciate suddenly), the project contract has to include mitigation clauses for such risk. For example, the contract can include a provision for sharing the risk of devaluation, allowing the private partner to receive compensation if devaluation is above certain thresholds. The PPP of São Paulo Line 4 has a foreign exchange mitigation clause. Chapter 9 includes a more detailed discussion of currency risk and associated mitigation or derisking options in PPPs.

### **Precontractual Risks**

During the period of project selection, preparation, and tender (for the purpose of this chapter, collectively referred to as the precontractual stage), various risks and threats may materialize and lead to project failure. Such failure may have different manifestations, including cancellation of the project before tender or before signing of the contract, failure to produce competitive bidding, early termination of an awarded contract, or overall project performance below expectations. The causes may include improper communication, lack of technical capacity to manage the project development process, errors and bias in appraisal, and the intrinsic complexity and natural challenges related to the project specifics. Some of the most recurring risks at this stage involve misrepresentation and optimism bias, insufficient market competition, and delay in contract award (either in a PPP or in a traditional project delivery model). The following subsections highlight the cause of some of these risks and provide insights on practical mitigation measures.

#### ***Misrepresentation and Optimism Bias Risk***

It is typical for persons developing a project to be overly optimistic. They tend to judge future uncertain events in more positive ways and tend to underreport levels and magnitudes of project uncertainty. At the same time, political actors involved in the process may strategically misrepresent the project, overestimating its benefits or underestimating its costs to increase the probability of project

approval and funding (Flyvbjerg 2006). Planners and implementers must be careful to avoid these traps.

Given these trends and the fact that urban rail and other transport megaprojects are often used to influence political processes, feasibility studies using high-quality data and analytical techniques applied in an impartial manner are needed to evaluate the proposed project (see chapter 3). The quality of these feasibility studies is dependent on the time and resources dedicated to them. An improper appraisal of a project can result in an undue investment decision or the tendering of projects that are not financially and economically viable.

#### *Insufficient Market Competition Risk*

Procurement procedures that foster competition among multiple bidders can help to drive down the total cost of a project. There is risk of insufficient competition in choosing procurement procedures that have not been evaluated properly with the market or that are not suitable for the particular project. Careful market analysis and consultation are needed before deciding whether the proposed procurement procedures (for example, unit costs or quantities versus lump-sum turnkey, size of individual contract lots, and others) are appropriate and best suited for the project (see chapter 8). For example, contractors who were used to unit costs or quantities resisted the introduction of turnkey procedures in São Paulo Line 4, leading to significant cost escalation.

Designing proper payment milestones in a turnkey bid to ensure that the contractor's cash flow remains positive is crucial for the success of the project and requires careful design by the owner. The type of bidding documents used (for example, documents of the International Federation of Consulting Engineers<sup>4</sup> or national procurement documents) may also affect the level of bidder participation and the bid prices offered. Including procurement specialists in early steps of project development to assess the market and advise on the appropriate procurement strategy can help to avoid delays and additional risks down the line.

#### *Interrupted, Ineffective, or Failed Bidding Process*

The number of large, capable construction firms and rolling stock suppliers active in the market even at a global scale is fairly limited; depending on the size and location of the project, only a handful of technically and financially qualified companies may be available or interested in participating in a tender. This may result in limited competition or even create the risk that no offer will be made. Such risks are present in a traditional procurement process in which the government procures services or goods in the market, but are even greater for projects tendered under a vertically integrated PPP, in which private sector bidders

must have a much greater risk appetite over a longer (operating) period. In many cases, the lack of sufficient bids for an urban rail project can result in the acceptance of low-quality proposals. In addition, project-implementing agencies are exposed to the risk of irresponsible bids from companies that propose terms that they know they may not be able to honor in order to win lowest-bid contracts. Additional risks may be posed by suboptimal bids from companies that do not have the required technical and financial capacity and experience or by budgets or terms that do not meet the requirements. Inadequate bidder participation or lack of responsive bids may require rebidding, delaying project implementation.

Numerous circumstances may affect the pace of a bidding process, making it lengthier and hence costlier than planned. Government oversight bodies may question projects, request clarifications, or even suspend bidding processes. Multilateral development banks may be unable to finance projects that have not been procured in line with their specific procurement requirements and guidelines. Also, potential bidders may request clarifications or take legal steps to suspend or delay the tender. Therefore, attention has to be given to factors ranging from formalities in the publication of bidding documents to preparation of public consultations. Potential mitigation actions for delays in the bidding process and potential cancellation include (1) ensuring an adequate project structure with sufficient time for preparation and consultation with stakeholders (including financiers) and (2) a comprehensive market research process featuring sufficient dialogue with the private sector.

### **Site Risks**

For urban rail projects, site risks are mainly associated with the availability and quality of the land where the infrastructure will be constructed. Site risks also include the possibility of interference with existing utility networks (see chapter 11) as well as the presence of hazardous materials, contamination, and archeological or paleontological findings (see chapters 14 and 15). Because urban rail projects are linear and their construction works are staged, the materialization of site risks can generate significant delays and cost escalation (World Bank 2014).

### *Land Acquisition Risk*

Land acquisition risk refers to the possibility of delays in acquiring land for the project—including permanent land needed for right-of-way, stations, and support facilities as well as land needed temporarily for staging construction. This risk is typically retained by the public sector, although the land acquisition

process can be delegated to a private partner or contractor. In their bids, private firms usually stipulate acquisition of the necessary land as a condition for contract effectiveness. In the case of a PPP arrangement, this risk can be mitigated by ensuring that the contract is clear on when the project-implementing agency needs to make what land available. A best practice in early risk mitigation is to acquire all land before the start of the project, as the government of Bogotá intends to do for the city's first metro line. Another mitigation measure is to minimize land purchases by locating station entrances and exits on existing public lands such as parks, as was done in the Quito Metro Line 1 project.

### *Geological Risks*

Unforeseen geological conditions encountered during civil works require project-implementing agencies or construction firms to take measures that may increase the scope of the work and the cost of the project. These geological conditions include soil instability that results from man-made or non-man-made soil alterations and issues such as earthquakes and natural impacts. The first step in managing geological risks is to determine the nature and potential impact of a given risk. Normally, geological studies are carried out well before the start of construction, by the public sector, by private parties, or by both (see chapter 11).

Despite geological investigations, it is not unusual for unforeseen issues to materialize, causing cost overruns and delays. In the case of the metro of Porto, Portugal, there were multiple incidents of tunnel collapse due to deep weathering of granite and resulting soil heterogeneity. These conditions were not anticipated due to insufficient geological characterization and deficient design. The design-build-operate-transfer contract between Porto Metro and the private contractor, Normetro, allocated all geological risk to the contractor under the incorrect assumption that soil conditions were well known. The contractor demanded financial compensation from the public agency in a court of arbitration. The court confirmed a compensation of approximately €94 million or 11 percent of the initial contract value.

Although it is infeasible to conduct an exhaustive investigation to rule out all uncertainty, it is important to define a baseline of geotechnical conditions (with specific and clear conclusions) that can be used to set up a risk-sharing mechanism (see box 7.3). Budgets at the outset of the project have to allocate the resources necessary to undertake what experts consider to be an acceptable geotechnical, geophysical, and hydrological report. Money should not be saved by skimping on the scope of these surveys, because the cost of inadequate surveying will often lead to much higher project development costs.

In addition to the geotechnical baseline report (GBR), other geological risk mitigation actions include the development of detailed underground soil surveys

**BOX 7.3.****Managing Geological Risks through a Geotechnical Baseline Report**

A widely accepted practice in the tunneling industry is to prepare a geotechnical baseline report (GBR), which contractually defines anticipated underground conditions. The GBR involves a wider scope than the traditional geotechnical study. It includes soil characterization based on existing geotechnical reports and defines a range of actions for the contractor, including key limitations and considerations to be taken into account in the final design. A GBR mitigates risk by reducing uncertainty for the contractor and lowering the probability of cost overruns (in the absence of force majeure events).

A GBR involves choosing reference cost parameters and linking them to soil characteristics, establishing a range of expected values

for the parameters, and accounting for the influence of the chosen construction methods and sequencing on those parameters. The GBR can then be used to establish a baseline cost and define how the risks of cost deviation will be allocated and shared between the contractor and the public sector.

In the concession contract for the Red Line of the Tel Aviv Metropolitan Transit System, a GBR served as reference for the sharing of geotechnical risk. At each construction milestone, the GBR conditions were compared with actual conditions (as reported by the concessionaire). Differences gave rise to payments in favor of the project-implementing agency or the concessionaire, and disputes could be submitted to a panel for resolution.

based on geological area maps. These surveys collect data as often as every 30–40 meters (for an underground system), identify terrain conditions, and investigate areas that may require more attention and site-specific studies.

*Utility Interference Risks*

Although project design and alignment selection normally consider possible physical conflict with public utility networks (pipelines and cables), undesired interference often occurs in urban rail projects. In such cases, unplanned utility network relocation or protection work may be required, resulting in higher project costs and delays. Old utility networks are often poorly mapped and, despite good surveys to identify existing utilities, surprises arise.

Important investments in research and good data on utility mapping along with careful coordination between the government or regulator, utility companies, and the project-implementing agencies will reduce risks and costs. It is very important to have good utility information before tendering the project. Having more information allows the development of better mitigation actions (by both the private and public sectors). To mitigate risk effectively, it is also important for the project-implementing agency to have good channels of communication with utility companies, who may see the project as an opportunity to finance network



rerouting. Furthermore, engineering studies are needed to locate telecommunications, gas, and water lines (and other utility services). A specific utility service identification study is needed to minimize project interference (see also chapter 11).

### *Risks of Unexpected Cultural Heritage Findings*

Unexpected cultural heritage (archaeological, paleontological, and historical building) discoveries can cause construction delays and result in higher costs when project development plans and construction schedules have to be reevaluated as a result. Specifically, these findings may require a change in project alignment, additional works to preserve or relocate the findings, or the stoppage of works to accommodate the appropriate examination and documentation of findings. Capable professionals should evaluate the presence of findings in the project area and assess related excavation risks. The risk of cultural heritage findings in densely populated cities with long and rich histories or in areas designated as World Heritage Sites by the United Nations Educational, Scientific, and Cultural Organization is relatively higher.

If professional services deem that there is a significant risk in the area, project-implementing agencies should commission archaeological maps or assessments, including digging tests as part of project preparation activities. These maps can help to determine the areas where excavations should be avoided or where they should be undertaken at a greater depth to avoid disrupting heritage sites closer to the surface. This risk can be managed and even partially shared with private contractors and concessionaires if a solid risk baseline exists. Chapter 14 discusses best practices in the management of cultural heritage and other social impacts of urban rail projects.

## **Design, Construction, and Commissioning Risks**

Starting at the design step, project-implementation agencies and project managers should consider identifying all risks that could materialize during design, construction, and project commissioning. Assessing these risks in detail is essential for allocating them properly.

### *Design Risks*

Design risks can result in cost overruns and delays in civil works. Flaws in project designs or modifications made to the project after construction has started (either by the public agency or by the private partner) are examples of this type of risk. To satisfy contractual requirements or laws, whichever party takes responsibility for the design generally assumes the risk of errors in design that could lead to project failure. The risk of errors or changes in design, latent defects, and asset life expectancy have to be specified and responsibilities

allocated. If the grantor requires variations, it typically bears that risk and its potential costs (Mandri-Perrott and Menzies 2010). One way to mitigate some of these risks is to ensure that engineering designs include field tests and indicate detailed component specifications. Another way is to transfer the design risk to the contractor or concessionaire, following its review of the adequacy of the owner's design.

Another approach is to have an independent third party review the project design for constructability and operability and to perform a value engineering (VE), analysis to improve the project before tendering (see chapter 6). This third-party review is rarely carried out due to lack of funds, but it is strongly recommended. Such project optimizations would be carried out using a life-cycle cost framework; otherwise, design optimizations that save capital costs up-front may increase the future operation and maintenance (O&M) costs of the project. The project-implementing agency, with the advice of external experts and a "shadow operator," will need to assess such trade-offs carefully.

### *Construction Risks*

Construction risks refer to the possibility that construction costs or time exceed original projections. This risk is caused by events that require additional construction inputs (increased materials and execution time) or that increase the prices of these inputs. These events include unsuitable construction methods, faulty planning, ineffective project and schedule management, and underperformance or negligence by the builder. The careful selection of an experienced builder is the most effective way to mitigate construction risks.

Construction risk is generally transferred to a builder—either a private contractor in traditional procurement or a private partner or concessionaire and its subcontractors in a PPP. The efficiency and effectiveness of this risk transfer depend on many factors, including the financial and technical capacity of the ultimate bearer of the risk, clear delineation of responsibilities in the contract, and a strong security package for the obligations assumed by contractors and subcontractors. This security package may take the form of unconditional bank guarantees, performance bonds, and cash retention. For PPPs, the security package is central to any analysis of risk allocation. In this case, even if the party with ultimate responsibility is the private partner or concessionaire, the security provided to the granting authority under the PPP agreement has to be backed by the conditions and security established in the contracts between the private partner and its contractors and subcontractors, and the suitability of these parties has to be ensured.

In addition to these factors, the traffic diversions and street closures required during construction pose additional risks and delays. Traffic management should

be planned carefully during construction. This responsibility is often transferred to the contractor, with the public sector retaining oversight and coordination responsibilities (see chapter 11). For example, the concessionaire for Lima Metro Line 2 is contractually responsible for developing specific traffic management plans that have been revised and approved by the project-implementing agency.

Construction delays and cost overruns can also result from the materialization of other design and site risks described in this chapter (for example, land acquisition, utility interference, geotechnical or cultural heritage findings, and other social and environmental impacts). Given their high incidence and impact on urban rail projects (particularly those built underground), these other risks should be evaluated independently when identifying and assessing risks in a risk register.

### *Risk of Accidents*

Accidents during construction may affect the development of project infrastructure, personnel, or even third parties, causing delays and raising costs. The risk of accidents can be mitigated by requiring contractors to adopt good environment, health, and safety practices, including good construction practices, the use of safety equipment, and proper evacuation plans that are tested frequently (see chapter 15). Commonly used actions to mitigate the risk of accidents include implementation of a rigorous supervision system and the application of safety measures; development and implementation of an alert system; and rigorous government regulation of environmental, health, and safety issues.

### *Social and Environmental Risks*

Social and environmental risks can affect project delivery and result in additional costs and delays and even lead to project failure. Some of the most common risk events include delays in obtaining environmental licenses; additional costs required to manage unforeseen environmental and social impacts or to deal with identified impacts that are not properly managed; and additional costs related to compensation for noncompliance with environmental and social regulations.

Environmental and social impacts include noise, air, and water pollution in the area surrounding project sites, physical and economic displacement of populations, cultural heritage impacts, and other short- and long-term impacts on workers and local communities. The most effective way to mitigate these risks is to invest in environmental and social impact assessments and management plans and to dedicate sufficient resources to the supervision and execution of those plans (see chapters 14 and 15). Environmental and social risk management activities are fundamental to ensure project success, and project-implementing

agencies should not underestimate their importance or only consider them as a requirement to obtain permits.

### *Interface Risks*

Given the complexity of urban rail projects, interface issues are a prime source of project risk. Urban rail projects involve multiple steps of development (for example, design, construction, and O&M) and components or subprojects (for example, civil works, equipment, systems, and rolling stock) (see chapter 5). These steps and components need to interface seamlessly for the project to be successful and sometimes have to be delivered concurrently because of physical and operating interdependencies. Interface risks refer to problems resulting from the incompatibility among various project development steps or components delivered or supervised by different entities (for example, engineering firms, contractors, and public agencies). The more components and entities involved, the greater the likelihood that interface issues will occur. Interface risks originate in different situations that include improper planning of integration between the different steps or components; changes in contracts for the delivery of one step or component that have implications for other contracts that implementing agencies fail to recognize and address; and unclear delineation of integration responsibilities in contracts among multiple entities.

There are potential interface risks within the same step of project development, across steps, and among components. For instance, signaling systems may be designed to provide a specific maximum service capacity, but if track geometry does not also support such high speeds and frequencies of service, the system may face long-term operating constraints (see chapter 5). Finally, if project components are supervised by different agencies or sourced from different contractors or suppliers, there is a risk that the various components will not work well together. For instance, the entity in charge of operations may procure rail cars that are not compatible with the rail tracks or with the platforms at stations (see box 7.4).

Another facet of interface risk relates to the potential difficulties arising from the expansion or upgrade of existing urban rail systems. In such projects, project operation and construction need to coexist, and special arrangements are needed to coordinate these activities. Deficient integration of new construction and ongoing operation may lead to losses and delays on both fronts.

Project-implementing agencies have to identify all forms of interface risks and implement mitigation strategies, including the transfer of some of these risks to third parties. The project-implementing agency may choose to

**BOX 7.4.****Interface Problems: Regional Express Rail Network, France**

The operator of the Regional Express Rail network in France—the National Society of French Railways (SNCF)—ordered more than 300 trains (2,000 cars in total) designed to be wider than existing trains in order to respond to larger demand and user requests for greater comfort (Hurst 2014) (see image B7.4.1). Once train deliveries started, SNCF discovered that the trains were too wide to fit into many platforms (1,300 out of the 8,700 in the network) or to allow one train to pass another on adjacent lines in certain locations. Once the mistake was discovered, it was too late to modify the specifications of the trains, resulting in more than €50 million in additional costs to modify platforms at one out of six stations across the French rail network, rail tracks, and related equipment to accommodate the new trains (Hurst 2014; Samuel 2014).

The incompatibility between the components originated in lack of coordination and miscommunication between the entities in charge of infrastructure and rolling stock. SNCF asked the owner of the rail infrastructure, French Rail Network Company—Réseau Ferré de France (RFF)—to supply the specifications for platform dimensions. RFF provided the standard dimensions for stations built after the mid-1980s, but did not consider that many stations in the network were built before the standard came into effect. Older stations had narrower dimensions that could only serve smaller trains. SNCF did not verify the dimensions and ordered the trains based on the new standard provided.

Although rail infrastructure and operations had previously been under SNCF, in 1997

SNCF's infrastructure assets were transferred to the newly created RFF, which was placed in charge of maintaining the rail network and stations. This separation between infrastructure and operations created an interface risk that, without appropriate communications channels to mitigate the risk, culminated in the need for expensive modifications throughout the rail network.

**IMAGE B7.4.1. Bombardier B82500 Rolling Stock Operated by SNCF on Its Regional Express Service (TER)**

Source: Renaud Chodkowski via Flickr Commons.

contract out the development of all project components to a single party under an integrated turnkey contract. In this case, the winning bidder may then decide to do a part of this work directly (for example, civil works) and to subcontract the remaining pieces (for example, supply and installation of electromechanical systems and manufacture of rolling stock), retaining the responsibility for coordinating the various inputs. Similarly, in a PPP context, the agency may transfer this risk by establishing a vertically integrated contract requiring the private partner to be responsible for all project functions and components and their integration (see chapter 9). However, the fact that interface risk is transferred to another party does not make that risk disappear. The project-implementing agency may have a contract with a developer that, in turn, has multiple subcontractors that do not interact with each other. Therefore, contracts should specify clearly that these subcontractors have to work together and jointly test interfaces among components. Where possible, the agency should seek integrated contracts or agreements that specifically include interface management as part of the obligations of the contractor or private partner.

In projects where the project-implementing agency contracts out project components separately, interface risk can be mitigated by hiring a project integration specialist (usually a consultant) to be responsible for the smooth integration of civil works, systems, and rolling stock. The project integrator should be in place from the beginning of the project.

Regardless of the procurement model chosen, the project-implementing agency should have an interface manager who oversees the integration process and plans for and manages impacts of changes in one component on others. The interface manager relies on tools, such as an interface matrix, to track the linkages between project components (see table 7.4).

### **Operational Risks**

Operational risks are those that materialize after the commencement of urban rail operations. This section discusses four critical types of operational risks: demand risk, tariff risk, risk of fraud, and O&M risk.<sup>5</sup> Although operational risks only materialize after construction, it is important to identify and manage them from the very beginning of the project and to involve the actual project operator (public or private) or a shadow operator early. Operator inputs are required before the commencement of operations to establish the requirements for testing and commissioning, define O&M parameters, prevent interface issues among components, and ensure that planning, design, and construction all support the long-term operations of the system.

**TABLE 7.4.** Example of Part of an Interface Matrix between Components of Structures and Signaling Contracts on the Gouda-Alphen Section of the Rijn Gouwe Line: The Netherlands

MAJOR COMPONENTS OF STRUCTURES CONTRACT	MAJOR COMPONENTS OF SIGNALS CONTRACT														
	SECURITY			CONTROL			CROSSINGS			UNDERGROUND INFRASTRUCTURE					
	SIGNAL EQUIPMENT ROOM	SIGNALS	RELAY BOXES	SIGNS AND BEACONS	CONNECTION TO TRAFFIC CONTROL	ATC SYSTEM	SWITCH CONNECTION BOXES	PEDESTRIAN CROSSINGS	LEVEL CROSSING (GOUDA)	AHB	CABLE AND PIPE WORKS	TELECOMMUNICATIONS	CABLING FOR 3 VOLT POWER SUPPLY	1,500 VOLT POWER SUPPLY	FIBER-OPTIC CABLE
Guideway															
Track			■								■	■	■	■	■
Required groundwork															
Mound for relay boxes			■												
Shielding															
Sleepers															
Structures (bridges, tunnels)											■	■	■	■	■
Rail-carrying structure											■	■	■	■	■
Nonrail-carrying structures															
Guidance systems															
Railway								■	■	■					
Point switches							■								
Switch-heating system															
Energy supply															
Derailment guidance															
Flooring overways															
Track provisions (such as signs)															
AHB level crossing										■					
Pedestrian AHB										■					

Source: Adapted from Couwenberg 2015.

Note: Different colors can be used in the cells to indicate the magnitude or level of the interaction among the different components. AHB = automatic half-barrier; ATC = automatic train control.

### *Demand Risk*

Demand risk relates to the possibility that actual ridership of the urban rail system will be different from what was originally forecasted. In many cases, urban rail projects have begun operations with a level of demand lower than originally estimated (Flyvbjerg 2007). Demand risk also arises when ridership exceeds projections and the urban rail system is unable to absorb it. This is the case of Line 1 of the Lima Metro, where the operator had to regulate access to stations due to insufficient capacity and service levels. This resulted in a loss of potential revenue and an opportunity cost to society from denied trips.

Demand estimates are complex and subject to error and optimism bias. They should be carried out using the best available data and analytical methods, reviewed by impartial third parties, and, if possible, benchmarked against comparable systems in the country or region. Situations that are impossible to anticipate at the time of the forecast can render even the most accurate forecasts erroneous, so uncertainty analysis should accompany any demand projections (see chapter 3).

Even if forecasts are robust and an adequate level of initial demand has been established, ridership is volatile and may be affected over time by changes in economic activity and demographics. Various actions or inactions of the project-implementing agency or relevant government—such as integration of the project with the other transport modes that make up the urban transport system, service scheduling, fare structures, and land use policy—also impact ridership levels (Siemiatycki and Friedman 2012). Therefore, project design and supporting policy interventions should aim to clamp down on the causes of demand shortfalls by incorporating modal integration, limiting the development of competing systems, and avoiding unnecessary or unsound changes in tariffs.

Deficient integration with other transport modes is a common reason why demand falls below expectations, as was the case initially with the Bangkok Mass Transit System (BTS) project. Integration may not happen due to the lobby of existing bus operators or poor policy coordination with other jurisdictions in charge of other transport modes. Therefore, demand risk can be linked closely with other forms of institutional and political risk. Lower-than-projected ridership may also be the result of tariff levels that are unaffordable, particularly for low-income segments of the population (see chapter 2). Willingness to pay across different sociodemographic groups should be studied properly at the project feasibility stage and revised periodically during system operation.

Because many broader metropolitan transport governance and development decisions impact urban rail ridership more than small service changes, the ability of the private operator to take on demand risk is generally limited by its lower capacity to influence ridership. However, the sharing of demand risk with a private



partner (even if a small fraction) is possible and may be desirable. In PPP projects, demand risk can be managed to some extent by including contractual conditions that link part of the private partner's remuneration to the system's ridership, providing an incentive for the operator to maximize demand. Some PPP projects incorporate demand-risk-sharing mechanisms that not only protect the private partner and financiers from drops in demand below projections but also provide incentives for the private partner to increase ridership (see box 7.5).

### *Tariff Risk*

An urban rail project's financial plan (when operated by a public entity) may be negatively affected by the setting of initial fares or changes in policies related to the determination of fare levels. When a project is developed in a PPP context in which the private operator retains some revenue risk (or related demand risk), tariff changes can be harmful for the project's economic sustainability.

#### **BOX 7.5.**

### **Managing Demand Risk in a PPP Context: São Paulo, Brazil Line 4 and Vancouver, Canada Line**

#### **Metro Line 4: São Paulo, Brazil**

The first phase of the São Paulo Metro Line 4 was finished in 2010 and featured 8.9 kilometers of new rail infrastructure. Under the terms of the public-private partnership (PPP), the private partner has the right to operate the line for a period of 30 years and is entitled to receive revenues from fares, retail, and advertising as well as payments from the government of the state of São Paulo.

It was projected that, by the time the first phase was finished, base-case ridership would be above 700,000 passengers per day. Given that the private operator's revenue was highly dependent on this level of ridership, the private partner and financier required an effective risk mitigation mechanism. The contract established ridership bands built around the

projected base-case demand. If demand falls below the base-case band, the government compensates the private partner. If demand exceeds the base-case band, the government receives a share of the extra profits. The three demand bands were as follows:

1. 90–110 percent of base-case demand: no compensation is required.
2. 60–140 percent of base-case demand: the government compensates the private partner if demand is below the base case, and the government and private partner share the revenues if demand is above the base case.
3. Less than 40 percent and greater than 140 percent deviation from base-case demand: the contract terms are renegotiated.

*(box continues next page)*

**BOX 7.5.****Managing Demand Risk in a PPP Context: São Paulo, Brazil Line 4 and Vancouver, Canada Line** *(Continued)***Canada Line: Vancouver, Canada**

When allocating risks for the Canada Line's concession agreement, the project-implementing agency decided that the regional transportation authority (TransLink) would be best suited to face and manage the demand and revenue risks, given the impacts of decisions by the metropolitan transport authority on system ridership. This meant that TransLink would manage risks and absorb costs resulting from planning decisions that could potentially affect system demand or efficiency. It also meant that TransLink would receive all fare revenue and provide set payments to the concessionaire. To align some portion of the concessionaire's interests with TransLink's ridership-related goals, Canada Line's contract tied 10 percent of the concessionaire's remuneration to the volume of customers. The calculation of concessionaire remuneration involves a base ridership estimate (excluding airport-only ridership), an agreed base-volume payment, and an agreed shadow (or estimated) fare per paying customer.

This scheme has three possible payment scenarios:

- If ridership equals forecasts, the concessionaire receives the base-volume payment.
- If ridership exceeds forecasts, the concessionaire receives the base-volume payment plus the difference between

actual and forecast ridership, multiplied by the agreed shadow fare.

- If ridership falls below forecasts, the concessionaire receives the base-volume payment minus the difference between forecast and actual ridership, multiplied by the agreed shadow fare.

Independent consultants prepared the Canada Line's initial ridership study, which formed the basis for the system's base credit ridership estimate. However, the Canada Line's contract specified automatic revisions to this forecast at the commencement of service, two years after service commencement, and every five years thereafter. In addition, both the regional transport authority and the concessionaire can trigger a forecast reassessment if any of the following events occurs: the system's service plan changes; planners expand services by adding stations along the existing route; changes occur in bus services; changes occur in the region's traffic demand management initiatives (for example, changes in road pricing or tolls); TransLink increases fares more than 5 percent (in real terms) over the average fare during the previous five years; other significant changes occur in the system's fare structure; or average morning peak-hour ridership during a three-month period exceeds a certain level near the system's maximum designed capacity.

Governments should reserve some flexibility to update the tariff policy given social circumstances, but also recognize that any major deviations are likely to undermine financial sustainability of the system. For a PPP structure, an appropriate mechanism has to be included in the contract to rebalance the financial equilibrium by compensating the private partner for any such changes (for example, defining technical fare or “payment per user,” regardless of the actual level of user tariff in place).

### *Fraud Risk*

Fare evasion, also known as fraud, is another problem that may seriously affect the financial balance of the project. The possibility of fare evasion, including the type and cost of measures to mitigate or manage such fraud, should be considered at the design stage. These measures should be incorporated into the project’s financial plan no matter the project delivery model. Controversy can emerge when demand risk is mostly retained by the public sector (for example, when payments to the PPP operator are based on availability and only marginally on demand), and the private partner does not have a proper incentive to dedicate resources to control fraud. In such cases, specific service requirements with associated payments or incentives should be built into the contract.

### *Operations and Maintenance Risks*

O&M risks refer to issues affecting the operation of existing and new urban rail assets and their maintenance to required standards (Mandri-Perrott and Menzies 2010). Although O&M risks can only materialize after construction, it is important to identify them and to develop a management strategy early on, ideally during project planning. O&M risks arise from events that demand additional (not previously estimated) O&M activities.

Maintenance risks arise from the lack of adequate budgets to undertake the routine, periodic, and major maintenance required for fixed facilities, systems, and rolling stock or from the failure to perform such maintenance. Systems with insufficient funding to cover the costs of maintenance and asset replacement are particularly exposed to this risk. On the operational side, the main source of O&M risk is volatility in the price of some inputs—such as labor and energy costs—and inability to run programmed services.

It is important to clearly define normal and routine maintenance as well as additional tasks that may be required as a result of construction defects or the improper definition of the scope of maintenance. Design and construction defects can require costly and difficult major maintenance interventions or increase long-term maintenance costs considerably. For this reason, operators

need to be very wary of the conditions of the infrastructure and systems prior to taking on any operational responsibility.

O&M risk allocation and approaches to its management depend on the decision whether to have a public or private operator. For a new system in a metropolitan region or country with limited rail experience, the set-up of a new public operator can be a huge undertaking requiring the development of O&M parameters and manuals, the training of staff, and initial advice from an experienced operator (see chapter 12). In the case of a PPP or concession, the private partner or concessionaire assumes most O&M responsibilities and risks.

However, even when the operator is private, the risk of deferred maintenance can be high if not properly addressed in the contract and duly supervised by the granting authority or regulator (for example, by requiring the submission of periodic renewal plans and the establishment of a reserve fund for this purpose). One approach that is becoming commonplace and that provides a natural framework for ensuring the adequate performance of O&M activities is the establishment of payment systems based on availability and quality (that is, the existence of effective service provision according to certain standards). Linking operator payments to quality and availability encourages preemptive maintenance, but it requires the definition of adequate performance indicators that can be measured and monitored by the PPP or concession-granting authority (see chapter 9).

Regardless of the project delivery model adopted, some of the most commonly used mitigation measures for O&M risks include involving the actual project operator or a “shadow operator” in the early stages of project development, developing detailed performance standards for O&M activities and related indicators, and hiring specialized supervision firms to oversee operations. The best way to mitigate O&M risks in the early stages of project development is to take a long-term, life-cycle cost approach to avoid only thinking about construction to the detriment of considering operational sustainability.

### **Transferring Risk through a PPP**

The ability to transfer risks to the party best suited to manage them is one of the main justifications for involving private partners in infrastructure projects. Aside from cost-efficiency considerations in project development and implementation and the potential to mobilize commercial financing and spur innovation, private participation is frequently acknowledged as a way to relieve the pressure of important project risks on the public sector. Some risks are, in fact, better managed by a private partner. However, it is important to remember that private partners will charge a premium for taking on these risks and that some risks are best retained

**TABLE 7.5. General Risk Allocation for Recent Urban Rail Projects in Latin America and Turkey**

RISK	QUITO METRO L1	PANAMA METRO L1	LIMA METRO L1	LIMA METRO L2	SÃO PAULO METRO L4	SÃO PAULO METRO L6/L18	ISTANBUL METRO M4 AND M7
Construction risk	Public	Private (EPC contract)	Public	Private	Public-private (EPC contract for civil works)	Private	Private
Demand risk	Public	Public	Public	Public	Public-private	Public-private	Public
Operation risk	To be determined	Public	Private	Private	Private	Private	Public
Interface risk	Public (mitigated by PMOC)	Private (single contract with integration)	Public-private	Private	Public	Private	Public-private
Geological risk	Public	Public-private	Public	Public	Public-private	Public-private	Public-private

Note: EPC = engineering, procurement, and construction; PMOC = project management oversight consultant.

and managed by the public sector. Table 7.5 offers a practical illustration of the general risk allocation carried out in various metro projects in Latin America and in Turkey. Although it does not show the specifics and degree of risk sharing or transfer, the table does show the overall responsibilities as determined in the contracts. Chapter 9 contains a more meaningful discussion of risk allocation in PPPs.

Risk can be completely or partially transferred to a private partner even in a complex project such as an urban rail PPP. However, risk transfer and sharing require the development of a robust risk baseline that can help to establish the extent of risk taken on by the different parties (see box 7.6). In addition, for the benefits of risk transfer to materialize, the public partner needs to have the required capacity to manage and enforce contracts with private partners that often have more experience, better information, and more resources.

The transfer of risk to a private partner comes at a cost commensurate with the level of risk. Certain risks over which the private partner can have good control (for example, design and construction risk) can be transferred very efficiently at a reasonable premium; other risks over which the private partner has little control, such as demand risk, are very costly to transfer.

Finally, some urban rail projects have failed not because the private partner has been unable to manage the risks under its responsibility, but because the

**BOX 7.6.****Developing a Risk Matrix for a PPP Project: São Paulo Lines 6 and 18, Brazil**

Although the state of São Paulo was aware that a PPP project involves a reasonable and effective risk allocation between public and private partners, it did not have a methodology and process for incorporating risk analysis into its evaluation and due diligence process. Through a Reimbursable Advisory Service contracted by the state, the World Bank introduced a risk evaluation and quantification methodology as part of the evaluation of PPP project proposals.

First, the World Bank helped the state to identify key project risks during bidding, design, construction, and operation and to develop a risk matrix. Once the risk matrix was prepared, the World Bank team facilitated a collaborative risk assessment based on the risk workshop methodology (also known as expert panel) implemented by various PPP agencies around the world. In a risk workshop, a group of relevant experts provides inputs to identify, assess, and allocate risks. Specifically, the workshop brought together representatives from all relevant project stakeholders for an evaluation of

Metro Lines 6 and 18. Participants in the discussion had different experience and points of view and shared their opinion on the risks that the projects faced and the optimal allocation of risk. The risk matrix not only identified the risks and proposed an allocation, it also identified potential incentives that could be put in place to ensure that each risk was adequately mitigated.

The World Bank introduced the concept that PPPs must offer good value for money (VfM). One of the key drivers behind VfM is effective risk transfer. The conclusions of the risk matrix discussion served as a basis for preparing a VfM analysis, which addressed the estimated likelihood and impact of each of the main risks and the degree to which the public authority either retained or transferred these risks. Although the World Bank facilitated the exercise, the risk quantification, allocation, and VfM evaluation was the result of inputs provided by participants in the risk workshop (see chapter 9 for more details on the preparation of a VfM analysis).

public sector has been unable to manage the ones it has retained. For instance, some project-implementing agencies have been unable to fulfill their land acquisition commitments, generating costly delays that offset the expected gains from the transfer of other risks.

## Conclusions and Recommendations

Given the scale and complexity of urban rail projects, the occurrence of unforeseen events is the rule rather than the exception. Risks can materialize in any step of the development process of an urban rail project: planning, design, procurement, construction, and operations and maintenance. The following lessons and

recommendations are useful for decision makers and project-implementing agencies, regardless of where a project is in the development process.

***Project-implementing agencies need to carry out an impartial risk identification and assessment early in project development.*** International experience suggests that some basic questions often go unasked or are improperly addressed up-front. In considering project risk during planning and preliminary design, the project-implementing agency and other authorities should ask questions such as the following:

- Is the project timeline realistic?
- What is the risk of launching an urban rail project without a functional metropolitan transport authority?
- Can the agency effectively manage the risks that it is taking on, particularly in the context of a PPP?
- When implemented by different levels and departments of government, can policy and regulatory coordination across relevant jurisdictions and sectors be ensured?
- What are the risks of delays in property expropriation and utility network relocation?
- What is the risk of cost escalation when detailed geological surveys and project engineering designs are not carried out and vetted by an independent third party?

If these questions cannot be answered impartially up-front, urban rail projects will not live up to their potential and project-implementing agencies will have to deal with excessive risk.

***Risk management should be given special attention and be a regular and iterative exercise throughout the project development process.*** Risks should be managed from early stages of project conception. "Absent or inadequate risk assessment and management are, in themselves, an important source of risk for projects" (Flyvbjerg 2007, 4). Risk management consists of a series of six tasks: risk identification, risk assessment, risk mitigation, risk allocation, risk treatment, and risk monitoring. Each risk should be assessed based on the likelihood of something happening and the impact that occurs if it does happen (HM Treasury 2004).

The project's risk assessment should be updated regularly as implementation advances and more information becomes available (Choi, Cho, and Seo 2004). Developing risk registers, financial models, and other tools to facilitate risk management is key during all steps of project development. The risk management function should be given special attention in the project-implementing agency's

planning and organization. It is recommended that project-implementing agencies engage a PMOC to take charge of updating the risk register under the framework of a long-term risk management strategy.

***A private contractor or concessionaire will only take responsibility for project risks when duly compensated.*** Risk premiums form part of any project's price. In general, the public sector may be better placed to handle unknown or not quantifiable risks than the private sector. The project-implementing agency should strive to allocate project risks optimally between the public and private sectors. The public sector needs to have adequate institutional capacity to assess the risk and negotiate with private sector contractors, equipment suppliers, or operators to achieve a project price that reflects a fair (that is, commercially reasonable) risk-reward balance.

***Cost-effective risk transfer from the public to the private sector in urban rail projects is possible, but it requires an investment in the development of robust risk baselines.*** Generally, a private party will not accept a risk that is unknown or not quantifiable. Risk sharing or transfer require establishing a baseline that identifies the known risks and provides estimates of the costs required to manage them. This increases the importance of preparatory studies, such as detailed engineering, geological surveys, and demand analysis certified by third parties. The amount invested in these studies will pay off in the form of lower contractual premiums required to share or transfer these risks. Project-implementing agencies should not look to save any time or money by short-cutting these essential elements of a risk management strategy, particularly when more experienced stakeholders have more information regarding different risks and will use this greater knowledge to negotiate favorable contractual terms.

***Risk management involves looking at the project from the perspectives of multiple stakeholders.*** Risk management should not be restricted to the perspectives of the public project-implementing agency and private contractor involved in the project. It also has to consider the views of other stakeholders, including financiers, future users, and project-affected persons. Local circumstances and specific characteristics of the stakeholders involved in a project may affect the risk management process.

## Notes

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1. For identifying the typical risks faced by light rail projects and recommended mitigation measures, see Mandri-Perrott and Menzies (2010, ch. 4).
2. The Global Infrastructure Hub has developed risk matrixes for various sectors, including light and heavy rail. These resources describe the main risks as well as indicate the typical risk allocation under a PPP arrangement. For more information, see [https://ppp-risk.github.org/risk\\_category/heavy-rail/](https://ppp-risk.github.org/risk_category/heavy-rail/).
3. A turnkey contract is one where a single entity takes total responsibility to provide a fully equipped facility ready for operation at “the turn of a key” and is responsible for detailed design, construction, and the procurement, supply, and installation of all equipment.
4. The International Federation of Consulting Engineers (FIDIC) has produced standard forms of contract for use between employers and contractors on international construction projects.
5. Although not discussed in detail in this chapter, other operational risks include vandalism, technological obsolescence, and risks related to the performance of ancillary revenues. Additional risks specific to the context of PPP arrangements—such as handback risks and retrenchment risks—and their related contract structuring and provisions are discussed in chapter 9.

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# 8

## PROCURING THE PROJECT

Daniel Pulido and Joanna Moody

Urban rail projects are inherently complex. They require the acquisition of different types of goods, including civil works, equipment, rolling stock, and systems, and different types of services, such as engineering and operations and maintenance (O&M). These different goods and services need to be compatible with each other (see chapter 3). They have to be sequenced properly and delivered in a way that minimizes the implementation time and total cost of the system. Therefore, defining a procurement strategy that properly defines roles and responsibilities, incentivizes cost and time savings during construction, and leverages the expertise of the public and private sectors is of critical importance. As soon as the project moves from planning to preliminary design, the project team should start considering how it intends to procure the project.

This chapter provides guidance on how to go about defining and developing the most appropriate procurement strategy for an urban rail project—the development of the first line of an urban rail system or an additional line or upgrade of an existing system.<sup>1</sup> The procurement strategy defines how the project's infrastructure and systems will be delivered and how it will be operated. Furthermore, which agent(s) will deliver and operate the project infrastructure depends

*Photo:* World Bank staff touring newly purchased rail cars, Lima Metro Line 2.  
*Source:* Julio César Casma, World Bank.

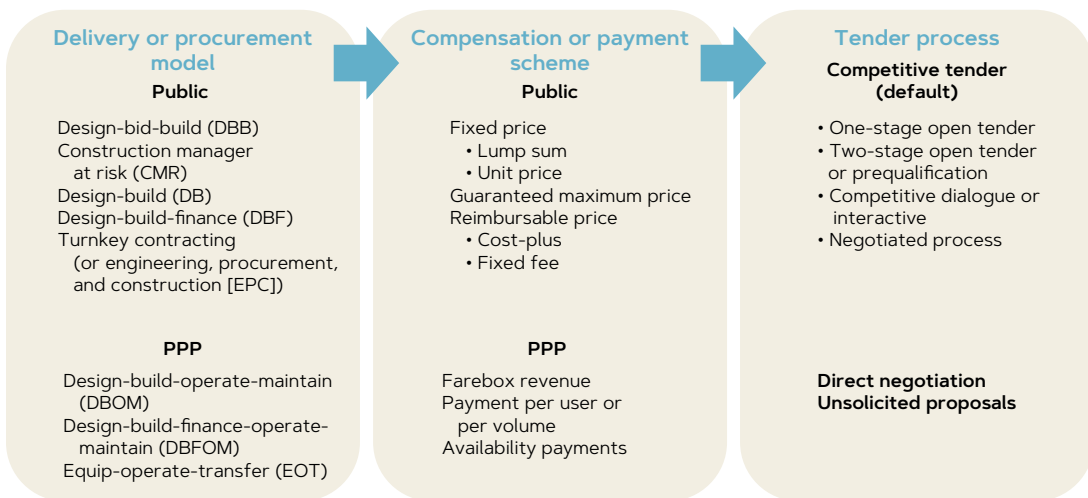
on the procurement strategy selected. Unless otherwise stated, this handbook refers to the procurement of infrastructure and equipment (including, where relevant, the operation of the service).

This chapter presents public authorities with practical recommendations for designing and implementing a procurement approach that delivers value for money (VfM).<sup>2</sup> After introducing the concept of procurement strategy, the chapter (a) outlines the spectrum of available procurement delivery models and discusses their advantages and disadvantages; (b) deliberates on the selection of the most appropriate project delivery model or procurement method by considering characteristics of the project, project-implementing agency, and market for the goods and services being procured; (c) discusses potential options for compensation mechanisms (mostly based on risk allocation and incentives); and (d) presents the tender procedures available for urban rail projects. A final section offers recommendations for selecting the best proposal and making the most of the procurement process.

### Procurement Strategy

Procurement strategies involve three sequential choices: (1) a project delivery model or procurement method, (2) a compensation or payment scheme, and (3) a type of tender process or selection method (see figure 8.1). For a public authority or project-implementing agency looking to develop an urban

**FIGURE 8.1. Choices in the Definition of a Procurement Strategy**



Note: PPP = public-private partnership.

rail system, it is fundamental to define a procurement strategy that responds to the specific needs and interests of the project, the market, and the authority itself and to do so early in the project development process. Many low- and middle-income countries have limited experience in the delivery of urban rail projects or are operating under constrained technical and oversight capabilities, limited financing and funding, and legal frameworks that preclude certain contracting alternatives. A thorough analysis of procurement options and early planning are fundamental to surmounting these challenges and ensuring compliance with the requirements of potential financiers.

Determining the delivery method is one of the most important decisions made by the project-implementing agency. It is important to choose a delivery method that best meets the unique needs of each project-implementing agency and project. Choosing the best method for any project starts with having a good understanding of the available choices and of the views of different stakeholders regarding the delivery model. Also important is having a firm grasp on the impact of each choice on the project scope, budget, and schedule and on institutional relationships. These impacts are often poorly understood, so the project team has to spend sufficient time examining the options with both existing and nascent agencies.

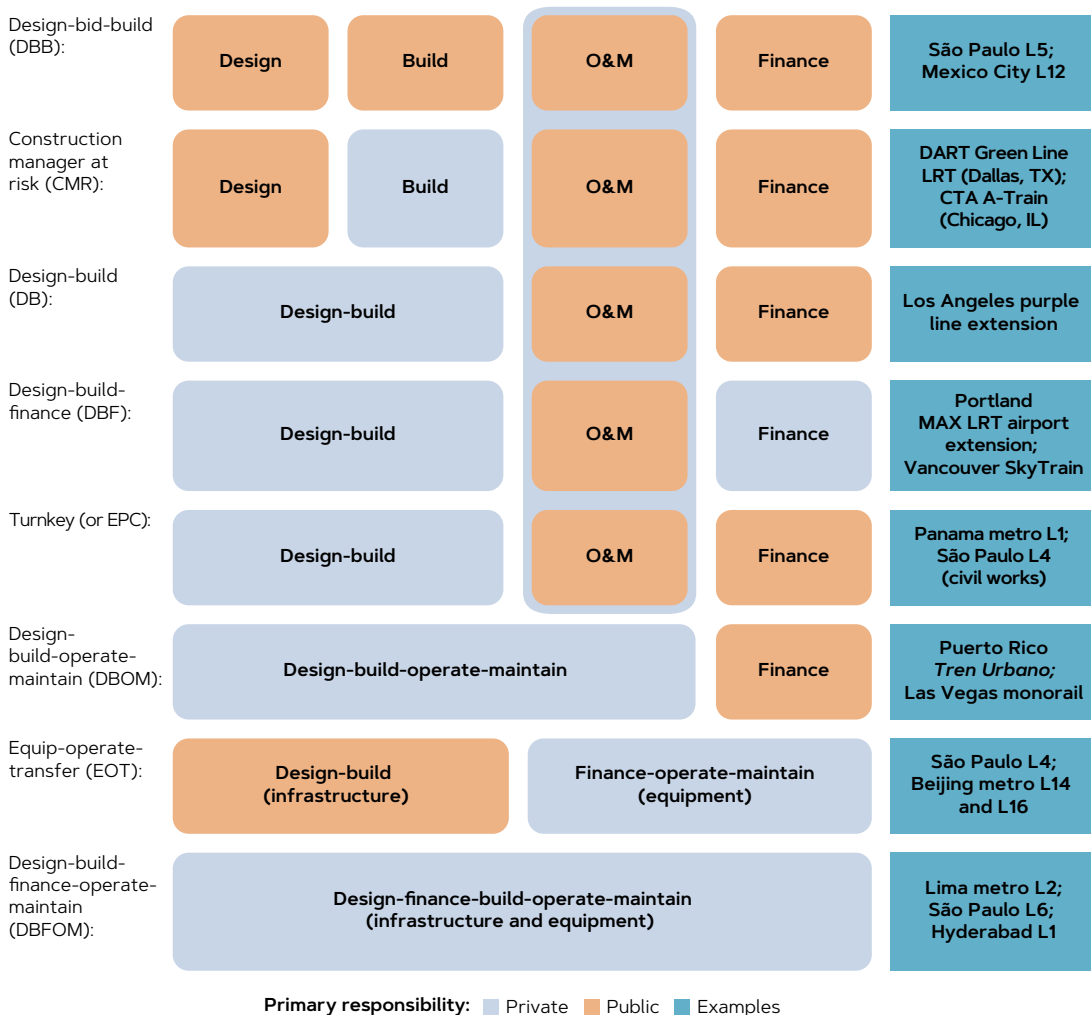
Project considerations have fundamental impacts on the delivery method selected. These considerations include (1) a realistic budget, (2) a schedule that includes a reasonable performance period, (3) a responsive and good-quality design process, (4) a risk assessment and allocation of risks to the appropriate parties, and (5) a recognition of the level of expertise within the project-implementing agency and the national construction and supply market. The choice of delivery method also (1) establishes when parties become engaged, (2) influences the choice of contractual relationships, and (3) influences ownership and the costs of changes and modifications to the project design.

### **Spectrum of Project Delivery Models**

Most project-implementing agencies in the world have used the traditional design-bid-build (DBB) method to deliver new urban rail projects. However, beginning in the second half of the 1990s, a few low- and middle-income countries in East Asia and Latin America started using alternative procurement methods with the goal of lowering costs and reducing project delivery time. They did not always achieve these results. More recently, public authorities have again turned to alternative procurement methods that transfer more responsibility and risk to private developers.

This section describes the most common alternatives in the spectrum, ranging from (a) the traditional method in which the public sector takes responsibility for managing project delivery, subcontracts different functions separately, and manages interfaces to (b) an alternative approach in which the public sector completely contracts out project delivery to a private party (see figure 8.2). No one delivery model works best for all projects. It is important for the public project-implementing agency to consider all alternatives in the spectrum during project planning and early design to determine what method offers the best solution.

**FIGURE 8.2. Delivery Methods of Urban Rail Projects**



Note: CTA = Chicago Transit Authority; DART = Dallas Area Rapid Transit; EPC = engineering, procurement, and construction; LRT = light rail transit; MAX = Metropolitan Area Express; O&M = operation and maintenance.



As shown in figure 8.2, for projects built using the DBB model, construction manager at risk (CMR), design-build (DB), and design-build-finance (DBF) modalities, the responsibility for operation and maintenance (O&M) is separated from the delivery of infrastructure and systems. Thus, O&M responsibilities can be transferred to a private partner under a concession or public-private partnership (PPP) after delivery of the civil works. However, project-implementing agencies should not wait until after construction is complete to consider how O&M will be delivered, since service provision is fundamental to achieving the project development objectives.

In addition to multiple steps (design, finance, construction, O&M), an urban rail project also implies the procurement of various types of inputs (civil works, goods, software, and services) that may be needed for delivering one or more components (see box 8.1).

#### **BOX 8.1.**

### **Examples of Multiple-Contract Project Delivery for Urban Rail Projects in the United States**

#### **Bay Area Rapid Transit (BART) extension to San Francisco International Airport**

This 8-mile (14-kilometer) US\$1.55 billion project extended the BART heavy rail system to San Francisco International Airport and added four new stations. The project was procured primarily with two DB contracts. The Sverdrup Corporation and Conco joint venture was awarded a US\$70.5 million DB contract to construct the Millbrae intermodal station, with connections to Caltrain. The Tutor-Saliba Corporation and Slattery Construction joint venture was awarded a US\$526.5 million DB contract to construct the BART line from Colma to Millbrae, including all track and systems work, accounting for about 90 percent of the cost to construct the extension (Freeman, Wei, and Gosling 2012). The DB contract model allowed the project to move quickly from design to construction, but BART had difficulty managing the nontraditional procurement method and experienced cash-flow shortfalls and could

not obtain funding to match the pace of construction. In the end, inexperience with the DB procurement model in the project-implementing agency contributed to the project being delivered 16 months late (in June 2003) and nearly US\$500 million over budget.

#### **Washington Metropolitan Area Transit Authority (WMATA) Blue Line extension**

The 3.1-mile extension of WMATA's Blue Line east to Prince George's County, Maryland, was awarded two DB contracts and one DBB contract for a total cost of US\$456 million. A contract to prepare the site for 2 miles of underground track and 0.5 mile of at-grade track as well as a 0.5-mile aerial track over the Washington Beltway was included in the DBB contract. All electromechanical systems, the construction of two new stations, and parking facility work fell within the boundaries of the two DB contracts (Kay 2009). The project opened on time and on budget in 2004.

### **Design-Bid-Build or Traditional Procurement**

DBB is a method in which the project-implementing agency contracts the delivery of various project components with different entities. This method breaks up project delivery into separate contracts, giving the project-implementing agency greater control and flexibility. Variations of DBB include general or prime contractor and multiple primes.

#### *General or Prime Contractor*

In many countries, the DBB model with a general or prime contractor is the most traditional procurement process for developing urban rail projects. In such an arrangement, the public project-implementing agency hires separate contractors to design and construct the project. There are three distinct linear phases:

1. The project-implementing agency hires and oversees an engineering firm to complete the project design based on planning specifications and assumes responsibility for that design, which is the basis for the construction bid; the project design may be the final detailed design or an advanced basic design.
2. The project-implementing agency procures the services of a contractor.
3. The contractor develops the project following the project-implementing agency's designs and specifications.

Once the project is constructed, the project-implementing agency normally operates the system. However, it can also turn over system O&M to a public operator or private partner.

DBB is the traditional public delivery method because the public sector—which has the greatest accountability to the public—is in control of all phases of project delivery. However, this type of control requires levels of experience, expertise, and involvement that are difficult to achieve in some public institutions in low- and middle-income countries, particularly for new urban rail projects. From the perspective of an agency aiming to develop a new urban rail project (the first line), the DBB approach has the additional advantages and disadvantages detailed in table 8.1. Time might be saved if, for example, the agency is responsible only for the preliminary design undertaken with a comprehensive geotechnical analysis, and if the winning contractor undertakes the detailed (as-built) design. However, both the project-implementing agency and, in most cases, an independent third-party consultant have to review the detailed design and costs produced by the contractor.

São Paulo Metro Line 5 (phase 1), M7 Metro Line in Istanbul, and Mexico City Line 12 were procured using a traditional DBB project delivery model.

**TABLE 8.1. Advantages, Disadvantages, and Risks for the General or Prime Contractor Design-Bid-Build Delivery Model**

ADVANTAGES	DISADVANTAGES	RISK ALLOCATION
<ul style="list-style-type: none"> <li>• Generally, the project-implementing agency has more experience using this approach</li> <li>• Breaking down the process into separate design and construction steps allows specialized companies to compete in their own area of competence, which expands the pool of bidders, compared with a situation where bidders are forced to form consortia with companies that specialize in other areas</li> <li>• The design professional is independent and monitors the project in the best interest of the project-implementing agency</li> <li>• The project-implementing agency has the freedom during project design to make changes and explore alternatives</li> <li>• Costs are more certain because construction is bid out with complete design</li> </ul>	<ul style="list-style-type: none"> <li>• Delivery can take longer than in other methods because all design work must be completed prior to the solicitation of construction bids. This can cause delays and loss of the political window to implement the project.</li> <li>• Separating design and construction deprives the project-implementing agency of the contractor's planning knowledge for value engineering and constructability and makes changes in design during construction costlier. This is not true if the value engineering clauses are included in the bidding documents.</li> </ul>	<ul style="list-style-type: none"> <li>• The project-implementing agency assumes all cost, design, construction, and O&amp;M risks. Most of these risks within each segment can typically still be transferred to the respective contractors or operators by including appropriate liability clauses as part of their contracts.</li> <li>• The project-implementing agency faces interface risk between the designer and the contractor and is responsible for any gaps between design and construction</li> <li>• Any undetected soil problems in the design that may require more expensive construction solutions are the responsibility of the project-implementing agency<sup>a</sup></li> </ul>

Note: O&M = operation and maintenance.

a. This is not a feature exclusively of design-bid-build. Other types of procurement may also choose to leave this risk with the procuring agency if it is best suited to handle the risk and if the cost premium charged by the private sector for the transfer of the risk is unacceptable (see chapter 7).

### *Multiple Prime Contractors*

The multiple prime contractor model is a variation of DBB in which the project-implementing agency contracts directly with separate trade contractors (or primes) for specific project components, rather than with a single general or prime contractor (see table 8.2).

The Metro de Santiago in Chile, an established public agency with experience in the development of urban rail projects, uses this procurement method for developing new urban rail lines. For the development of Lines 3 and 6, it launched 45 bidding processes for various services, including civil works, equipment, and supervision.

**TABLE 8.2. Advantages, Disadvantages, and Risks for the Multiple Prime Contractors Design-Bid-Build Delivery Model**

ADVANTAGES	DISADVANTAGES	RISK ALLOCATION
<ul style="list-style-type: none"> <li>• Project-implementing agency has control over the entire process</li> <li>• Availability of more trade contractors to choose from in selecting each prime increases competition and reduces price</li> <li>• The delivery of certain components can accelerate because the project-implementing agency can bid design packages to different primes as they are completed</li> <li>• If one contractor fails, only its lot is delayed</li> </ul>	<ul style="list-style-type: none"> <li>• Project-implementing agency needs to have sufficient capacity and experience to take on the coordination and contract management role effectively for multiple procurement processes and bids</li> <li>• Potential exists for numerous claims among various contractors</li> <li>• Final price is not known until the final prime is procured</li> <li>• Contingency plans are needed if the contractor of one intermediate link fails</li> <li>• The process requires a very strong project integrator</li> </ul>	<ul style="list-style-type: none"> <li>• In addition to interface risk, the project-implementing agency assumes integration risk across multiple prime contractors</li> </ul>

### Construction Manager at Risk

In a CMR arrangement, the project-implementing agency procures the design separately and enters into an agreement (through a competitive hiring process) with a construction manager who assumes the risk of delivering the project on time and within budget (see table 8.3). The construction manager effectively takes on the role of project manager on behalf of the project-implementing agency, which may not have the required experience and capacity to carry out this task on its own. The construction manager provides construction input to the project-implementing agency during design and becomes the general contractor during construction. As general contractor, the construction manager can then subcontract specific components to trade contractors. After design and construction, all O&M responsibilities remain with the public project-implementing agency.

Generally, CMR contracts have a defined price in the form of a fixed lump sum or a guaranteed maximum price (GMP) determined when at least 60 percent of the designs are completed. When using a GMP, the project-implementing agency and the construction manager can share any cost savings relative to the GMP.

**TABLE 8.3. Advantages, Disadvantages, and Risks for the Construction Manager at Risk Delivery Model**

ADVANTAGES	DISADVANTAGES	RISK ALLOCATION
<ul style="list-style-type: none"> <li>• Allows price competition in the subcontract works packages combined with the qualifications and price-based selection of the construction manager at risk model</li> <li>• Allows for overlapping design and construction schedules, saving time</li> <li>• Allows for early input from the builder (civil works contractor) in the design of the project, reducing cost and schedule deviations</li> <li>• Encourages teamwork between the project-implementing agency, designer, and construction manager</li> <li>• Provides opportunity to build internal knowledge and improve experience</li> <li>• Incentivizes the construction manager to optimize O&amp;M</li> </ul>	<ul style="list-style-type: none"> <li>• May not be supported by the procurement laws and regulations of some jurisdictions</li> <li>• Eliminates the opportunity to bid the work out (if the project-implementing agency does not require the construction manager to conduct an open and competitive bidding process to select subcontractors)</li> <li>• Project-implementing agency still has to resolve conflicts between the designer and construction manager</li> </ul>	<ul style="list-style-type: none"> <li>• The allocation of design risk is unclear since the CMR is responsible for managing preconstruction and construction</li> <li>• Construction manager assumes some of the implementation risk during design and construction</li> </ul>

Note: CMR = construction manager at risk; O&M = operation and maintenance.

A CMR project delivery model was adopted for a 44-mile extension of the Weber County Commuter Rail System in Salt Lake City, Utah (National Academy of Sciences, Engineering, and Medicine 2010).

### Design-Build

In the DB delivery method, the project-implementing agency hires a single business entity (the design-builder) to perform both design and construction activities under a single contract (see table 8.4). The design-builder may be a consortium, joint venture, or other organization assembled to deliver the project.

Compared with traditional DBB procurement, DB arrangements can provide economies of scale and complementarities by combining the tasks of designing and building the project (see chapter 6). However, the project-implementing

**TABLE 8.4. Advantages, Disadvantages, and Risks for the Design-Build Delivery Model**

ADVANTAGES	DISADVANTAGES	RISK ALLOCATION
<ul style="list-style-type: none"> <li>• Single point of responsibility for both design and construction</li> <li>• Faster implementation since bidding and selection process for the contractor is eliminated between design and construction</li> <li>• More opportunities for project optimization early in the project development process, where changes are less costly</li> <li>• Transfer of design risks to the contractor</li> </ul>	<ul style="list-style-type: none"> <li>• Less competition in selection of design-builder</li> <li>• Unless contract conditions require the design process to include operator input, operational issues may not be considered adequately</li> <li>• Contractor may appropriate economies if adequate incentives are not put in place</li> <li>• Project-implementing agency has to be well resourced to be able to approve as-built designs</li> </ul>	<ul style="list-style-type: none"> <li>• Design risk shifts to the contractor; design-builder is responsible for shortcomings in design</li> <li>• Design-builder may be responsible for delivering all components, reducing interface risk</li> </ul>

agency still has to outline its design and construction requirements and standards in sufficient detail to enable it to receive comparable offers from bidders and to perform appropriate selection, pricing, and contract management. Such oversight is needed to realize economies and to ensure that the contractor does not appropriate all of the savings. After construction of the system is complete, the public project-implementing agency is responsible for O&M, which it can choose to carry out in-house or to outsource through a separate contract.

In 2015, the Los Angeles Metro Board authorized staff to use a DB contract-delivery approach to complete the final design and construction of the Westside Purple Line Extension project Section 2, comprising a 2.6-mile dual-track heavy rail extension and two new underground stations. Ultimately, the project will extend the Purple Line for about 9 miles (seven new stations) from Wilshire/La Cienega to Westwood/Veterans Administration Hospital.

### Design-Build-Finance

The DBF delivery model is similar to the DB model in the sense that the private contractor performs both design and construction services and the project-implementing agency receives the asset once it is constructed, retaining responsibility for O&M (see table 8.5). In a DBF model, the project-implementing agency does not pay for construction as it progresses, but instead defers the payment until construction is completed, relying on the contractor as a financier. The contractor raises this financing on the back of government payments that are not made until the project is commissioned, often in several fixed installments over a number of years.

**TABLE 8.5. Advantages, Disadvantages, and Risks for the Design-Build-Finance Delivery Model**

ADVANTAGES	DISADVANTAGES	RISK ALLOCATION
<ul style="list-style-type: none"> <li>• Same advantages as DB</li> <li>• Allows the project-implementing agency to overcome short-term restriction of funds</li> <li>• Increases oversight, adding an additional layer of due diligence from commercial lenders providing financing for the contractor</li> </ul>	<ul style="list-style-type: none"> <li>• Same disadvantages as DB</li> <li>• Higher financial cost (premium of structured public credit over straight public sector debt), but lower than in PPP methods</li> <li>• Financing relies on the credit standing of the government alone</li> </ul>	<ul style="list-style-type: none"> <li>• Potential greater transfer of construction risk than in DB, given extended financial exposure of contractor beyond the normal construction defect liability period</li> </ul>

Note: DB = design-build; PPP = public-private partnership.

When these government payments are unconditional and irrevocable, they are not subject to project performance risk after construction, when the project is handed to the public sector. In this case, the financing provided by the contractor is not considered private finance (see chapter 10). This procurement method is considered public finance under many national accounting regulations because the procuring authority assumes full control over the assets and risks once the project is constructed (ADB et al. 2016). For these reasons, this method is not considered a PPP in this handbook.

The Province of Ontario (Metrolinx) in Canada used this delivery model to develop improvements in the GO Transit Milton and Stouffville corridors in the City of Mississauga. DBF delivery was also used in the Portland MAX light rail transit (LRT) airport extension<sup>3</sup> and an 11-kilometer extension of the SkyTrain system in Metro Vancouver.<sup>4</sup>

### Engineering, Procurement, and Construction or Turnkey Contracting

Engineering, procurement, and construction (EPC)<sup>5</sup> or turnkey contracts refers to legal agreements whereby a project owner gives a contractor the responsibility to engineer, procure, and construct the project and ready it for operations on time and in budget. Turnkey contracting is also referred to as lump-sum turnkey, indicating that the contractor is most often responsible for delivering the project at a fixed price. Although the terms are often used interchangeably, the term *turnkey* goes beyond EPC because it implies the inclusion of commissioning of the project (that is, proof that the train service can be operated reliably and safely). In EPC contracting, the contractor controls the project budget, timeline, and operational performance (subject to contractual requirements) and effectively becomes the single counterpart to the project owner.

DB and EPC contracting are similar in the sense that the responsibility for design and construction is transferred to the same party. Therefore, the main advantages and disadvantages of EPC contracting are similar to those of the DB modality (see table 8.4). However, EPC contracts tend to transfer more risks from the project-implementing agency to the contractor than DB contracts, including unknown site conditions as well as testing and commissioning (FIDIC 2017; Hosie 2007). A single EPC contract may include the delivery of various project components and their integration, or the project-implementing agency may enter into different EPC contracts to deliver different project components. In addition, certain rolling stock companies now offer turnkey solutions that bundle together track work, electrification, train manufacturing, rail control systems, and maintenance in a single contract.

The first line of the Panama Metro was developed using an EPC contract that encompassed all of the project components (including civil works for line construction and stations, all electromechanical systems, information and ticketing systems, and rolling stock). The government of the state of São Paulo in Brazil procured civil works through an EPC contract for Line 4 and procured the rolling stock and O&M services through a PPP.

### **Public-Private Partnerships**

A PPP is defined as a “long-term contract between a public party and a private party for the development (or significant upgrade) and management of a public asset (including potentially the management of a related public service), in which the private party bears significant risk and management responsibility throughout the life of the contract, and remuneration is significantly linked to performance, and/or the demand or use of the asset or service” (World Bank Institute 2012). In a PPP, the public project-implementing agency transfers more responsibility and risk to a private party, bundling together design, construction and O&M under a single contract. This private party subcontracts the delivery of different project components to specialized companies, operates and maintains the system, and (in some schemes) raises financing in exchange for the right to collect project revenues or receive government payments. Concessionaires or private partners may enter into an EPC or turnkey contract with a third party with obligations that mirror the project delivery commitments it is undertaking under a PPP agreement.

In some PPPs, the private party is responsible for raising a significant part of the financing for the project. If the ability to repay this financing is linked to the project’s operational performance through the contract payment mechanism, then the PPP can be considered a private finance PPP. The link between payment and performance aligns the profit motive of the private sector with the



service quality and reliability interests of the public sector and allows implementing agencies to benefit from the discipline introduced by private financiers in project financings. If, however, the ability to repay project financing does not depend on the project's operational performance, the PPP is not considered a private finance PPP.<sup>6</sup>

Like other models, PPPs may not encompass the full delivery of a project but may only cover certain project functions or components. PPP contracts may coexist with public management of rail infrastructure or public operation of urban rail services. For example, project-implementing agencies may use PPPs only to build stations (such as in the Barcelona Metro Line 9 project) or only to deliver infrastructure, retaining the operations (such as in the Madrid Metro line project to the Barajas Airport).

This section introduces the most frequent PPP modalities that have been used to deliver urban rail projects and notes their relative advantages, disadvantages, and risks compared with other project delivery models. Critical factors when designing the PPP contract for urban rail projects are discussed in chapter 9.

#### *Design-Build-Operate-Maintain*

Under a design-build-operate-maintain (DBOM) arrangement, the design and build activities are bundled together with the operation and maintenance of the project and contracted out to a private entity under a single long-term contract (in some cases, up to 30 years), with financing provided by the public sector (see table 8.6). In a typical DBOM contract, the private contractor's remuneration is not linked to the performance of the asset, which may be undesirable from the perspective of risk transfer. The public sector pays for construction as work progresses and pays for O&M based on the service provided and not the condition of the asset. In some instances, these contracts may contain provisions linking payments to performance.

Several urban rail projects have been developed under this model, including the Hudson-Bergen Light Rail in New Jersey, the Las Vegas Monorail, and the Tren Urbano in San Juan, Puerto Rico.

#### *Design-Build-Finance-Operate-Maintain or Build-Operate-Transfer*

Under a design-build-finance-operate-maintain (DBFOM) or build-operate-transfer (BOT) arrangement, the contractor takes on all the responsibilities discussed in the DBOM model and also brings its own financing (for all or a significant part of project costs) in what is deemed a private finance PPP (see table 8.7).<sup>7</sup> This arrangement results in a completely vertically integrated PPP in which the private partner oversees all project components for a predetermined concession period. Introducing private financing creates stronger incentives for performance and

**TABLE 8.6. Advantages, Disadvantages, and Risks for the Design-Build-Operate-Maintain Delivery Model**

ADVANTAGES	DISADVANTAGES	RISK ALLOCATION
<ul style="list-style-type: none"> <li>• Private partner can implement the most cost-effective delivery option when considering the entire life of the project (life-cycle costing advantage)</li> <li>• Lower risk of issues with component integration and interfaces</li> <li>• More flexibility for contractor, which can conduct its own value engineering</li> </ul>	<ul style="list-style-type: none"> <li>• Project-implementing agency loses control over project delivery and flexibility</li> <li>• Counterparty risk increases</li> <li>• Requires the formation of consortia among suppliers of different components, potentially resulting in a lower number of bids than if such components were procured separately</li> <li>• Project-implementing agency gives up the possibility of running a different competition for O&amp;M</li> <li>• Requires a very good advanced basic project design for bidding and a strong project-implementing agency, supported by a PMOC, to monitor construction</li> </ul>	<ul style="list-style-type: none"> <li>• Transfers risks across project stages (life-cycle risks) to the private party</li> <li>• To the extent that different project components are integrated into a single contract, mitigates interface risk</li> </ul>

Note: O&M = operation and maintenance; PMOC = project management oversight consultant.

**TABLE 8.7. Advantages, Disadvantages, and Risks for the Design-Build-Finance-Operate-Maintain or Build-Operate-Transfer Delivery Model**

ADVANTAGES	DISADVANTAGES	RISK ALLOCATION
<ul style="list-style-type: none"> <li>• Same life-cycle costing advantages as in DBOM</li> <li>• Private financing at risk generates incentives for alignment of private and public parties' objectives in efficient implementation</li> </ul>	<ul style="list-style-type: none"> <li>• Same as in DBOM</li> <li>• Higher financing cost (financiers are exposed to project performance risk and the grantor's creditworthiness when a stream of government payments is involved)</li> </ul>	<ul style="list-style-type: none"> <li>• Risk allocation is similar to the DBOM option, with the added benefit that private finance increases the alignment of incentives for the private partner</li> </ul>

Note: DBOM = design-build-operate-maintain.

introduces a side benefit in the form of rigorous due diligence imposed by commercial financiers.

The DBFOM model has been used recently to develop urban rail projects both in high-income and in low- and middle-income countries, including Metro Line 1 in Hyderabad, Metro Lines 6 and 18 in São Paulo, Metro Line 2 in Lima, the Purple Line in Washington, DC, and the Canada Line in Vancouver. Metro Lines 1 and 2 in Salvador (Brazil) are currently under construction under a DBFOM contract.

In recent greenfield urban rail projects procured through DBFOM PPPs in Latin America, competition has been limited to one or two bidders, and the difference between the maximum reference price and the bid price has been relatively low. This was partly due to the difficulties in forming consortia for the delivery of vertically integrated DBFOM projects, requiring negotiations between companies from different industries and with dissimilar business models (see tables 8A.1 and 8A.2 in the annex to this chapter).

#### *Equip-Operate-Transfer or Equipment BOT*

Under an equip-operate-transfer (EOT) arrangement (sometimes called an equipment BOT arrangement), the project-implementing agency develops the infrastructure (and systems) through a more traditional DBB or DB model and then enters a long-term agreement with a private entity for the delivery and financing of the required rolling stock and O&M services over a long concession period, usually 20 to 30 years (see table 8.8).

EOT was used to develop Line 4 in São Paulo, Lines 14 and 16 in Beijing, and Line 1 in Hangzhou.

**TABLE 8.8. Advantages, Disadvantages, and Risks for the Equip-Operate-Transfer Delivery Model**

ADVANTAGES	DISADVANTAGES	RISK ALLOCATION
<ul style="list-style-type: none"> <li>• Lower overall financing cost by financing high-risk construction activities through public finance and rolling stock through project finance and export credit agencies</li> <li>• Higher potential number of bidders (operators in partnership with rolling stock providers)</li> </ul>	<ul style="list-style-type: none"> <li>• Potential integration problems between infrastructure and equipment and rolling stock</li> <li>• Project-implementing agency needs the support of a strong PMOC with access to monitoring data</li> <li>• May lead to interface risk if there is not a strong integrator or if the private entity is not involved in supervising the construction of infrastructure</li> </ul>	<ul style="list-style-type: none"> <li>• Infrastructure and systems integration and interface risks persist</li> <li>• Reduced ability to transfer risks to private partner, which will only accept risks directly related to the components that it is supplying</li> </ul>

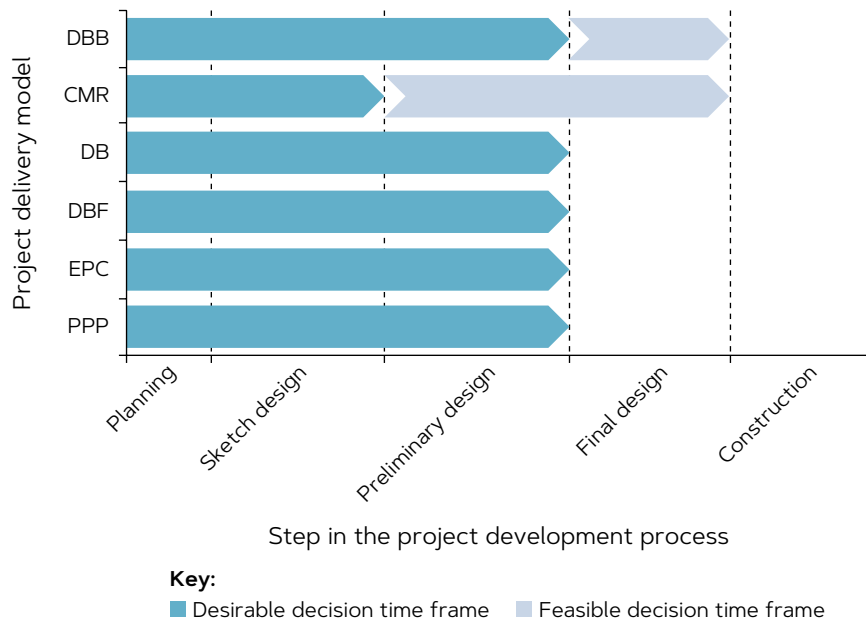
Note: PMOC = project management oversight consultant.

### Choosing the Best Project Delivery Model

The window of opportunity for selecting among different project delivery models or procurement methods closes as the project moves through the steps of development (see figure 8.3). For most project delivery models, benefits are realized by engaging the expertise of the builder as early as possible (Transportation Research Board 2009). Furthermore, decisions regarding procurement strategy<sup>8</sup> can affect the level of design needed before packaging bids and soliciting proposals. It is advisable to choose the type of delivery early in the project development process so that the design and bid documents can be developed to accommodate the targeted delivery model properly (Transportation Research Board 2009).

Defining a project delivery model is a critical decision that can influence the cost, time, and quality of project delivery. There is no single “right method” for delivering urban rail projects. When deciding on the appropriate model, a

**FIGURE 8.3. Timing of Project Delivery Model Selection**



Source: Adapted from Transportation Research Board 2009, 18.  
 Note: CMR = construction manager at risk; DB = design-build; DBB = design-bid-build; DBF = design-build-finance; EPC = engineering, procurement, and construction; PPP = public-private partnership.

project-implementing agency should consider (1) the characteristics of the project and its political economy, as well as (2) its own sophistication, experience, capabilities, and financing capacity.

This section discusses these project and agency “drivers” and how they relate to the project delivery models outlined in the previous section. Although it is impossible to treat these drivers as completely independent, the discussion attempts to minimize overlaps and redundancies among them as well as those related to their interactions with different project delivery models. Mapping the needs of the project and project-implementing agency to the strengths and weaknesses of different project delivery models creates a systematic and structured framework with which to determine the choice of project delivery model and to document this decision transparently for financiers and other stakeholders.

### **Project Drivers**

Some key project drivers should be considered when choosing which delivery model is most appropriate. Key project drivers include time constraints, flexibility needs, preconstruction service needs, level of interaction within the design process, and financial constraints of the project-implementing agency.

#### *Costs*

Costs include several aspects of project cost, such as the ability to handle budget restrictions, the feasibility of early and precise cost estimation, and consistent control of project costs. In a traditional DBB model, costs are known at the time of bidding, before construction begins, but the process is prone to change orders and additional costs after the award (Transportation Research Board 2009). In alternative delivery models, projects are bid in multiple packages or at a lower level of design where contract costs are not known up-front. Weak project design, poor geotechnical surveys, heritage findings, close basement buildings, inefficient identification of utilities to be removed, and delays in expropriation in key parts of the alignment are common problems in urban rail projects that end up costing much more than initially planned.

#### *Schedule*

The project-implementing agency has to decide whether the project should be conducted over a normal, sequential schedule or whether a fast-track schedule—which overlaps design and construction or eliminates additional bidding time—is needed. This decision involves financial analysis of the possible cost of fast-tracking versus the value of early completion, as well as review of the

technical and regulatory feasibility of fast-tracking (Gordon 1994). In general, a traditional DBB model yields the longest delivery schedule due to its linear nature and the largest potential for delays. Alternative delivery models can shorten the project schedule, but fast-tracking will require effort from the project-implementing agency in design and construction reviews (Transportation Research Board 2009).

### *Flexibility*

Flexibility considers how much flexibility the project-implementing agency may need during the construction process. Many urban rail projects are too large or complex to be designed completely ahead of time, thereby requiring some amount of flexibility in the process. Some agencies may be unable to finalize construction documents because of indecisiveness or lack of political consensus, permit requirements, market fluctuations, time constraints, or unknown site conditions (Gordon 1994). In these cases, the DB and PPP approaches provide more flexibility, allowing projects to move forward under greater uncertainty.

### *Preconstruction Advice*

Project-implementing agencies have to decide the value to the project of preconstruction services, such as input from the civil works contractor into cost estimates, value engineering, and constructability reviews of design (see chapter 6). Preconstruction services can be of particular importance for urban rail projects given their complexity and uniqueness, particularly when the project is the first line in the city. Project-implementing agencies undertaking their first urban rail project tend not to have the staff to prepare the basic (or advanced) design and other studies that are required to prepare for procurement. There is a tendency to try to save costs during up-front project planning and design, for example, by not completing proper soil and water table surveys. However, such cost cutting only increases project risk and bid costs since consultants or private partners will price this uncertainty. Financiers have to ensure that adequate project design is available and vetted by a third party.

### *Design Interaction*

Project-implementing agencies have to assess how much interaction they want to have with the designers. This interaction can be particularly important if the project design is intended to be highly creative, the aesthetic appearance is critical, or, as is the case with urban rail projects, the project's functionality (such as the provision of rail service) is essential. In project delivery models involving an independent designer—such as in the DBB or construction manager models—the project-implementing agency has complete control over the design.

With alternative delivery models, design is often included in construction contracts, and project-implementing agencies have less control over the detailed design (Gordon 1994).

### *Maintainability*

Maintainability considers the project-implementing agency's ability to specify quality and ease of maintenance. In traditional DBB project delivery, the opportunity to view completed plans allows project-implementing agencies to review maintenance issues in designs. However, there is little opportunity for contractors to provide input into maintenance issues until the design is bid for construction (Transportation Research Board 2009). In alternative delivery models such as CMR and DB, the project-implementing agency can emphasize maintenance issues by including performance criteria in the contract and can leverage construction input into maintenance issues. In other project delivery models such as DBOM, the private consortium is responsible for maintenance and is highly motivated to provide optimal life-cycle designs. This was seen in São Paulo Line 4, where the consortium ViaQuatro opted for communications-based train control signaling to reduce operating costs (see chapter 5). Project-implementing agencies and operators often neglect this aspect.

### *Life-Cycle Costs*

Project delivery models can influence costs during operation and maintenance of urban rail projects. In traditional DBB delivery, the project-implementing agency can control life-cycle costs through complete design and performance specifications. However, this type of delivery allows for very little contractor input in determining these costs. In alternative delivery models, the project-implementing agency can use performance criteria to set life-cycle performance standards, but if these criteria are poorly understood at the procurement stage, they may not be incorporated fully into the contract (Transportation Research Board 2009).

### **Project Owner Drivers**

In addition to the characteristics of a project, it is also necessary to consider the experience and sophistication of the project-implementing agency when choosing the appropriate project delivery model. Project-implementing agencies around the world are at different levels of institutional development and sophistication and manage different transport networks, from one transit line and one mode to dozens of lines and various modes.

Different project delivery models require different levels of agency capacity and involvement, which are captured in "agency drivers." Consideration of these

drivers allows project-implementing agencies to weigh trade-offs, such as the loss of some control and flexibility in contractual arrangements, to make up for their lack of internal capacity or experience.

The key question revolves around the government's experience with the use of different delivery methods and the expertise of the procuring agency in the development of urban rail systems. For example, countries that have more experience with PPP than with urban rail projects may choose an integrated DBFOM model that brings in the external urban rail development expertise of a private consortium and capitalizes on existing internal capacity to coordinate contracts and manage interfaces (Phang 2007).

### *Agency Experience*

Project-implementing agency experience relates to the level of comfort and confidence of agency staff in applying a specific delivery model. Transit agencies around the world have historically employed DBB as their project delivery model. Therefore, most project-implementing agencies have the most experience with that model. Agency staff with DBB management experience should have most of the skills necessary to manage the CMR delivery model because of the similarities in relationships and roles. For project-implementing agencies with no background in DB, some training may be required (Transportation Research Board 2009). PPPs represent a significant departure from DBB, and few agencies have experience with these project delivery models. In many cases, the project-implementing agency can transfer most of the traditional responsibilities of its staff to the private contractor. However, the loss of control that goes with this transference of responsibility can be a disadvantage if the agency does not have experience in managing and monitoring the outsourcing of design, construction, and maintenance services (Transportation Research Board 2009).

For nascent urban rail agencies developing their first line, it is particularly important to have not only a project management consultant with strong experience, but also very experienced advisers to guide key decisions proposed by the project management consultant during project conception and implementation. A strong team is also needed to supervise these advisers and internalize the experience gained throughout project implementation (see chapter 4).

### *Agency Control of Project*

Since different project delivery models have different checkpoints and decision-making steps, as well as different allocation of roles and responsibilities to designers and contractors, they afford the project-implementing agency different levels of control over the details of design and quality of construction.



In general, traditional DBB project delivery provides the project-implementing agency with the greatest number of checks on design and construction (but often with the consequence of expensive change orders if designs need to be adapted later in the process due to unexpected situations). This high level of agency control comes with greater requirements for agency staffing and staff capabilities (see the discussion of staffing requirements).

Alternative project delivery models provide greater flexibility at the expense of some agency control. In the case of new urban rail lines, it is very important to have in place a project management consultant with recognized experience in these types of projects and a supervision consultant (often referred to as the engineer in the International Federation of Consulting Engineers [FIDIC] bidding documents). The project-implementing agency or the financiers should consider hiring a project management oversight consultant who will provide risk identification and mitigation advice and quality and safeguards assurance (for more detail on project management, see chapter 4).

### *Staffing Requirements*

Staffing requirements capture the amount of agency involvement required by each delivery model based on the total number of agency employees needed to oversee the project development process through administrative decisions, contractor monitoring, or on-site management. In general, DBB requires a larger project-implementing agency staff and more detail-oriented agency involvement than the other delivery models (Gordon 1994).

In most cases, the project-implementing agency for a new urban rail line needs to have managers, technical experts, accountants, and lawyers to oversee the project. In low- and middle-income countries, it is often difficult to find in-country professionals with the required experience. Therefore, while the project is being developed, on-the-job training of the proposed staff should be part of the terms of reference of the advisers mentioned above (see chapter 4).

### *Staff Capability*

Staff capability captures the level of technical sophistication of agency staff needed to oversee and manage contractual arrangements for design and construction. If project-implementing agencies are not prepared, they are going to need a model that provides someone, in a fiduciary relationship, to advise them. DBB is traditionally aligned with agency staff capabilities, but as the size and complexity of the projects grow, more experienced staff are required. With CMR contracts, the construction manager can augment a project-implementing agency's capabilities with its own staff, while with DB contracts, the agency must interact with a single entity responsible for both design and construction.

### **Legal and Regulatory Drivers**

Most countries have a consistent and clear precedent for how to implement traditional DBB contracts. However, it is important to consider the legal framework when implementing a less traditional arrangement. When considering PPP, the legal framework under which the project will be procured needs to be specified clearly in order to provide a sound legal basis for the process and to establish the preparation and implementation requirements.

For example, in the analysis of different business models for the Bogotá Metro project, the project-implementing agency compared the preparation and evaluation requirements established by the new PPP legislation (Law 1508 of 2012) and those established in the traditional procurement legislation (Law 80 of 1993), which includes the BOT concession model. The analysis established that the traditional procurement legislation allowed for certain private participation models that did not require the project-implementing agency to go through the detailed evaluation and various approvals required in the PPP law.

Many PPPs may not affect public deficit and debt if they meet certain criteria (depending on the national accounting standards followed by the country). Therefore, developing the project through a PPP may allow a government to develop infrastructure that otherwise could not be developed. This very fact could lead to a dangerous abuse of PPPs as a tool to avoid deficit or debt restrictions. Such abuse would unduly burden society, either directly through user charges or indirectly through the impact of future government payments (World Bank Institute 2012).

### **Market Drivers**

Current market conditions are one of the main drivers of the choice of procurement model. Market drivers—such as availability of appropriate contractors, competition in the market, package size of the project, and availability of financing—should be assessed to help the project-implementing agency to understand the business environment in which the project is to be awarded. Deep knowledge of the market allows project-implementing agencies to make informed selection decisions that balance cost, risk, business needs, and objectives (APTA 2010) (see box 8.2).

#### *Availability of Appropriate Contractors*

Project-implementing agencies need to be sure that appropriate contractors with experience in the desired project delivery model are available to work in the location of the project. In general, multilateral development banks (MDBs) require

**BOX 8.2.****Considering Market Drivers in Alternatives Analysis: São Paulo Line 18, Brazil**

As part of the alternatives analysis for the development of Line 18 of the São Paulo Metro, the government had to consider the market implications of using monorail technology that had only three manufacturers worldwide. The small number of monorail manufacturers would limit initial competition for the project bid and the options available to the government if something went wrong

with the original contract. Furthermore, the limited number of players in the monorail market could potentially lead to higher construction prices, offsetting the cost savings that were considered the main advantage of this technology. In São Paulo Metro Line 18, it was important to understand the limitations and the opportunities of extending the network using monorail technology.

international competitive bidding for urban rail projects, giving contractors and suppliers equal access to business opportunities, while also increasing competition and achieving economy and efficiency goals.

*Competition in the Market*

Project-implementing agencies have to determine how competitive the market is. If their procurement strategy is not designed to foster competition, they may bid the project in an imperfect market, which risks inflating the project price above the theoretical market price.

One way of attracting the attention of major contractors is to announce clearly the longer-term vision or program for developing the urban rail network beyond the project at hand. This can help to attract large global contractors that may not otherwise consider participating in a one-off bid. It can also incentivize the domestic construction industry to invest in developing the required capability. Although MDBs normally require international competitive bidding, which heightens the level of competition, it is possible to require international companies to hire local contractors to build up experience in the domestic construction market.

*Package Size of the Project*

Project-implementing agencies have to decide how to package the project to maximize efficiency and gain the most from market competition. If necessary,

small works and components can be combined to produce a more attractive lot that benefits from economies of scale, while large projects can be broken down into smaller packages (Gordon 1994). This is a major decision. Small contractors complain when the lots for bidding are too big. In such instances, only major contractors can bid, and small contractors are only able to participate as subcontractors. This can be of particular concern for low- and middle-income countries, where construction industries are less experienced and large lots often favor international contractors.

The project-implementing agency has to balance economies of scale with the number of potential qualified and interested bidders. Having just one lot, as in the case of Quito Metro Line 1 in Ecuador or Salvador Line 2 in Brazil, may generate economies of scale but also reduce the number of bidders. For Santiago Metro Lines 3 and 6, there were several lots to increase competition; the same was the case for São Paulo Line 5 (phase 2). The package size should be discussed at length by the project team so that all the advantages and disadvantages are mapped out for decision makers. An optimum-contract packaging strategy should be adopted that produces the lowest overall project costs, consistent with other political economy objectives.

#### *Availability of Financing*

When pursuing a private finance PPP option or when public project-implementing agencies wish to raise commercial financing directly for a part of the project, the availability of long-term financing at a reasonable cost and the mix of currencies chosen to mitigate exchange rate risk are relevant considerations. Chapter 10 discusses financing options for urban rail projects.

#### *Implications of Market Drivers*

Knowledge of the type of competition that exists is a prerequisite to developing the right procurement approach (see box 8.2). For example, in a monopolistic or oligopoly market (where one or a few suppliers hold all the power), designing a procurement approach that is characterized by competitive bidding, with significant risk transfer to the supplier and with supplier selection based on the lowest evaluated cost, is not likely to produce the most cost-effective outcome. In these circumstances, a negotiated approach based on open-book pricing potentially linked to a longer-term contract is more likely to be effective.

Since the 1990s, rail manufacturers that originally concentrated on their own domestic markets started to focus on international markets. Following a series of mergers and acquisitions, a few rail vehicle manufacturing giants have emerged, and increased competition has driven down prices dramatically

(Hein and Ott 2016). On the construction side, few contractors have extensive experience in underground construction in urban areas.

### **Risk Drivers**

Project-implementing agencies need to take a risk-based approach to developing their procurement strategy, seeking to choose the strategy that maximizes VfM. Different procurement strategies, including the choice of project delivery model and contract pricing mechanism, result in different allocations of risks between the public sector agency and private sector parties. Major financial risks that need to be allocated include design risk, construction risk, interface risk, and O&M risk (see chapter 7). The most effective approach to allocating these risks is to assign project risks to the parties in the best position to manage them.

### **Choosing a Compensation Mechanism**

Under any of the project delivery models discussed in this chapter, a contractor can be paid for the work performed using different compensation mechanisms. In most of them,<sup>9</sup> such payments relate only to civil or electromechanical works and equipment supply (with a component of interest rate and financial cost in the case of DBF). However, under PPP schemes, payments are made to compensate for construction and O&M (DBOM) and also to cover the repayment of private financing (DBFOM).

DBFOM incorporates specific compensation mechanisms during construction and operations. During construction, a portion of the capital expense is often financed directly by the government. During operations, the government pays the contractor based on the performance of the system or the effective use of the service (that is, part of the compensation comes from fare revenues or from government payments linked to demand). The options for compensation or payment mechanisms in the PPP context are discussed in detail in chapter 9.

The discussion of compensation mechanisms offered in this section is centered on traditional procurement methods. In this context, compensation mechanisms fall into three main categories—fixed price, reimbursable price, or a common hybrid known as guaranteed maximum price:

- Fixed-price mechanisms (such as lump sum or unit price) are the most commonly used and refer to schemes where a project-implementing agency contracts with an entity to deliver a given scope of work in exchange for an agreed fixed payment. For urban rail projects, the most common pricing

mechanism remains lump sum (fixed price). This mechanism is also applied to “nonconventional public finance methods” such as DBF or DBOM.

- In a reimbursable-price contract, the project-implementing agency contracts with an entity to perform a fixed or variable scope of work in exchange for a payment based on an agreed calculation method that is linked to actual quantities and costs.
- In a GMP contract, the project-implementing agency and contractor agree to a maximum price consisting of a base price plus various contingencies that may or may not be used.

### **Fixed Price**

There are two types of fixed-price compensation: lump sum and unit price.

#### *Lump Sum*

In a lump-sum contract, the contractor agrees to perform the stipulated work in exchange for a fixed sum of money. This lump sum commonly includes all labor, materials, project overhead, company overhead, and profit. A lump-sum contract places maximum risk and full responsibility for all costs and resulting profit or loss on the contractor and, therefore, provides maximum incentive for the contractor to perform efficiently. Furthermore, since the contractor’s cost experience is not a factor in determining compensation, it imposes a minimum administrative burden on the contracting parties (Institute of Urban Transport 2012).

A lump-sum contract is suitable for acquiring commercial products, construction, or services based on reasonably definite and detailed specifications and when a fair and reasonable price can be determined at the outset—such as when there is adequate price competition, there are reasonable price comparisons prior to purchase, or performance uncertainties can be identified and reasonable estimates of their impact on cost can be made.

When there is a high potential for unexpected situations and the project involves the integration of various components (for example, turnkey), contractors factor uncertainty into the price. Unless the contractors are sure that the project design used for bidding is detailed and vetted by third parties, they are not keen on lump-sum contracts. In order to minimize bid prices for lump-sum payments, milestones for payment have to be defined in a way that will ensure positive cash flows by providing sufficient working capital to undertake the next step of the project. Also, clauses on how to deal with problematic soil or water tables not identified in the project have to be spelled out clearly. If the project design is not detailed enough and the geotechnical surveys are

not comprehensive, chances are that bidders will allocate a substantial risk contingency to their prices.

### *Unit Price*

In a unit-price contract, the contractor agrees to be paid a set cost per unit of each item, such as per meter of track. The total amount paid is based on the actual measured units constructed in the project multiplied by the agreed unit price. The unit cost for each item commonly includes all labor, materials, project overhead, and company overhead.

Unit-price contracts are used when quantities cannot be determined in advance; for example, when uncertainties are too great to permit a lump-sum offer without a substantial contingency or when quantities can change significantly during implementation within certain limits (Institute of Urban Transport 2012). This is the most common method for developing urban rail projects and is preferred by contractors.

### **Reimbursable Price**

Reimbursable-price contracts are suitable for use when the nature and complexity of the procurement are such that the costs and performance cannot be estimated with the accuracy needed for a fixed-price contract. As this type of contract gives less incentive for efficient performance, provisions have to be made for appropriate surveillance by agency staff to curtail wasteful contractor spending (Institute of Urban Transport 2012).

There are two types of reimbursable-price contracts:

- *Cost-plus*. The contractor is reimbursed the cost of doing the work, including labor, materials, and project overhead, plus a fee (including company overhead and profit). The fee can be a fixed sum, a percentage of the cost, or a formula incorporating both.
- *Fixed fee*. The contractor is paid a lump-sum fee, including company overhead and profit, but is reimbursed for labor, materials, and project overhead.

### **Guaranteed Maximum Price**

Under a GMP compensation mechanism, the contractor is reimbursed the cost of doing the work (including labor, materials, and project overhead) and paid a fee (including company overhead and profit) up to a prearranged maximum price. Once that price is reached, the contractor must finish the job at no additional cost to the project-implementing agency. If the job is finished under the maximum price, the cost difference is often shared between the agency and the contractor as an incentive for the contractor to reduce costs. A GMP can be

very useful as a reimbursable contract with an upper limit, but it can also provide a false sense of security if the GMP is unrealistic. If it is too low, lump-sum adversarial relations may develop. If it is too high, the project-implementing agency is not guaranteed a reasonable price.

The agency's decision regarding the contract pricing mechanism should revolve around the allocation of financial risk—the risk of what the final cost of the project will be (Gordon 1994). Optimizing the cost of the project will depend on properly assessing and allocating risks and ensuring that each party manages the risks allocated to it (see box 8.3). Risk should be balanced between the

### BOX 8.3.

## Contract Pricing Mechanisms: Quito, Ecuador Metro Line 1 and São Paulo, Brazil Metro Line 4

### Quito Metro Line 1

Given the complexity and level of design for the construction of Quito Metro Line 1, the government of Ecuador decided to implement a unit-price contract for the construction of 23 kilometers of underground tunnel, 13 underground stations, a yard and maintenance shop, and all facilities for metro operations from track to electrification equipment (for more details, see tables 8A.1 and 8A.2 in the annex to this chapter). This contract was developed using international construction project standard contract forms written by the FIDIC.

The government of Ecuador used an FIDIC construction contract (Conditions of Contract for Construction for Building and Engineering Works Designed by the Employer) harmonized to be used in projects financed by MDBs. Such contracts are divided into two parts, the first containing general conditions and the second containing specific conditions related to the project. The benefit of using FIDIC contracts is that they feature a clear and balanced approach to obligations and responsibilities for each party (contractor and contract awardee) and transparent procedures for allocating risks. Furthermore, the government hired a consulting firm that specialized in FIDIC international construction contracts to provide support in

designing parts I and II of the contract.

### São Paulo Metro Line 4

The São Paulo Metro Line 4 project was developed through two main contracts: (a) a fixed-price turnkey contract for the provision of civil works and electrification for the 12.8 kilometers of metro line financed by the state of São Paulo, the Japan Bank for International Cooperation, and the World Bank and (b) a concession to operate the system for 30 years in exchange for the provision of rolling stock and systems, financed mainly by the private sector and the state. After signing the turnkey contract, the Brazilian *real* started to appreciate in relation to the U.S. dollar and the inflation rate began to rise, although at a steady pace. These macroeconomic trends affected the annual price readjustment formulas in the turnkey contract and resulted in the need for additional financing from the project financiers and a larger share of counterpart financing from the state of São Paulo. The impact of the contract price readjustment was estimated at US\$75 million. This highlights that even fixed-price contracts include price readjustment clauses that can result in a higher end-price.



project-implementing agency and the contractor or designer to use the incentive value of bearing risk while minimizing a contingency charged for accepting the risk (Levitt, Ashley, and Logcher 1980). A contractor's efficiency in handling risk is based on its power to control the risk, its potential reward for controlling the risk, and its financial position to assume the risk. Most contractors include in their bid a large contingency for any unknown or uncertain costs for which they bear the financial risk. Many project-implementing agencies put as much financial risk as possible on the contractor as an incentive for productivity. However, for a credible transfer of this risk, the security package included in the contract (such as performance bonds or retained payments) has to be sized appropriately to reflect this higher level of risk. If it is not and the risk materializes, the contractor may simply walk away and saddle the project-implementation agency with the risk (see chapter 7).

The project-implementing agency needs to choose a contract or series of contracts that most efficiently allocates the financial risk of the various parts of the project. Pushing all of the risk to a contractor with a lump-sum (fixed-price) contract is only recommended if the project is very well defined, which is particularly difficult for multifaceted and complex urban rail developments (Gordon 1994). This pricing scheme works best with project delivery models that award later in the project development process, after much of detailed design is complete and the cost of the project is well known. The other extreme, a pure cost-plus (reimbursable-price) contract, is almost never recommended except for exceptional cases where the project-implementing agency is confident of its ability to control costs.

## Choosing and Designing the Tender Process

### Choosing the Tender Process

In very broad terms, the process of procuring or selecting a contractor may consist of a competitive tender, an unsolicited proposal, or a direct selection:

- A competitive approach to the procurement of urban rail projects is the preferred approach, with very few exceptions. International competitive procurement is often required by MDBs for complex, high-risk, or high-value contracts, such as the procurement of urban rail goods and services and has been shown to provide important savings (box 8.4). Exceptions include situations in which only a limited number of firms can provide the goods and services.
- In direct selections, a project-implementing agency approaches and negotiates with only one firm. Direct selections are warranted in only a few cases,

**BOX 8.4.****The Importance of Fostering Competition in Rolling Stock Procurement: Rio de Janeiro, Brazil**

Over the last two decades, the state of Rio de Janeiro has made important investments in the modernization of its urban rail system, operated under a long-term concession scheme with private operator SuperVia. Under this PPP, the state pledged to invest in new trains, while SuperVia made a commitment to rehabilitate rail infrastructure, electrical and signaling equipment, and stations. With World Bank financing, the state acquired 112 new trains

(with four cars each) that provide greater comfort to users and are more energy efficient thanks to regenerative braking technology (see image B8.4.1). The successful acquisition of the trains was fundamental for improving the quality, frequency, and reliability of train service. This improvement attracted more users to the public transport system, discouraged private vehicle use, and reduced carbon emissions and air pollutants.

**IMAGE B8.4.1. New Train Acquired with World Bank Financing versus Older Model Still in Service**

Source: Daniel Pulido, World Bank.

*(box continues next page)*

**BOX 8.4.****The Importance of Fostering Competition in Rolling Stock Procurement: Rio de Janeiro, Brazil (Continued)**

A bidding process for the acquisition of a 60-train lot that was launched in 2011 culminated in a contract between the state and the CMC-CNRCRC Consortium in October 2012. The process was undertaken in record time and attracted most international equipment suppliers. The price of the lowest and winning bid was 40 percent lower than the budget estimate (based on the average of similar procurement processes in Brazil) and 18 percent lower than the prior train procurement conducted by the state. With these savings, the state was able to acquire more trains.

The success of this procurement process resulted from efforts to foster greater competition. Wanting to attract as many international suppliers as possible, the state decided not to include a domestic-preference clause (in contrast to other train procurement processes in Brazil). In addition, contrary to local regulations, the state did not disclose a reference price in the bidding documents. This allowed the state to

acquire high-quality equipment that met all of the system operator's technical requirements at a competitive cost.

Learning from this positive experience, the state sought to increase competition in its next rolling stock procurement process. In 2015, specifications in the bidding process were even more flexible (allowing any trains with four or eight cars and American or European standards) in order to attract more bidders and maximize competition.

In the acquisition of trains financed by the World Bank, both for São Paulo Metro and for the suburban rail company (CPTM), the results of competitive bidding were also impressive when compared with previous acquisitions. However, the results were not as good as in Rio de Janeiro because the state decided to adopt a domestic-preference clause, which favored manufacturers who would build trains in São Paulo. This led to a winning proposal, which was not the lowest once the 15 percent surcharge stipulated by the domestic preference was added.

such as low-value contracts or situations in which equipment is proprietary and can be obtained from only one source. In general, direct selection is not acceptable for financing from MDBs and other bilateral organizations.

- Unsolicited proposals or “privately initiated projects” have some benefits and may be appropriate in specific circumstances, especially when they allow for some degree of competitive tension (allowing interested third parties to bid under an open tender, even while reserving some limited advantages to the private initiator),<sup>10</sup> but their use should generally not be considered for projects that are strategically and appropriately planned.

The general rule should be to have open, international competition. According to the World Bank's *PPP Certification Guide*, “Competition is what brings

innovation into the equation, as companies under competitive pressure have the incentive to innovate to be efficient and proactively assess and manage the risks in the most efficient manner. Clearly, without competition, the price of the same project with the same approach will be higher” (World Bank Institute 2012).

A competitive tender process may be organized and handled in different ways (to the extent allowed by the given procurement framework). A typical tender process is structured and ruled by a document or set of documents commonly known as a request for proposals (RFP). RFPs include the requirements to be followed to submit a qualifiable offer or bid, the criteria that will be used to select the awardee, and (within the very same document or in an annex) the contract. The RFP may be inclusive of the qualification criteria (that is, the capacity and capability conditions to be met by each of the bidders for their offers to be accepted), or qualifications may be requested previously in a specific document, usually referred to as a request for qualifications (RFQ).

The first choice to be made when designing the tender strategy is whether to establish two phases—(1) “prequalification” to evaluate the sufficiency of the capacity or qualify the bidders through an RFQ, and (2) inviting those that prequalified to submit their bids through an RFP—or to organize the process in a single stage so that qualifications and bids are submitted at the same time. Prequalification is appropriate for large or complex contracts where there is a need for custom-designed equipment or specialized services. It is also appropriate in procurement processes for PPPs that integrate various services and where the high costs of preparing detailed proposals or bids could discourage competition (World Bank 2016).

The selection of the most convenient type of tender process will depend on various factors and objectives (such as the level of detail of completed design and availability of applicable technology, size of project, relevance of risks, existence of short political time frames, as well as what is allowed in the legislation in place). The more complex the project, the more convenient it may be to introduce interaction and communication with the private sector. A key aspect for the success of the selection process is to create avenues for productive dialogue between the public and the private sector. However, legislation does not always allow for this type of approach.<sup>11</sup>

### **Designing the Tender Process**

Once the project owner has chosen the type of tender process, it must define how it will select the contractor or contractors that will implement the project (and at what price) in the RFP (and, in some cases, the RFQ as a separate document). The owner uses market forces and expertise to obtain the desired value at the most reasonable price. The main objective of the selection or

award process is to ensure economy, efficiency, and transparency in delivery of the project. Such goals can only be achieved by properly defining the project's technical specifications, setting clear and balanced qualification requirements, and promoting robust and reliable competition by selecting appropriate evaluation criteria.

### *Defining Project Specifications*

Defining project specifications is the first step in the procurement and tender process and the one on which its success most depends. The more responsibility that is transferred to the private sector, the more important it is to specify clear performance targets that are specific, measurable, achievable, reasonable, and time-bound; to include penalties or payment deductions for failure to meet these performance targets; and to establish performance monitoring mechanisms and means to enforce penalties for failure to comply with targets. The level of detail of the project specifications depends on the project delivery model being used and the completeness of the design documents.

### *Setting Qualification Requirements*

The project-implementing agency needs to define technical, financial, and legal qualification (or prequalification) requirements to ensure that bidders have the required capacity to undertake the project. However, setting the bar too high may limit competition, particularly in markets where potential qualified bidders may not be active due to considerations of scale. Table 8A.1 in the annex to this chapter summarizes the prequalification and qualification requirements in some recent urban rail projects.

To preclude the possibility of collusion in bidding processes, some project-implementing agencies have imposed rate-of-return limits through maximum reference prices, rather than letting the market define a price. The idea is that limiting the rate of return protects the owner from paying too much if interested companies collude to submit only one bid for the project. This approach may also limit the interest of potential bidders and reduce competition. Hence, it is important to open up the procurement process to international firms and to drop any requirements that may prevent foreign companies from bidding.

### *Considering Selection Criteria*

Given their size and nature, urban rail projects are developed through various multimillion-dollar contracts covering preconstruction services, construction, and supervision. Project-implementing agencies will be subject to pressure from different industries and must ensure that they conduct the procurement process with due attention to the need to ensure transparency, integrity, and fairness.

This is very important, particularly because, in some countries, political parties may seek legal and illegal contributions from major civil works projects. MDBs have strict clauses against corruption and fraud, and safeguards against this are critical for any project.

The risk of fraud may be mitigated by developing clear and transparent evaluation or selection criteria, limiting subjectivity to the maximum extent possible, and establishing internal manuals and procedures for evaluation that ensure integrity and fairness to the maximum extent possible. Putting in place credible and efficient bidder protest mechanisms may help to hold implementing agencies accountable in case of noncompliance.

Urban rail projects are complex endeavors; as such, proposal selection criteria should be used carefully to evaluate contractors. Using a best-value contracting approach that makes final selection based on a mix of factors such as cost, quality, and expertise (rather than lowest bid) is a good practice. In general, market mechanisms will guide the price of the bids, meaning that market forces (if competition exists) will determine a price range for concessionaires to carry out the task. However, some outliers may exist, and selecting the lowest-cost proposal may not bring the best value. In a recent study, the Los Angeles County Metro Authority found that (a) unknown or inexperienced contractors represent high risk to project success, (b) a best-value procurement process is a good practice, and (c) low-bid contracting on major, complex projects, such as urban rail, is problematic.

## **MDB Procurement Requirements**

The implementation of an adequate procurement approach also has implications for the availability of financing. The World Bank and other MDBs have established procurement regulations with which borrowers have to comply. These regulations are designed to ensure that loan proceeds are used with due attention to the considerations of economy, efficiency, and transparency.<sup>12</sup>

The World Bank requires agencies that are implementing projects with Bank financing to prepare a Project Procurement Strategy for Development (PPSD) and a specific procurement plan. The PPSD should address how the procurement activities will support the development objectives of the project and deliver the best VfM under a risk-based approach. It should also provide adequate justification for the procurement methods selected. The procurement plan should describe the activities, selection methods, cost estimates, time schedules, and any other relevant information for planning the implementation of the procurement process. Considering the size and complexity of urban rail

projects, the PPSD should have a high level of detail and analysis proportional to the level of risk. For World Bank financings, the project-implementing agency prepares the PPSD and submits it to the Bank for approval prior to loan negotiations.

For PPP projects, World Bank guidelines require that the project has been identified as a priority investment or derived from an approved national infrastructure plan or sector program. In addition, the project-implementing agency (directly or indirectly the borrower of a World Bank loan) must provide proof that the underlying project is adequately justified on the basis of a sound economic analysis; that the project's revenue requirements are within the capacity of users, the government, or both to pay for the infrastructure services; and that the project risks were identified and assessed and mitigation measures were considered. Concerning this last requirement, the borrower is required to present a risk matrix that exhaustively lists project risks and their allocation among the parties in the principal and subsidiary PPP agreements. In addition, the borrower is required to establish a payment mechanism based on performance.

Regarding the selection method, the borrower has to use a selection method that is consistent with the World Bank's procurement guidelines. The borrower may proceed with procurement prior to engaging with the Bank, but an ex post evaluation of the initiated procurement processes and awarded contracts must find them to be consistent with the Bank's procurement regulations in order for the project to receive financing.<sup>13</sup>

## Conclusions and Recommendations

Having described the key issues that project-implementing agencies will face in choosing a procurement strategy, it is useful to consider the actual outcomes (in terms of efficiency, economy, and transparency) of recent procurement processes in the urban rail sector (see table 8A.2 in the annex to this chapter). In addition to learning from the experience of other projects are general recommendations for decision-makers evaluating the procurement of an urban rail project:

***Project-implementing agencies should invest in planning and feasibility studies as a first step in determining the appropriate procurement strategy.*** Project-implementing agencies should first concentrate on procuring the studies required to conceptualize the project and determine its feasibility (see chapters 3–6). High-quality, comprehensive studies implemented by capable consultants are the foundation for successful project development and are a

necessary input in choosing the appropriate procurement strategy for the project. Project-implementing agencies should allocate sufficient time and resources to the selection, award, and supervision of the firms carrying out these studies and communicate this information to decision makers choosing the method of project procurement.

***The procurement method needs to be chosen relatively early in the project development process, particularly when involving private participation.***

A procurement model needs to be chosen relatively early. Its suitability is fundamental to project success, defined as the on-time, under-budget (or cost-effective), and quality delivery of the specified project, with safe, efficient, and financially sustainable operations serving the projected demand at overall life-cycle costs in line with good industry practice. While the project concept is being developed, a key input is to decide how it is going to be procured. Procurement regulations, or lack thereof, may sometimes lead to changes or adjustments in the project concept. It is less costly (in terms of budget and delay) to make these changes early in planning and preliminary design.

***There is no single “best” project delivery model.*** It is important to match the project delivery model to the characteristics of the project, capabilities and absorptive capacity of the project-implementing agency, and international and national market characteristics. A careful study of each of these project, agency, and market drivers is an important input in deciding the most appropriate procurement strategy.

***Considering the requirements of MDBs is crucial to facilitate the approval and provision of financing from these sources.*** It is important to anticipate the requirements of MDBs to facilitate the approval and provision of multilateral financing, especially when the project is started without their support. Later on, if they are asked to consider financing, compliance with their procurement guidelines is a major aspect in favor of authorization.

***It is important to ensure that the project-implementing agency management and staff have the capacity to implement the delivery model chosen.*** If this is not the case, they should complement their own capacity with the external expertise required to adequately manage the implementation and supervision of the selected model. This is a particularly critical point for project-implementing agencies in countries or cities constructing their first urban rail line.

Potential consultants that the project-implementing agency may engage to complement or supplement their experience include the following: (1) a project preparation consultant specializing in urban rail systems; (2) a project engineering consultant to prepare the detailed design; (3) a value engineering consultant to vet the proposed project design; (4) project management consultant to



manage the project implementation; and (5) a supervision consultant to oversee and approve project implementation and variation orders. The implementing agency may choose to procure a project management consultant early to manage many of the preparation, bidding, implementation, and supervision functions (see chapter 4). When the procurement is going to be based in a PPP approach, it is important to determine the presence and role to be played by a transaction adviser with specific experience in the technical, legal, and financial structuring of PPPs in this sector (see chapter 9).

## Annex 8A. Qualification Requirements and Results for Recent Urban Rail Project Procurements

**TABLE 8A.1. Qualification Requirements for Recent Projects**

PROJECT	COMPONENT	MAIN REQUIREMENTS
Lima Metro Line 2 (DBFOM)	Construction	<p><i>Specific experience</i></p> <p>(a) 1 project of 15 kilometers, 15 stations, and US\$800 million investment or 4 projects totaling 20 kilometers, 20 stations, and US\$1 billion investment;</p> <p>(b) 10 years in the supply and installation of electromechanical equipment with no less than 15 kilometers of ATP</p> <p><i>Equity</i></p> <p>US\$500 million</p> <p><i>Existence</i></p> <p>Minimum 7 years</p>
	Operation	<p><i>Specific experience</i></p> <p>Operating at least 1 type of metro underground railroad system or urban railroad system with &gt; 150 million passengers per year; passengers from more than 1 system cannot be considered</p> <p><i>Equity</i></p> <p>US\$200 million</p> <p><i>Existence</i></p> <p>10 years minimum</p>
	Rolling stock	<p><i>Specific experience</i></p> <p>Average annual production of 240 urban (metro) train cars; production of 20 trains a year with ATP technology</p> <p><i>Equity</i></p> <p>US\$400 million</p> <p><i>Existence</i></p> <p>7 years minimum</p>

(table continues next page)

**TABLE 8A.1. Qualification Requirements for Recent Projects (Continued)**

<b>PROJECT</b>	<b>COMPONENT</b>	<b>MAIN REQUIREMENTS</b>
<i>São Paulo Line 6 (DBFOM)</i>	<i>Construction</i>	(a) Participation in investment of at least R\$2 billion; (b) implementation of underground tunnel using TBM method featuring a minimum section of 25 square meters and minimum extension of 2,200 meters in urban area; (c) experience in the delivery of track superstructure using effective mass (spring-mass) system
	<i>Operation</i>	Operation of metro rail line featuring at least an average of 200,000 passengers per day, for at least 6 consecutive months
	<i>Financial</i>	Net worth of at least R\$850 million (individual) or R\$1.1 billion (consortium)
<i>Lima Metro Line 1 (EOT)</i>	<i>Operation</i>	Experience as an operator of one or more subway, light rail or tram, or interurban urban passenger rail systems, with a minimum demand in the last 3 years of 20 million passengers transported each year. This experience can be accredited through a strategic partner.
	<i>Rolling stock</i>	To be a supplier of rolling stock that has sold at least 250 cars in the last 3 years
	<i>Financial</i>	Net worth of at least US\$40 million Sales of at least US\$80 million per year
<i>São Paulo Line 4 (EOT)</i>	<i>Participation in major projects</i>	Demonstrate participation in at least 1 project in which the amount of the investment has been at least US\$150 million. Demonstrate participation in other projects in which the amount of the investment in each of them is at least US\$50 million.
	<i>Operation</i>	Operated for at least 3 consecutive years, metro or rail transport systems, alone or in consortium, with at least 250,000 passengers per day, obtained in the last 2 months
	<i>Financial</i>	Net worth of at least R\$81.7 million
<i>Quito Line 1 (DBB)</i>	<i>Financial</i>	(a) Indebtedness indicator: $\leq 85\%$ for consortium (weighted average) and $\leq 80\%$ for each partner (last 5 years); (b) average profitability (last 5 years) $> 0$ for each partner and for the consortium; (c) minimum liquid assets: for the consortium $\geq$ US\$150 million; (d) average turnover (last 5 years): for consortium $>$ US\$1.1 billion, for leader $>$ US\$550 million

*(table continues next page)*

**TABLE 8A.1. Qualification Requirements for Recent Projects (Continued)**

PROJECT	COMPONENT	MAIN REQUIREMENTS
Quito Line 1 (DBB) (continued)	Construction	<p><i>General experience</i></p> <p>Experience in construction contracts completed in the last 10 years: (a) at least 1 contract <math>\geq</math> US\$500 million (leader); (b) at least 2 contracts <math>\geq</math> US\$300 million; (c) other contracts up to US\$2.2 billion in contracts with amounts <math>\geq</math> US\$100 million each</p> <p><i>Specific experience</i></p> <p>Experience in contracts for the construction of at-grade, elevated, or underground works completed in the last 10 years with a physical progress greater than 70%: (a) at least 2 contracts <math>\geq</math> US\$350 million; for leader: at least 1 contract <math>\geq</math> US\$350 million; (b) at least 1 contract must integrate civil works with at least 3 equipment and facilities contracts; (c) other contracts up to US\$1.65 billion in contracts with amounts <math>\geq</math> US\$75 million; for leader: at least US\$825 million in contracts over US\$75 million</p> <p><i>Key experience</i></p> <p>Minimum experience in projects in which physical progress is equal to or greater than 70% of the contract (last 10 years)</p> <p><i>Component 1:</i> (a) Tunnels for simultaneous double railway track, with TBM or EPB tunneling machines, adding at least 6 kilometers in length; for leader: 3 kilometers ; (b) tunnels for simultaneous double railways, at least 2 kilometers in length, by conventional or traditional method (not including cut-and-cover); for leader = 1 kilometer; (c) at least 100,000 cubic meters of underground reinforced concrete walls, executed by cut-and-cover or between screens, in different infrastructure works; for leader = 50,000 cubic meters</p> <p><i>Component 2:</i> At least 3 projects in following areas: signaling, electrical substations, power distribution, electrification, telecommunications, and central control; equipment and facilities system <math>\geq</math> US\$150 million, in a maximum of 4 contracts. At least 1 of the contracts must be for minimum of 7 kilometers of line and 4 passenger stations.</p>

(table continues next page)

**TABLE 8A.1. Qualification Requirements for Recent Projects (Continued)**

PROJECT	COMPONENT	MAIN REQUIREMENTS
<p>Quito Line 1 (DBB) (continued)</p>	<p>Rolling stock</p>	<p><i>Specific experience in manufacturing</i>                      (a) Supply and operation implementation contracts for heavy metro rolling stock; minimum of 10 contracts in the past 15 years; (b) demonstrate that the train fabrication plant proposed has been fabricating rolling stock for at least 10 years; (c) demonstrate that the train fabrication plant proposed has manufactured at least 800 heavy rail cars in the last 10 years; (d) at least 1 rail car fabrication contract to manufacture trains with GoA2, including signaling subsystems featuring ATP and ATO.</p> <p><i>Specific experience in maintenance</i>                      (a) At least five heavy metro rail car maintenance contracts in the last 10 years in any geographic location; (b) at least two heavy metro rail car maintenance contracts in the last 10 years in Latin America; (c) the maintenance contracts must have included predictive, preventive, programmed, and corrective maintenance considerations; (d) at least 1 supply and implementation contract on a heavy metro rail system currently operating and transporting &gt; 20,000 passengers per hour per direction</p>

Note: ATO = automatic train operation; ATP = automatic train protection; DBB = design-bid-build; DBFOM = design-build-finance-operate-maintain; EOT = equip-operate-transfer; EPB = earth pressure balance shield; GoA = grade of automation; TBM = tunnel boring machine.

**TABLE 8A.2. Results of Recent Procurement Process**

PROJECT	PRIVATE CAPITAL (INITIAL INVESTMENT)	COMPETITION FACTOR	NUMBER OF OFFERS	WINNING CONSORTIUM	DIFFERENCE RELATIVE TO REFERENCE
São Paulo Line 4 (2006)	US\$246.1 million; 18% of total cost (rolling stock)	Lowest availability payment; maximum = R\$120 million per year	2 availability payments of R\$75 million (30-year concession)	ViaQuatro: Companhia de Concessões Rodoviárias, Montgomery Participações, RATP Development, Benito Roggio Transporte S.A.	R\$45 million per year (60%)
Hyderabad (2010)	90% of total cost	Lowest VGF requested; maximum = US\$720 million	3 financial offers (8 prequalified consortia); VGF = Rs 1,458 crore (US\$220 million)	L&T Metro Rail, a special-purpose vehicle 100% owned by Larsen & Toubro	US\$500 million
São Paulo Line 6 (2013)	US\$2.5 billion; 50% of capital expenses	Lowest availability payment; maximum = R\$606.81 million per year	1 availability payment of R\$606.79 million for 19 years (25-year concession with 6 years from construction)	Consórcio Move São Paulo: Odebrecht (Brazil), Queiroz Galvão (Brazil), UTC (Brazil), and Fundo Eco Realty (Brazil)	-R\$25,000 per year (0.04%)
São Paulo Line 18 (2014)	US\$900 million; 50% of capital expenses	Lowest availability payment; maximum = R\$316.8 million per year	1 offer: R\$315.9 million for 21 years (25-year concession with 4 years from construction)	Consórcio ABC Integrado: Primav (Brazil), Encalso (Brazil), Cowan (Brazil), and Benito Roggio (Argentina)	R\$855,355 per year (0.27%)
Lima Line 2 (2014)	US\$1,651 million; 31% of capital expenses	Lowest cofinancing amount; maximum = US\$386 billion and lowest O&M payment; maximum = US\$134 million	1 offer: US\$369 million of cofinancing and US\$108.9 million of O&M payment	Consorcio Nuevo Metro de Lima: Cosapi S.A. (Peru), Salini Impregilo Sp.A. (Italy), Iridium Concesiones de Infraestructura S.A. (Spain), Vialia Sociedad Gestora de Concesiones de Infraestructura S.L. (Spain), AnsaldoBreda Sp.A. (Italy), and Ansaldo STS Sp.A. (Italy)	US\$170 million (4%) in capital expenses and US\$25 million (18%) in O&M expenses
Quito Metro Infrastructure (2015)	N.A. (public works)	Lowest price (unit price)	7 consortia submitted a request for prequalification; 4 consortia prequalified; 4 consortia presented offers	Acciona Infrastructure (Spain)-S.A. Odebrecht (Brazil)	The offer was US\$1,777 billion, which was above the reference value by about US\$460 million

Note: N.A. = not applicable; O&M = operation and maintenance; VGF = viability gap funding.

## Notes

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1. Although some specific components of urban rail projects (for example, a new ticketing system or station) may deserve a single and specific procurement, this chapter focuses on the development of a new or extended urban rail line as a whole system, including operations and maintenance.
2. According to the *PPP Certification Guide*, the purpose of a VfM assessment is to indicate if a project would be implemented more efficiently under a public-private partnership scheme or under some other procurement method from the perspective of the procuring authority and society (ADB et al. 2016). VfM assessments typically involve a combination of qualitative and quantitative analyses.
3. The Portland MAX LRT system Red Line extension to the Portland International Airport was procured with a DBF contract awarded to Bechtel Engineering, which agreed to finance US\$25 million (or about one-quarter) of the US\$125 million project. Bechtel also received the rights to develop a 12-acre lot adjacent to one of the stations along the route (TriMet 2012).
4. In 2012, the province of British Columbia entered into a performance-based fixed-price project agreement with a private partner (EGRT Construction) to design, build, and finance the guideway, tunnel, and stations; install the automatic train control and other systems; and test and commission the Evergreen Line. The term of the contract was approximately 3.5 years, and the fixed price was US\$889 million (Partnerships British Columbia 2013).
5. Additional variants of the EPC contracting method are not covered here, particularly engineering, procurement, construction, and maintenance (EPCM), which incorporates some features of the construction manager delivery method into EPC contracts (Loots and Henchie 2007).
6. The World Bank, other multilateral development banks, and academic institutions have developed multiple definitions of PPP and provided various recommendations for practitioners (World Bank Group et al. 2014).
7. In most DBF or DBFOM (the most common forms of private finance PPPs) contracts, the private partner brings part of the financing for the project, but not necessarily all of it. The public sector can provide part of the financing in what is known as “cofinanced projects.” In urban rail projects, it is quite uncommon for PPPs to have 100 percent of financing supplied or raised by the private partner. Cofinancing is discussed in detail in chapters 9 and 10.
8. The decision point for a project delivery model should not be confused with the time of bidding or the time of engagement of the builder. For example, a project-implementing agency may decide to engage a DB contractor at the end of preliminary engineering in order to clarify project scope and reduce uncertainties.
9. Those compensation mechanisms related only to the construction, which are typically financed directly or indirectly (as in DBF) by the public sector and, therefore, are regarded as “public finance methods.”
10. Some governments have developed procedures to transform unsolicited proposals for private infrastructure projects into competitively tendered projects (UNESCAP 2011). By doing this, the initiator knows from the outset that the project will be tendered and other parties will be allowed to bid for it; as the initiator, a firm may be granted certain rights, usually a limited bonus in the scoring (in addition to the right to recover its investment in the studies). When the right includes a “right of refusal,” the incentive for competition is lost, and the context is much more like a direct negotiation.
11. ADB et al. (2016, ch. 4, app. A), “Different Approaches to Tender Processes,” summarizes the main factors to be considered when designing an RFP and the main types of competitive tender processes used worldwide.

12. The World Bank's new procurement framework, launched in 2016, incorporates greater flexibility for borrowers or project-implementing agencies in setting procurement strategies and plans that adapt to their specific needs (World Bank 2016).
13. For more information on World Bank procurement policies, see World Bank (2016).

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# 9

## STRUCTURING PUBLIC-PRIVATE PARTNERSHIPS

Daniel Pulido and Cledan Mandri-Perrott

Increasingly, governments both in high-income and in low- and middle-income countries are using public-private partnerships (PPPs) to develop urban rail projects. In the context of this handbook, a PPP involves a long-term contract between a public and a private party for the development (or significant upgrade) and management of an urban rail project (including potential management of the transport service) in which the private party bears significant risk and management responsibility throughout the life of the contract, and remuneration is linked to system performance or ridership (ADB et al. 2016).

Chapter 7 describes the main risks that project-implementing agencies face when developing urban rail projects and introduces PPPs as a way to manage these risks. Chapter 8 defines the different types of PPPs and introduces their advantages and disadvantages relative to other project delivery models.

This chapter presents the lessons from international experience in PPPs in urban rail, discusses how and where to incorporate the private sector, describes the purpose of the different contracts and contractual relationships that form an urban rail PPP project structure, and explains the main issues that project-implementing agencies need to consider when structuring PPPs: allocation of risk, definition of a payment mechanism, performance monitoring, and other key contractual provisions. It concludes with some recommendations for project-implementing agencies to get the most out of PPPs in urban rail development.

*Photo:* Bangkok Skytrain, 2014. *Source:* Michael O’Gorman via Flickr (CC BY-ND 2.0).

A more detailed discussion of the steps and tasks involved in the PPP cycle is beyond the objectives of this handbook. This chapter explains the fundamentals of structuring, drafting, and managing the contract and related tasks that are particularly relevant for an urban rail project. The *PPP Certification Guide* contains a detailed explanation of the main tasks and sequence of work for all phases of the PPP cycle, including some aspects that are discussed only superficially in this chapter, such as the appraisal and preparation of PPP projects and the process required for structuring and drafting the PPP contract and tender documents (ADB et al. 2016).

Chapter 10 introduces the concept of private finance and the potential sources of capital that private partners can tap into to develop their projects. It also introduces the concept of bankability, which is one factor considered in choosing a PPP structure, and describes key provisions supporting bankability that need to be included as part of the PPP agreement.

### PPP Experience in Urban Rail

Although many operating concessions in urban rail have been extremely successful in improving performance and financial sustainability—as proven by the positive results achieved through the concession of the suburban railways and metros of Buenos Aires, Argentina, and Rio de Janeiro, Brazil—the experience with green-field PPPs has been mixed. Early urban rail PPPs serve as cautionary tales for how difficult it can be to structure and sustain PPPs for large and complex urban rail projects. Despite these initial difficulties, the use of PPP arrangements for urban rail projects is on the rise. Out of the projects in operation, the Kuala Lumpur Monorail (awarded in 1997), Malaysia, and São Paulo Line 4 (awarded in 2006), Brazil, are examples of successful PPPs.

#### Early Private Participation in Urban Rail Projects: Cautionary Tales

In the 1990s, half a dozen PPPs for new urban rail projects (mostly at-grade light rail or elevated metro) were implemented in East Asian cities (for example, Bangkok, Kuala Lumpur, and Manila). These PPPs had difficulties, including delays, cost overruns, and contract defaults. The early urban rail PPPs in East Asia took, on average, nine years from development of the project concept to the start of operations. Of these nine years, approximately four corresponded to project construction. Delays often arose when project design was refined after the initial contract, revealing new information about the investment needs and costs. Two concessions for light rail development in Kuala Lumpur went into bankruptcy due to low ridership and had to be rescued by the government.

In other cases, construction risks involved in underground projects proved to be too high for the private sector to assume. The Blue Line project in Bangkok, Thailand, was initially launched as a full concession, but was subsequently unbundled, with the public sector ultimately taking responsibility for construction and only bidding out a concession to equip and operate the line (Phang 2007).

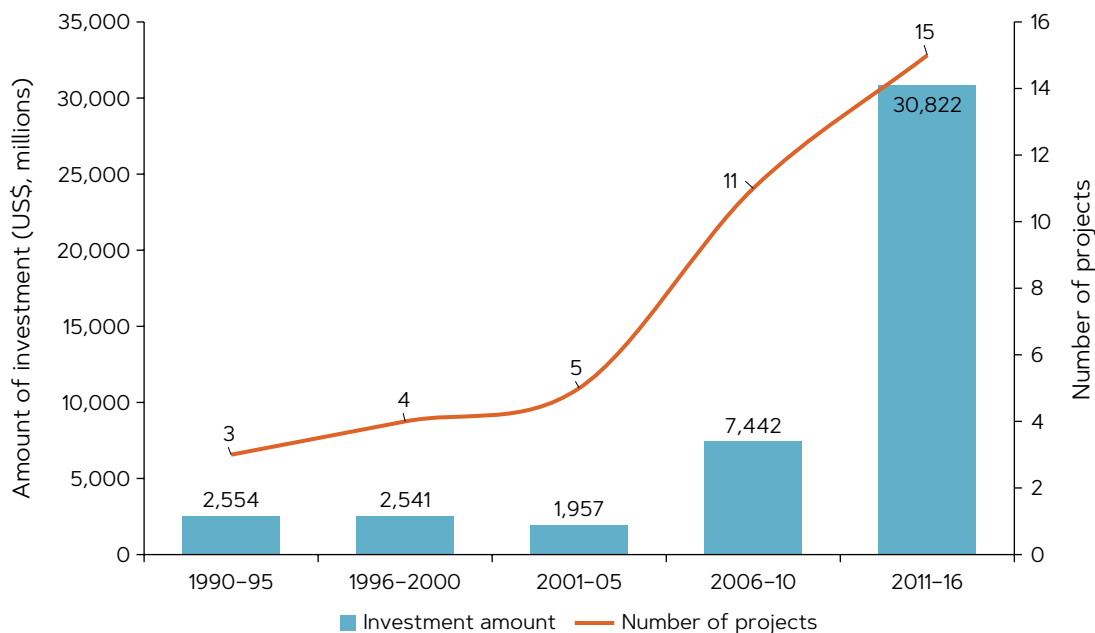
More recently, the Delhi Airport Metro Express Line operation and maintenance (O&M) PPP in India was delayed when defects were found in the infrastructure procured by the public sector in a separate contract. Even after revenue service began, the PPP faced problems such as lower-than-forecast ridership. Ultimately, after a dispute with the private partner, the government had to take over the project.

### **Recent Private Participation in Urban Rail Projects**

Despite the difficulties experienced by this first wave of urban rail PPPs, there has been a large increase in the number of urban rail projects with private participation since the early 2000s. According to data from the World Bank's Private Participation in Infrastructure database, a total of 16 rail projects involving private participation reached financial close in the first decade of the 2000s, more than double the number of projects in the 1990s (World Bank 2017). Since 2011, 15 more projects have reached financial close, with a total investment amount (including both public and private investments) of US\$30.8 billion (see figure 9.1). The total length (kilometers) of urban rail networks developed under PPP schemes almost doubled in the last five years (2012–16) relative to the preceding five-year period (see table 9.1).

Moreover, compared with PPPs in the early 1990s, most recent projects are larger and more complex, involving heavy rail systems with large underground sections and various functions integrated under a single contract. Until recently, fully bundled PPPs—contracts integrating design, finance, construction, and operation and maintenance—had been used mostly for simpler projects: at-grade or elevated trams or light rail projects. Before the Lima Metro Line 2 project (awarded in 2015 and currently under construction), Peru, very few projects involving underground construction had been done through fully bundled concessions (with the exception of small portions of Vancouver's Canada Line and Kuala Lumpur's STAR system). In addition, before the massive 71-kilometer Hyderabad Metro PPP project (awarded in 2011) in India, rail lines developed under a single fully bundled contract in Malaysia, the Philippines, and Thailand ranged from 9 to 29 kilometers (18 kilometers on average).

Although the final outcomes of the most recent PPPs for urban rail systems are yet to be seen, private participation in the development of these complex megaprojects is on the rise (see figure 9.1) and governments are

**FIGURE 9.1. Urban Rail Projects Involving Private Participation in Low- and Middle-Income Economies, 1990–2016**

Source: World Bank 2017.

**TABLE 9.1. Recent Urban Rail Projects in Low- and Middle-Income Countries Involving Private Participation, 2006–16**

PROJECT	COUNTRY	FINANCIAL CLOSE YEAR	TOTAL PUBLIC AND PRIVATE INVESTMENT (US\$, MILLIONS)	RAIL LENGTH (KILOMETERS)
Beijing Subway Line 4	China	2006	577	29
Buenavista-Cuautitlán Suburban Rail	Mexico	2006	639	27
São Paulo Metro Line 4	Brazil	2008	515	12.8
Mumbai Metro One (Line 1)	India	2008	363	13
Shenzhen Metro Line 4 (phases I and II)	China	2009	858	20.5
Delhi Airport Metro Link	India	2009	596	22.7
Rapid Metro Rail Gurgaon Ltd.	India	2010	238	6.1
Lima Electric Train Line 1	Peru	2011	290	11.7
L&T Hyderabad Metro Rail Private Ltd.	India	2011	3,640	71.16
Mumbai Metro (phase II)	India	2011	2,515	32

(table continues next page)

**TABLE 9.1. Recent Urban Rail Projects in Low- and Middle-Income Countries Involving Private Participation, 2006–16** (Continued)

PROJECT	COUNTRY	FINANCIAL CLOSE YEAR	TOTAL PUBLIC AND PRIVATE INVESTMENT (US\$, MILLIONS)	RAIL LENGTH (KILOMETERS)
Hangzhou Metro Line 1	China	2012	1,314	53
Beijing Subway Line 14 (part B)	China	2013	2,419	47.3
Metro Rio Line 4	Brazil	2013	3,611	16
Salvador Metro	Brazil	2013	1,657	33.4
São Paulo Metro Line 6 (Orange Line)	Brazil	2014	3,786	16
Beijing Metro Line 16	China	2015	2,295	50
Lima Metro Line 2	Peru	2015	6,445	35
Manila Metro Rail Transit Line 7	Philippines	2016	1,287	23
VLT Baixada Santista	Brazil	2016	594	7.5

Source: World Bank 2017.

increasingly interested in exploring this option. As more and more low- and middle-income countries adopt PPP laws and regulations, and in a context of limited fiscal space, use of the PPP delivery model for urban rail will likely increase.

### Rationale for Using a PPP

Most urban rail projects around the world have been funded and built and are being operated by public project-implementing agencies. PPPs have been more extensively and successfully used to develop other types of transport projects characterized by lower investment costs, capacity to generate revenues in foreign currency, and ability to cover investment and operating costs with user tariffs (for example, airports and container terminals). Although other transport PPPs face demand risks, they can be shielded from competition via contractual clauses more easily than an urban rail system, which competes with other transport modes under the jurisdiction of different authorities, including private vehicles.

If the results for urban rail PPPs have been mixed and they are more difficult to prepare and structure than those for other types of transport projects, why are project-implementing agencies pursuing them? Chapter 8 explains some of the factors driving the procurement decision, including project-implementing

agency experience, market drivers, and legal and regulatory framework. Cities around the world have been increasingly turning to private sector participation, seeking to achieve value for money (VfM) and to mobilize private financing to complement constrained public resources.

### **Value for Money**

VfM is defined as the optimal use of public resources to achieve intended policy outcomes (U.K. National Audit Office 2017). PPPs in urban rail achieve VfM when they can realize economy, efficiency, and effectiveness in project delivery. VfM analysis assesses whether a project would be implemented more efficiently under a PPP scheme or under traditional procurement (ADB et al. 2016). VfM analyses may be quantitative, qualitative, or both.

#### *Quantitative VfM Analysis*

A quantitative VfM analysis compares, in present value terms, the financial projections of the project based on traditional procurement (called the *public sector comparator*) with those based on the PPP delivery model or models under analysis. If the difference is positive in favor of the PPP—that is, if the present value of all net payments projected in the PPP mode are lower than in the public sector comparator—then the PPP is said to provide VfM.

The public sector comparator projections consist of the estimated government payments necessary to cover capital (construction) and O&M expenses net of user and ancillary revenues. In these projections, base construction and operating costs generally include an upward adjustment for the public sector retaining most of the risks under the traditional procurement model. In the PPP model projections, the estimated government payments to the private partner are included according to the potential terms of the PPP agreement.<sup>1</sup> The financial projections would include the estimated value of the risks retained by the public sector under the PPP agreement. The base construction and O&M costs would be adjusted upward to account for the risk premiums that contractors would be expected to charge to assume transferred risks and downward to reflect the efficiencies expected from private participation in the project (duly assessed during the evaluation of commercial feasibility).

When retained by the procuring authority, fare revenues would be deducted from the government payment projections. When assigned to the private partner, fare revenues would be reflected in a lower government payment to the private partner. In this last case, fare revenue projections should be high enough that the private partner can expect reasonable profits from its participation in the project.



The analysis uses a discount rate that accurately reflects the expected timing of payments. VfM analysis mainly uses the “opportunity cost” (cost of public financing) and “social rate of time preference” (value that society assigns to present, as opposed to future, consumption) as discount rates (HM Treasury 2013).<sup>2</sup>

### *Qualitative Considerations and Sensitivities*

The results of any quantitative VfM should be presented as ranges that account for a set of sensitivities rather than a point estimate. Qualitative factors—such as the alignment of incentives between the project owner and private partner(s) as well as public and political support—should be considered in the decision as well. According to the European PPP Expertise Center, “The incentives which are specific to PPP projects are specifically intended to deliver greater non-financial benefits than conventional procurements. Ignoring this issue could lead to an unwarranted bias against PPPs” (EPEC 2012a).

### **Complementing Constrained Public Resources**

In practice, one of the main reasons for the heightened interest in PPPs has been the opportunity to mobilize private cofinancing. However, the ability of such PPPs to raise long-term commercial financing based solely on the merits of the urban rail project remains limited due to their complexity, risk, and limited ability to recover investment costs from user fees. The Lima Metro Line 2 and São Paulo Metro Line 6 in Latin America managed to mobilize private financing ranging from 30 to 50 percent of capital expenditures (excluding land acquisition), but only with the public sector providing or guaranteeing financing on the balance. PPPs developed under the equip-operate-transfer (EOT) model described in chapter 8 have been able to mobilize private financing that amounts to the investment in rolling stock. In sum, PPPs in urban rail can mobilize part of the capital required to deliver the project, but public cofinancing may still represent the largest share of financing (see chapter 10).

### **Institutional Capacity for Implementing PPPs**

The benefits of a PPP will need to be assessed carefully against the governance and transaction costs of setting up a PPP, including not only the immediate costs of preparing, awarding, executing, and managing the contract, but also the potential costs emanating from the loss of government control, the need to renegotiate contracts (particularly for complex projects such as urban rail), and the need to deal with potentially opportunistic behavior (Phang 2007).

Project-implementing agencies in countries where governments have a higher capacity to implement PPPs than to implement urban rail projects may prefer to undertake a PPP to fill in this gap with the knowledge and expertise of private partners. The delegation of technical aspects associated with design and construction to the private sector does not come for free and requires strong contract management capacity. Experience shows that, regardless of the model chosen, it is critical for governments that embark on these megaprojects to have a robust institutional framework from the concept stage through implementation. This government team should involve high-caliber specialists with sufficient experience in PPP contract management as well as in various technical aspects: engineering, rail operations, urban transport, project management, finance, citizen engagement and communications, and environmental and social management, among others.

### The Private Participation Spectrum

The forms of private participation in public infrastructure projects can be classified according to the degree of risk and control taken on by the private sector and the specific project components or scope of work assigned to it. According to the *PPP Certification Guide* (ADB et al. 2016), the level of control and risk assigned to the private partner ranges from short-term service contracts, on the one hand, to full privatization, on the other (see figure 9.2).

Following the definition in chapter 8, PPP delivery models may not require the mobilization of private financing (design-build-operate-maintain [DBOM]) or may require the private partner to raise financing against performance-based compensation (private finance PPPs, including design-build-finance-operate-maintain [DBFOM] and EOT models). The transfer of financing responsibility increases the level of risk assigned to the private sector, placing the project delivery model on the right-hand side of the spectrum (such as #7 in figure 9.2). Although not as common, private participation may also involve divestitures (privatization) in which part or all of the ownership of an urban rail company is transferred to the private sector (#8 and #9 in figure 9.2), as exemplified by the urban rail operators in Singapore and Hong Kong SAR, China (see chapter 12).

### Operations and Maintenance Concessions

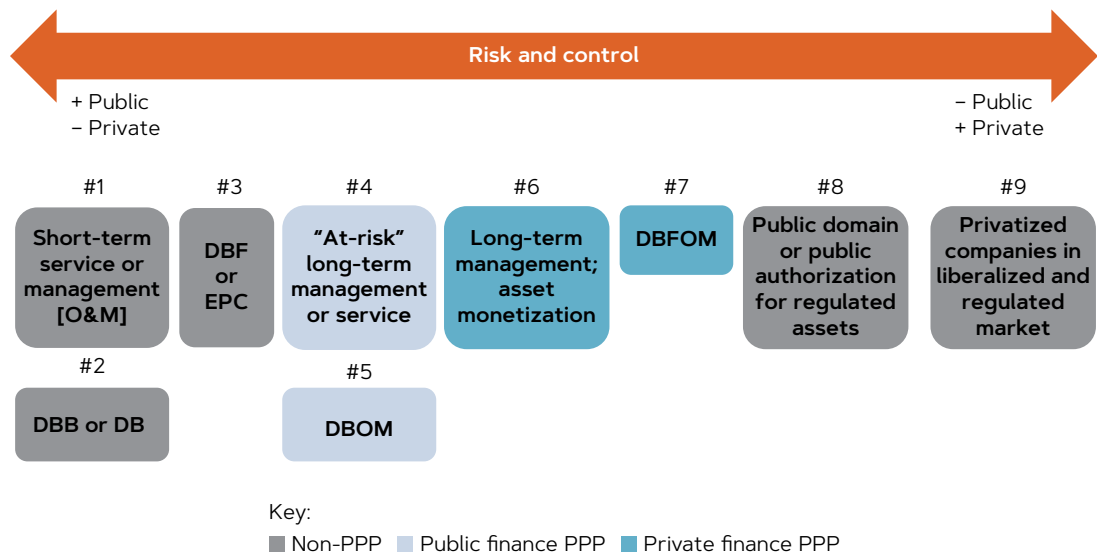
Private participation in a system or a single project could include only the management and operation of the service on the basis of existing or already

acquired rolling stock or the additional responsibility of supplying and maintaining it. In such cases, the core infrastructure is procured separately under non-PPP schemes or previously developed by the public sector. These operating concessions are long-term management contracts where the operator bears performance risk (#4 in figure 9.2). This is the case in the operational concessions of urban rail systems in Buenos Aires and Rio de Janeiro (see box 9.1).

### Vertically Integrated PPPs

In general, in urban rail projects delivered by “construction only” contracts that exclude operation—design-bid-build (DBB), construction manager at risk, design-build (DB), and design-build-finance (DBF)—the transportation service is usually delivered by a public company. Infrastructure related to the project, excluding rolling stock, is procured against the public budget in these cases. When infrastructure is delivered via a PPP scheme (DBOM, DBFOM, or

**FIGURE 9.2. Private Participation Spectrum**



Source: Adapted from ADB et al. 2016.

Note: DB = design-build; DBB = design-bid-build; DBF = design-build-finance; DBFOM = design-build-finance-operate-maintain; DBOM = design-build-operate-maintain; EPC = engineering, procurement, and construction; PPP = public-private partnership; O&M = operation and maintenance.

**BOX 9.1.****Operating Concessions in Rio de Janeiro, Brazil and Buenos Aires, Argentina**

In 1998, demand in the Rio de Janeiro metro and suburban rail systems plummeted under public operation due to low-quality, unreliable service. Both the metro and suburban rail systems had large labor burdens and required operational subsidies of US\$109 million and US\$180 million, respectively. The introduction of operating concessions for both systems significantly increased the number of passengers transported and eliminated the need for a subsidy.

Similarly, by 1992, Buenos Aires was experiencing low supply and deficient quality of service, safety issues, and demand that was 50 percent below the historical peak. The suburban rail system was receiving subsidies of US\$250 million per year, and the metro was receiving public support of about US\$20 million per year. Under private concessions, starting in 1994, demand in Buenos Aires increased 75 percent relative to 1990 (see image B9.1.1).

**IMAGE B9.1.1.** Buenos Aires Underground Train (Subte) Operated by the Private Concessionaire, Metrovías



Source: Zhu via Flickr Commons (CC BY-NC 2.0).

design-build-finance-maintain [DBFM]), operations are generally included in the PPP contract (vertical integration or bundling). Vertically integrated PPPs (such as DBFOM) for the delivery of a new urban rail project that includes all project components represent the greatest degree of private participation with regard to the transfer of control and risks. However, it is possible to have one or many vertically integrated PPPs delivering different components (see the section on structuring of project scope later in this chapter).

Under a DBOM or DBFOM model, the private partner may be involved in the financing, delivery, and maintenance of infrastructure, but be excluded from the delivery of trains and operation of services. However, the private partner may be involved in the financing, delivery, and operation of trains, but be excluded from the provision of civil works.

This handbook focuses on the development of new urban rail projects or extensions, including decisions on how best to deliver services (see box 9.2). However, much of the information and recommendations presented are also relevant to O&M service contracts or PPPs for individual system components.

#### **BOX 9.2.**

### **The Influence of a Public Operator in the Decision to Pursue a Public-Private Partnership**

One of the most important decisions to be made early during project preparation is who will operate the rail system (or new line), as this decision will clearly influence the procurement strategy and delivery method. Project-implementing agencies should formulate their policy objectives and operational requirements accounting for their experience (or inexperience) with operating an urban rail system. When project-implementing agencies are considering how to procure the expansion of an existing system, the fact that there is an incumbent public operator should not be an impediment for considering a public-private

partnership (PPP). Similarly, the development of a system extension using a PPP does not mean that the new infrastructure needs to be operated by a private operator. The following are the potential scenarios.

**Existing public operator.** When a rail system has an experienced public operator, the decision may be made to have the incumbent operator remain in charge of operations of the new line or system. In some cases, a PPP model is used to construct the new line, but, after the civil works are completed, operation and maintenance (O&M) is handed over to the incumbent operator (for example, the metro line to

*(box continues next page)*

**BOX 9.2.****The Influence of a Public Operator in the Decision to Pursue a Public-Private Partnership** *(Continued)*

Barajas Airport in Madrid, Spain). However, a new urban rail line may still be procured entirely under a PPP, including operation of service on the new line even in the presence of an incumbent operator elsewhere in the network (for example, Line 4 of São Paulo Metro or certain line extensions serving suburban airports).

***No previously existing public operator.***

In situations where a public operator does not exist, either because the system is new or because the current operator is a private concessionaire, two scenarios are possible, depending on the project-implementing agency's objectives:

1. *Create a new public company to operate the system.* For greenfield projects, infrastructure and equipment could be procured under a PPP or developed using public financing and traditional procurement. Regarding operations, considering the lack of experience in urban rail, project-implementing agencies could hire a specialized operator as an advisor early in project design and in the initial years of operation to inform operational decisions and train the new public operator in all of the areas required for providing good-quality services (see chapter 4). Another alternative is to incorporate an experienced private firm into the ownership structure of the public operator, perhaps as a joint venture or mixed-capital company with a private operator having a minority of the equity shares (for example, Metropolitano de Tenerife, Spain).
2. *Have a private company operate the system.* In this case, project-implementing agencies may opt to procure infrastructure and equipment via traditional procurement and to enter into a PPP agreement with a private partner (or concessionaire) for O&M. Increasingly, project-implementing agencies have resorted to vertically integrated PPPs in which the infrastructure, equipment, and O&M are lumped into a single contract. In these cases, project-implementing agencies need to develop sufficient operational knowledge to supervise the private operator adequately. The decision whether to pursue a vertically integrated PPP should be preceded by a careful value for money (VfM) analysis that accounts for the significant cost premium that is often associated with such arrangements.

**The PPP Process Cycle**

Assuming that the project has been determined to be the best solution and to be economically, technically, and environmentally feasible with regard to recommendations in this handbook, project-implementing agencies interested in exploring private participation options can focus on the steps required to prepare, implement, and procure, and manage the project as a PPP contract (see figure 9.3).

**FIGURE 9.3. The PPP Process Cycle**

### Preparation

The first step in any PPP process cycle is project preparation. Typically, preparation includes screening to determine whether PPP is the best option for delivering the project and preliminary structuring of the PPP contract.

#### *Screening*

Chapter 8 discusses some of the drivers behind the decision to choose one delivery model over another. To the extent that traditional DBB procurement is the default, this exercise could involve screening the project to determine the suitability of alternative business models involving private participation (PPP screening). Screening involves looking at lessons learned and best practices, assessing commercial feasibility and sounding the market, testing affordability, and determining the benefits of private participation with regard to efficiency and risk transfer (see box 9.3). Screening should also evaluate the institutional requirements for developing the project as a PPP, including contract management capacity, need to engage external advisers, and duration and nature of engagement.

#### *Preliminary Structuring*

The analysis carried out in the screening phase may give the project-implementing agency justification to pursue a PPP but fall short of defining the optimal PPP structure to pursue. At this point, project-implementing agencies have to define the structure that can best deliver the project objectives. The PPP structure is defined as the contractual architecture that determines the scope of the project (bundled versus unbundled), risk allocation between the parties, and way in which the private partner will be compensated (discussed later in this chapter). The PPP structure is conceptualized and contractual terms and conditions are outlined in the preliminary structuring stage.

PPPs are complex and expensive to prepare and structure, more so for challenging projects such as urban rail lines. The cost and complexity of structuring PPP agreements reinforce the importance of carrying out a preliminary

**BOX 9.3.****Public-Private Partnership Screening: Bogotá Metro Line 1, Colombia**

Under a technical assistance project funded by the Public-Private Infrastructure Advisory Facility (Bogotá Metro Financing Options Study-P149271), the World Bank supported the city government of Bogotá and the national government of Colombia in the preliminary evaluation of options for the procurement and financing of the Bogotá Metro Line 1 project. This technical assistance project was launched prior to the finalization of basic engineering studies, with the objective of evaluating different business models, defining the most suitable one, and defining a road map for downstream structuring. The assistance included the following tasks: (1) evaluation of international experience and lessons learned in the structuring and financing of urban rail projects with private participation; (2) identification and analysis of risk (preliminary risk workshop); (3) qualitative value for money (VfM) assessment; (4) market sounding with relevant industry players and financiers; (5) evaluation of the legal and regulatory regimes under which a public-private partnership (PPP) project could be delivered, including assessment of the suitability of using the concessions law or the PPP law; and (6) definition of a scope of work for structuring.

The technical assistance facilitated and encouraged early discussions regarding the business model for the project. Options ranging from public provision to a fully integrated PPP were discussed and evaluated considering the local legal context and international experience. As a result of this active and early engagement, the government of Bogotá was able to look at the project through the lens of its procurement and delivery model in addition to its engineering and design.

Although the scope and specifications of the project later changed, the technical assistance allowed for the examination of different project delivery models and the identification of desirable features for the procurement process that were analyzed later as part of the downstream project structuring contracted by the country's National Development Bank.

In Ecuador, the project-implementing agency in charge of the Quito Metro Line 1 project carried out a similar study to determine the best business model for the delivery of operation and maintenance (O&M) services. The study analyzed different options for private participation and compared their expected benefits and costs with a base case consisting of public O&M of the project.

structuring, defined as (1) evaluating different PPP structures from various angles (including legal, commercial, and financial viability), (2) choosing a preferred option, and (3) defining the preliminary terms and conditions for the PPP agreement. Preliminary structuring can also help project-implementing agencies to identify the approval process for a PPP project, which often involves the Ministry of Finance, the Ministry of Planning, and, in the jurisdictions where it exists, a PPP unit, which may or may not be under one of these two ministries.



A useful activity in preliminary structuring is to establish graphically the links between the different parties in two ways: (1) the contractual instruments linking the parties and (2) the cash flows (or potential cash flows) that will accrue to each party (see figures 9.4 and 9.5 in the section on PPP project structure). This approach can be used to establish agreement on broad principles of the structure before moving on to detailed structuring.

### **Implementation and Procurement**

Detailed structuring of the PPP agreement and its tendering and awarding make up the second step of the PPP process cycle: implementation and procurement. The PPP structure that is finally approved will be put in place via a PPP agreement or contract. As the contract is the core element of the project structure, the terms “PPP project structure” and “PPP project contract” are usually used interchangeably.

#### *Structuring*

Structuring requires comprehensive legal, technical, and financial due diligence to detail the terms and conditions of the PPP contract. That exercise may lead to further refinements or to the adoption of a new structure than the ones considered in preliminary structuring.

For complex contractual structures, such as those of urban rail PPPs, the term-sheet approach can help the grantor to ensure that key issues are established systematically and comprehensively and are agreed before detailed contracts are drafted. As a preparatory step, the grantor or its advisers prepares a term sheet for each contract or agreement, briefly summarizing the key issues to be covered in the document. The main advantages of this approach are that key issues and contractual principles are sorted out at an early stage, and the detailed drafting of the PPP agreement is carried out with more certainty, reducing the need for later revisions. This approach is also beneficial for establishing supporting documents, such as operational and technical annexes.

It is recommended that project-implementing agencies engage the services of a qualified transaction adviser that can assist them with the preparation, structuring, and execution of a PPP transaction. For example, support from the World Bank Group in project structuring can add a great deal of value when governments are undertaking projects in a new sector for the first time or the scope of reforms is ambitious (see box 9.4). Project-implementing agencies should engage advisers early to support their decision making and provide technical advice during the approval process.

**BOX 9.4.****The International Finance Corporation as Transaction Adviser for Metro Manila, Philippines**

The government of the Philippines is seeking to mobilize additional resources and expertise from the private sector to overcome limited fiscal resources and accelerate rapid transit development. In addition, it is seeking to separate ownership and regulatory functions from operations in the transport sector to address institutional weaknesses. To accomplish these policy goals, the government mounted an ambitious PPP program to attract private sector participation in the financing, development,

operations, and management of Metro Manila's mass/light rail transit (M/LRT) system, while retaining ownership and regulation of the public sector. The PPP program for the LRT system, under the leadership of the Department of Transportation and Communications, is expected to deliver much-needed investments required to integrate the LRT network, expand its reach, and increase service capacities and efficiencies through enhanced performance and accountability (see image B9.4.1).

**IMAGE B9.4.1. LRT Train at EDSA Station, Manila, Philippines, 2017**

Source: Fabio Achilli via Flickr Commons (CC BY 2.0).

*(box continues next page)*

**BOX 9.4.****The International Finance Corporation as Transaction Adviser for Metro Manila, Philippines** *(Continued)*

The Department of Transportation and Communications, with its attached agency, the Light Rail Transit Authority, engaged the International Finance Corporation (IFC) PPP Advisory Department in partnership with the Development Bank of the Philippines to structure the PPP and assist in conducting an international competitive tender for the Cavite Extension project. The IFC's mandate included formulating

the PPP transaction structure, preparing the concession agreement, and helping to select a private concessionaire through a competitive and transparent process to operate the existing system and to develop and operate the Cavite Extension. The IFC provided the Philippine government with recommendations on financing mechanisms, risk allocation, and design of the tender process.

The structuring of any urban rail PPP contract should completely resolve the following key questions:

- Is the PPP structure envisaged legally feasible (that is, consistent with the legal framework)?
- Are the PPP model and PPP structure, as designed, the most efficient manner in which to procure the project? Answering this question requires a VfM analysis comparing the expected financial outcome of the proposed PPP with that of the traditional delivery model (adjusted for risk).
- Which is the most efficient financially feasible structure for the PPP project? This is an iterative exercise that requires defining a base case and testing it in the market.
- Is the resulting cost-payment profile of the PPP project affordable?
- What are the contingent liabilities that the PPP contract will generate for the government?
- Will the project asset be regarded as a public investment and affect the level of government debt in national accounts? This analysis is demanded in some countries with specific regulations in terms of accounting standards and is sometimes referred to as “debt impact analysis.”

As part of structuring, project-implementing agencies will have to produce a series of assessments or complete certain milestones to ensure project approval.

Some countries will require a final central approval (usually from the Ministry of Finance or Treasury) of the business case to define the ceiling of payments (or floor in the case of user-pay projects) and an approval of the final wording of the tender documentation (including the contract, request for qualifications, and request for proposals). This approval is necessary before tendering of the project can begin.

#### *Tendering and Awarding*

Once the optimal transaction structure is defined, project-implementing agencies need to promote the project with potentially interested parties, prepare the draft project documentation (bidding documents and PPP or concession agreement), identify potential bidders, undertake the bid process (which often involves several iterations of the project documents before they are finalized), evaluate the bids, carry out negotiations with the preferred bidder, award the concession, and reach commercial and financial close. Chapter 8 provides guidance on the design and implementation of the tender process.

#### **Contract Management**

Contract management is often the most overlooked step in the PPP process, but is the most critical for project success. The optimal risk allocation designed as part of structuring will be reduced to good intentions on paper if the public grantor of the PPP is unable to monitor and enforce the obligations of the private party or if it fails to live up to its contractual commitments, including the expedient approval of final designs or the acquisition of land required for execution of the project. Project-implementing agencies are advised to include institution-strengthening activities to increase the capacity of the teams in charge of managing the PPP contract and to supplement their expertise with external advisers as appropriate. Contracting a project management oversight consultant, who can provide strategic and technical advice above and beyond what a contract supervision consultant can, is highly recommended (see chapter 4).

#### **The PPP Project Structure**

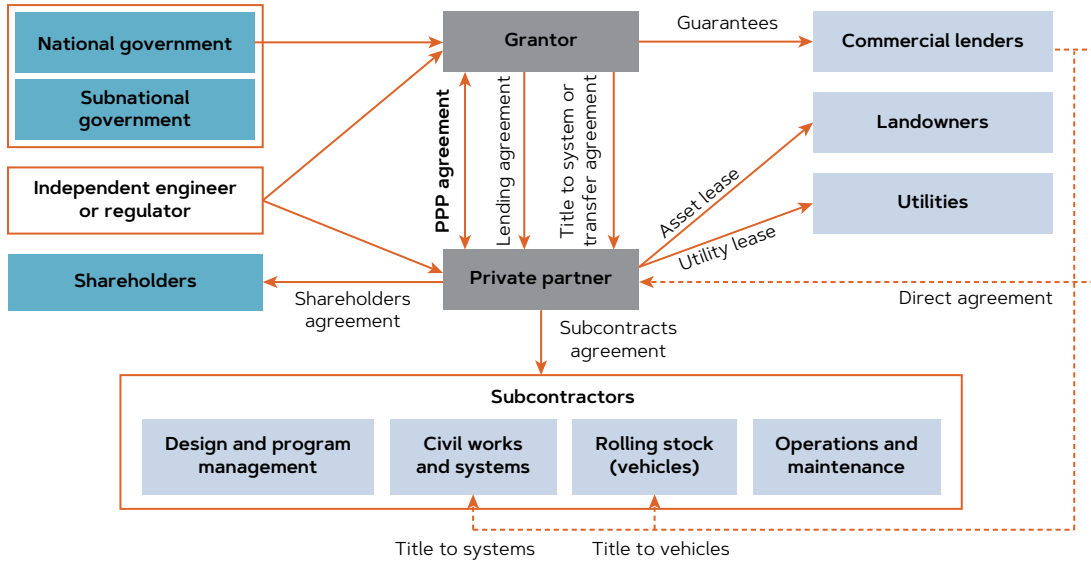
Project structure refers to the architecture of contractual relationships and cash flows governing the development and life of the project (ADB et al. 2016). A PPP project structure is based primarily on the PPP agreement or contract (also referred to as the “upstream contract”) between the public granting authority and the private partner or project company. The PPP contract

defines the scope of the project and regulates the rights and obligations of both the public and private parties. The project structure is also governed by contracts between the private partner and third parties that mirror or “pass through” the obligations, rewards, and penalties established in the PPP agreement (“downstream contracts”). First, the companies that make up the winning consortium formalize the project company by entering into a contract, which is the counterpart to the PPP agreement. Next, the project company enters into contracts with the third parties that will provide services in connection with the delivery of the PPP’s objective, including lenders, insurers, guarantors, contractors, and equipment suppliers. Finally, financiers may require other agreements, such as direct agreements between them and the public granting authority. The structure of downstream contracts follows from the PPP agreement. Together, upstream and downstream contracts are known as project documents.

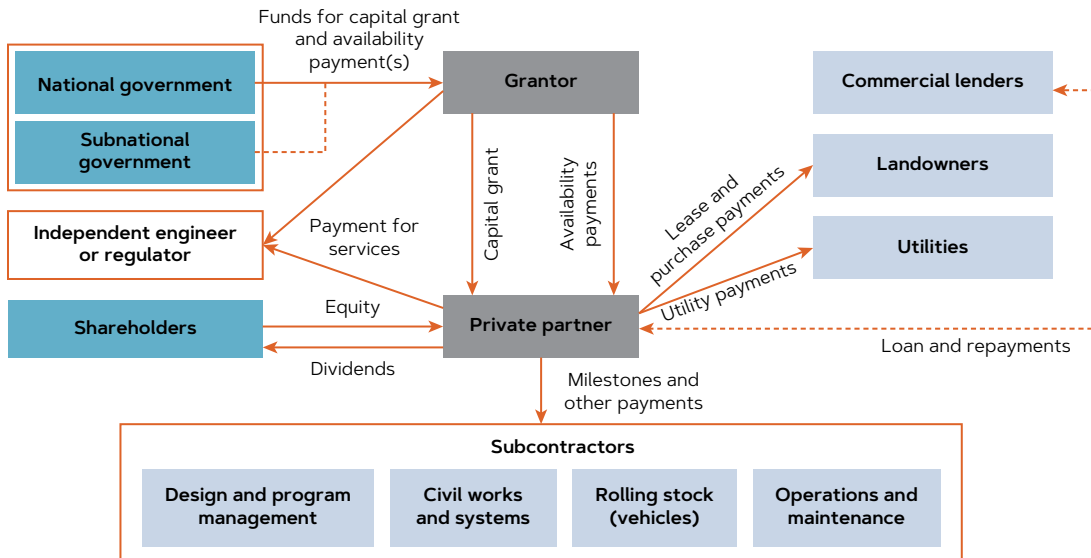
The PPP agreement includes terms and conditions that serve as the foundation for two interrelated contractual structures: the compensation or financial structure and the risk allocation structure. The financial structure is the means of compensation for the private partner’s investment and operation of service. The risk allocation structure is the assignment of economic consequences in the case of materialization of risk. These two structures are intrinsically affected by the scope of the contract, such as whether it includes operations as well as infrastructure. For example, if operations are not included in the scope, no demand risk is transferred, and compensation should not depend on ridership. In some risk allocation structures, demand risk may not be transferred even if the operation of the system is included in the scope of the PPP (see the discussion on availability payments).

Figure 9.4 illustrates a typical PPP project structure consisting of a concession for the development, operation, and maintenance of an urban rail system. It depicts the contractual linkages, while figure 9.5 shows the associated cash flows. In this example, through a PPP agreement, the grantor gives the right to build, operate, and maintain the project to a private developer (usually a consortium of firms), which creates a project company for the purpose of fulfilling the project objective (generally known as a “special-purpose vehicle”). The PPP agreement sets out the rights and obligations of the parties and the overall allocation of risk. The project company or special-purpose vehicle, in turn, enters into individual agreements with a designer, a builder, and equipment suppliers that may or may not be part of the consortium and that provide their services to the project company. The obligations in these downstream agreements should mirror the obligations in the PPP agreement. The available remedies and warranties should allow the

**FIGURE 9.4. Example of Contractual Relationships in an Urban Rail Public-Private Partnership Structure**



**FIGURE 9.5. Example of Cash-Flow Relationships in an Urban Rail Public-Private Partnership Structure**



project company to “pass through” the risks assumed vis-à-vis the grantor. In addition, the project company enters into agreements to fund the required capital expenditures and, if applicable, for private finance.

## Structuring of Project Scope

Structuring of PPP project scope involves decisions on the number of contracts that should be awarded (considering the associated tradeoffs in terms of risks flexibility, and control) and the contract term.

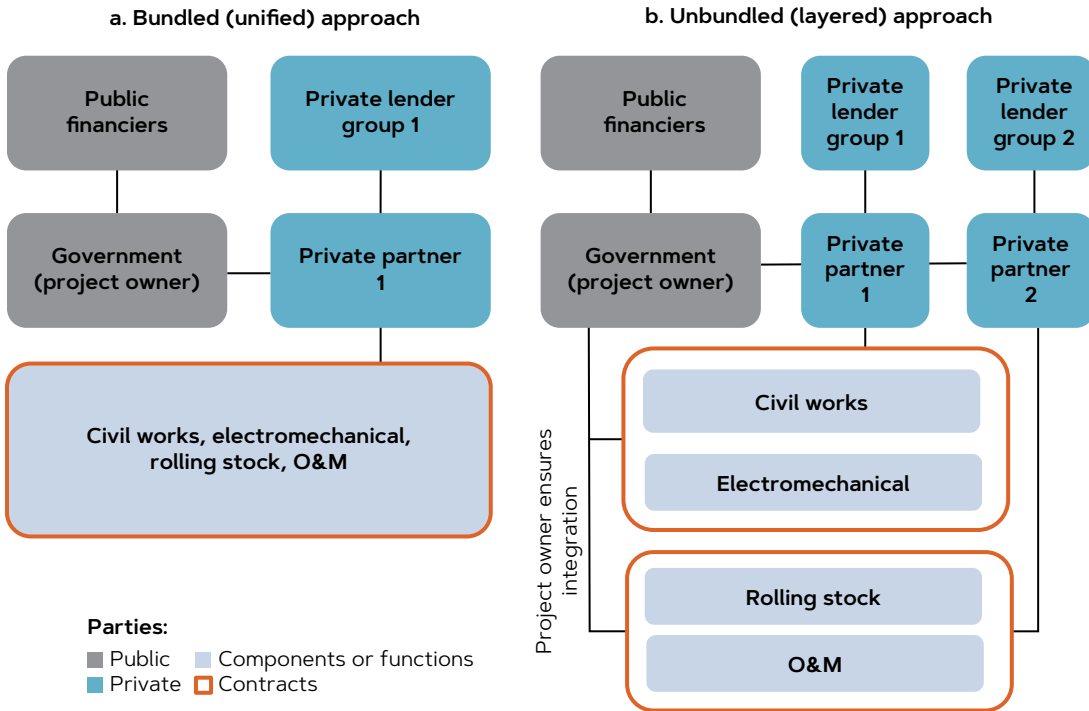
### One or More Contracts: Bundling versus Unbundling

One of the key decisions facing policy makers structuring the project scope of a PPP project is whether the PPP project should be contracted using a bundled or an unbundled approach. In a bundled approach, the project is implemented on the basis of one PPP agreement with a single private sector partner. In this situation, the private sector partner generally assumes responsibility for construction of civil infrastructure, mechanical and electrical work, procurement of rolling stock, and operation of the system.<sup>3</sup>

Alternatively, in an unbundled approach, the project may be split into various contracts (sometimes in more than one PPP agreement), each addressing one project component or a combination of components: (1) construction of civil works, (2) electromechanical equipment, (3) procurement of rolling stock, and (4) O&M of the system. Therefore, an unbundled approach can involve multiple private contractors or partners, each with its own lenders and compensation mechanisms. For example, a project could be developed with two contracts: one concession for infrastructure (civil works and equipment) and another for O&M with a commitment to invest in rolling stock. In this case, a set of lenders would finance the infrastructure works and rely on infrastructure payments to repay their debt, and a separate set of lenders would finance the procurement of rolling stock and rely on a different source of repayment during O&M (see figure 9.6). Unbundled approaches can also combine PPP contracts for certain project components with other project delivery models for other components (see box 9.5).

There are distinct advantages and disadvantages to pursuing the bundled and unbundled approaches. The public project-implementing agency should consider how each approach may allow the agency (cost-effectively) to draw on the largest possible market interest when bidding out the project, to transfer more risk, to retain flexibility to replace contractors, and to

**FIGURE 9.6. Bundled (Unified) versus Unbundled (Layered) Approaches to Private Participation**



Note: O&M = operation and maintenance.

**BOX 9.5.**

**Examples of Unbundled Public-Private Partnership Contracts**

- Design-build-finance-operate-maintain (DBFOM) only for developing, financing, and managing the stations of an urban rail line, such as Barcelona Metro Line 9
- DBFOM only for designing, supplying, installing, operating, and maintaining the ticketing system of an urban rail system or even an entire public transport system, such as in Attica in Greece and Barcelona in Spain
- Public-private partnership (PPP) for acquiring, financing, and maintaining new rolling stock, such as some acquisitions by Madrid Metro under operating leases
- Concession for developing shopping malls associated with stations in the São Paulo Metro (publicly operated)
- Equip-operate-transfer for acquiring, financing, and maintaining rolling stock, including operation of the transport service, such as the São Paulo Line 4 PPP in Brazil and the Beijing and Hangzhou PPPs in China.



undertake future expansions. Table 9.2 presents the main considerations involved in the decision to pursue one approach over the other.

### Interface Risk

The main difference between the bundled and unbundled approaches is the way in which interfaces are managed between civil infrastructure, mechanical and electrical works, rolling stock, and O&M obligations.

In a single “unified” contract, the project owner has one contracting counterpart with full responsibility for ensuring component interfaces and managing all of the risks associated with the various activities of the project. Under the unbundled approach, the project owner or project-implementing agency (in the case of a PPP, the grantor) retains responsibility for integrating individual project components and, therefore, bears interface risk. The owner is responsible for designing, executing, and managing multiple contracts and for ensuring that the project operates as originally intended. This responsibility and the associated risk may be perceived as major disadvantages of the unbundled approach.

However, under a bundled PPP, the fact that the private partner has assumed responsibility for integrating individual components of the system does not mean that this risk has been fully mitigated. If the private partner does not manage integration appropriately, the grantor will ultimately bear the consequences after resorting to the available remedies under the PPP contract.

**TABLE 9.2. Main Considerations for Deciding on the Bundled versus Unbundled Contract Approach from the Perspective of the Public Sector**

CONSIDERATION OR RISK	BUNDLED APPROACH	UNBUNDLED APPROACH
Interface risk transfer	●	○
Firewall risk transfer	●	○
Ability to transfer demand risk	◐	◑
Dispute resolution	●	○
Flexibility	○	●
Future expansion	○	●
Market response (and hence competitive pressure)	◐	◑

Note: ● = most advantageous; ○ = least advantageous.

Facing an interface issue, the grantor can withhold payments, apply penalties, and, ultimately, if the problem is not solved and is of significant magnitude, terminate the PPP agreement. Although the grantor will have the ability to incentivize the private partner to integrate project components well, it will not have the power to intervene and correct the faults unless a termination or step-in event has occurred under the contract. The grantor will have to wait for the urban rail system to be fit to operate, trusting that the private partner will be able to remedy any problem. The grantor, therefore, loses the ability to influence integration at a practical level and has limited ability to influence the private partner's behavior other than by specific remedies under the PPP contract.

Conversely, under an unbundled approach, while the grantor will have to assume the interface risk, the assumption of this responsibility should allow it to identify problems as they arise and find a timely solution. In an unbundled approach, the grantor can manage the interface risk by the following:

- Appointing appropriate internal staff or external consultants to monitor interface and integration issues throughout development of the project so that any problems can be identified and addressed at an early stage.
- Including provisions in each of the relevant project contracts to ensure that there is appropriate liaison between the relevant suppliers, perhaps with a specific coordination (interface) agreement entered into by all relevant parties. This agreement would identify the procedures to be followed by each of the grantor's counterparties in order to ensure that interface issues are taken into account in the design, procurement, and construction processes. By way of example, a design review procedure could be permitted in each contract to enable the grantor's counterparties to identify problems in any designs proposed by others that will affect their own obligations.

### *Firewall Risk*

Firewall risk relates to situations where nonperformance in one of the project components affects the performance of the entire system and the project-implementing agency is unable to exercise effective remedies to resolve these issues or obtain adequate compensation for their materialization. Under an unbundled approach, each contract entered into by the grantor will result in a separate payment stream. If the system as a whole is not working due to the failure of one of the project components—for example, a problem in the tracks—the payments due to the infrastructure contractor will most likely be reduced, but the payments due to the operator and the rolling stock

provider will not be affected. In this situation, the grantor will still be paying the performing party in full even though no transportation services are being provided. The performing providers (in the example, the operator and rolling stock provider) will be indifferent to whether the nonperforming party (in the example, the infrastructure contractor) sorts out the problem. This is not the case with a bundled PPP, where the whole consortium is incentivized to resolve the problem. However, under the bundled approach, the private sector will have factored in the impact of deductions arising from failures in individual parts of the system. In other words, under a bundled approach, although the firewall risk is not apparent, it will likely be reflected in the pricing offered by the private sector.

#### *Demand or Farebox Risk*

Farebox or demand risk relates to the risk that the number of paying passengers will be lower than anticipated, leading to revenue shortfalls. Under a bundled approach, the grantor has freedom regarding how to deal with farebox risk. It may transfer all farebox risk to the private sector or retain it and make payments to the private sector on an availability basis (see the section on structuring payments). Under an unbundled approach, farebox risk is often retained by the grantor or partially transferred to the private partner of the operations contract. Although the grantor could seek to transfer additional ridership risk to private infrastructure providers, doing so would be in conflict with a central tenet of PPPs—risk should sit with the party best placed to manage it—and therefore is unlikely to deliver VfM.

#### *Flexibility*

A major advantage of the unbundled approach is that it enables the public sector to adjust components of the project at various points as conditions change, without needing to trigger a special contractual variation mechanism and the associated risk of cost claims from the incumbent private partner.

For example, service levels may need to be changed from those originally envisaged at the outset of a project to meet new economic and social conditions. These differing service levels can be introduced whenever a new operations contract is entered into (for example, at five-year intervals), rather than needing to be negotiated with the incumbent private partner. In the United Kingdom, changes in the hours when bars are open and when shops are allowed to open on Sundays have had a significant impact on the times when the public requires and expects public transport services to operate. The resulting changes in the services to be provided by light rail operators have been the subject of expensive negotiations with incumbent private partners.

Similarly, the interests of the public and private sectors may conflict when increases in passenger levels cause overcrowding. In such circumstances, the public sector may wish to increase the capacity of the system to alleviate overcrowding, but the private sector may prefer to increase prices to reduce ridership and avoid further congestion, maximizing the revenues arising from its existing assets rather than making further investments. Even if the private sector is not bearing demand risk, the public sector may have limited ability to require more capacity, especially when more capacity would require additional capital expenditure on the part of the private sector or if the private sector or its lenders believe that such increases in capacity would increase debt servicing and other project risks.

#### *Future Expansions of the System*

The bundled approach has proven to be inflexible and extremely expensive in cases where system expansions have been required. This is the case in Manchester, United Kingdom, where the government adopted a bundled approach to develop the Metrolink system, which has since been expanded twice (see images 9.1 and 9.2). Each time the Metrolink system was expanded, the grantor was obliged to exercise the voluntary termination rights in the concession contract and “buy out” the existing concessionaire, paying a very large sum of money equal to the predicted future profits that the concessionaire might have earned during the remaining term of the contract.

**IMAGE 9.1. Manchester Metrolink Phase 1  
Tram, 2011, United Kingdom**



Source: Magnus D. via Flickr Commons (CC BY 2.0).

**IMAGE 9.2. Manchester Metrolink Phase 2  
Tram, 2015, United Kingdom**



Source: A.P. Photography via Flickr Commons (CC BY-NC-ND 2.0).

Such termination decisions may be even more controversial and difficult to make in low- and middle-income countries where clear precedents and available funding may be lacking.

Furthermore, multiple contract terminations can send the wrong signals to the private sector. If the private partner believes there is a chance that the PPP will be terminated to accommodate an expansion, it may have less interest in keeping the system in good condition and less concern with long-term system failures. In contrast to the bundled approach adopted for the Manchester Metrolink, the provision of separate contracts for the London Docklands Light Railway, United Kingdom, has facilitated the on-time and on-budget delivery of major extensions. However, shorter-term and smaller contracts for expansions may also reduce the incentive for private partners to focus on long-term operations and maintenance.

A variation of this situation involves the hand-back of portions of existing systems developed under PPPs. The Lima Metro Line 2 PPP includes the development of a section of the future Line 4 connecting Line 2 with Lima's international airport (Av. Faucett–Av. Gambeta Branch). To provide more flexibility, the PPP contract for Line 2 allows the government to demand that the private partner hand back the portion of Line 4 whenever required for the development of the whole Line 4 under a new PPP contract with a different party. At the moment that hand-back is requested, the private partner should already have been remunerated for its capital investment in the development of this section, but it will cease to receive tariff revenue and O&M payments associated with its operation.

### *Competitive Pressure*

As discussed in chapter 8, the bundling of multiple services (design, construction, supply and installation of equipment, and O&M) in a single contract requires interested bidders to form consortia of multiple specialized companies. The negotiations required to form these consortia are difficult, the risks assumed by private partners are higher, and the number of eligible companies is limited. This situation may reduce the number of potential bidders and limit competitive price pressure in the bundled approach relative to the unbundled approach. If the project-implementing agency decides to contract out project components separately, it may be able to maximize price competition for each of those components.

### **Contract Term**

The contract term is a cornerstone decision when designing the structure of the PPP project. Some factors favor a shorter term (for example, the

willingness to avoid or diminish in time the lack of flexibility that a PPP imposes and the higher accrued financial costs), while others favor a longer term (ADB et al. 2016).<sup>4</sup>

In principle, a longer PPP contract term should allow for the dilution of government payments across an extended period of time. However, stretching payments may not be possible where the private partner is unable to obtain long-term financing consistent with a longer PPP period or its advantages may be counterbalanced by the higher interest cost that the private partner would have to pay if it obtained long-term financing. At any rate, the term of the contract should be long enough to transfer life-cycle risks and maximize leverage (which, in turn, decreases the cost of capital for the project).

## Structuring Risks

Chapter 7 describes risk management in urban rail projects, including some fundamentals of risk assessment and risk allocation in PPP contracts. Much of the value proposition of PPP contracts is based on the transfer of certain risks to the private sector. An optimal risk-reward balance is needed since too much risk may not necessarily bring VfM. The contract should transfer only those risks where use of the private partner's capacity will reduce costs to users and the public sector over the life of the project. In such cases the risk premium (either in the form of contingencies in the budget or in the form of an increase in interest costs or return on equity) will be lower than the expected value of such risks if retained by the grantor. When the private sector is clearly not better placed to manage a certain risk efficiently or is unwilling to carry that risk at a reasonable price premium, the risk should be retained by the public project-implementing agency or shared (with a cap on the risk transferred to the private side).

Risk structuring builds on the risk allocation exercise explained in chapter 7, translating the allocation into contractual terms that can be enforced by the parties. Risk structuring involves the following tasks:

- Defining risk events
- Developing the benchmarks and baselines required to define risk thresholds objectively (for example, geotechnical baseline conditions or a map of utility locations and necessary protections and diversions)
- Establishing the limits or boundaries (thresholds) of risk assumption by each party

- Defining force majeure events—those circumstances under which the parties would be excused from taking responsibility for a risk event
- Devising risk-sharing mechanisms
- Establishing the manner in which the parties will be compensated financially for the consequences of the materialization of a given risk (compensation events)
- Outlining the derisking mechanisms made available by each party and the manner in which they will backstop their obligations in the event a risk materializes
- Defining and regulating the mechanisms for economic rebalancing of the PPP and the risks and magnitude of impact that would trigger such rebalancing.

Tables 9A.1 through 9A.4 in the annex to this chapter describe best practices in risk allocation for urban rail PPPs; table 9A.5 presents the risk allocation structures that have been used in recent urban rail projects in Latin America.

## Structuring Compensation

Given that fare revenues do not pay even for full O&M costs in most urban rail systems, let alone for capital expenditures, governments must often pay for a big portion of the capital costs up-front in order to make the project more affordable in the long term. This public cofinancing helps diminish the financial burden on the private partner and is governed by specific eligibility conditions as well as type and timing of payments in the PPP contract (see the discussion of public cofinancing in chapter 10).<sup>5</sup> In addition to cofinancing, the contract may also provide for the right of the private partner to receive sufficient revenues during the operations period to cover expenses such as O&M costs, taxes, debt service, and dividend distributions to the equity investors.

The fact that the government provides cofinancing or that part of the compensation for services provided comes in the form of government payments does not necessarily mean that the private partner will not be exposed to project performance risk. Careful compensation structuring ensures that the private partner's compensation is aligned with its performance. It defines the set of rules that regulate how and when the private partner is entitled to charge the government for service, including which conditions are to be met to deserve payment, the mathematical formulas for calculating the amount of such payment, and the process and timing by which the payment is made.

### **Payments during Construction or Public Cofinancing**

When a cofinanced approach is pursued, the contract will include provisions that regulate the conditions and timing of grant payments. Typically, those payments are for a total amount predefined in the contract when issuing a request for proposals, or they may refer to a percentage of the total capital expenditure as proposed by the private party in the successful bid.

These payments usually are made during construction either at set time intervals (where the authority reviews the value of the work delivered since the last payment according to the construction price submitted in the offer) or at specific milestones. The amount is calculated considering the defined percentage being covered by the cofinancing, with payments executed over a short period of time as committed in the contract (for example, 90 days). In some projects, part or all of the grant payments are made on a long-term deferred basis (for example, 10 years); they need to be regulated clearly in the contract as irrevocable and unconditional once the value of works executed or the accomplishment of a specific milestone has been cleared. In these situations, the private partner raises a specific tranche of financing to pay for the works. This amount is repaid through deferred grant payments (see chapter 10).

It is important for the contract to include compensation provisions that align the project delivery interests of the public and private sectors. For example, the grantor may need the urban rail system to be completed within a given time frame. In a bundled approach, the private partner will also be keen to adhere to the construction schedule as it will want to start operating the system and obtaining revenues as quickly as possible to repay its debt.

### **Payments during Operations**

It is also important to ensure that the private operating partner performs against a minimum set of standards and overall requirements. Service payments should, therefore, be linked to the level of accomplishment of such standards (that is, linked to performance), or a clear and enforceable system of penalties should be in place for underperformance (even when payments are not relevant or are nonexistent).<sup>6</sup> Performance requirements will cover issues such as service frequency, efficiency of operation, maintenance needs and costs, life cycle, passenger safety, and comfort (see the discussion of performance management and control later in this chapter).

Grantor requirements will logically be different depending on the type of contract. Under any contract that includes operations, performance



requirements will be related to serviceability and passenger comfort. If the PPP agreement includes the development and management of the infrastructure, provisions will need to ensure that adequate maintenance is carried out during the contract period, including the replacement of parts and materials and asset renewal.

### *User or Farebox Revenues*

Farebox revenues are often not sufficient to cover recurring costs and are sometimes discounted as a source of revenue for private partners on account of their exposure to demand risk. User revenues may pay for part of the private partner's costs, diminishing the amount of service payments. But they may also be retained by the grantor to fund part of the service payments, thus shielding the private partner from demand or farebox risk.

While determining the allocation of farebox risk, PPP agreement provisions will need to consider how the PPP may be affected by factors outside the partner's control and against which it must be insulated. Farebox risks are magnified when projects are launched without resolving key uncertainties, including the following:

- Competition from overlapping transport services
- Availability of connecting transport links and establishment of physical and operational integration arrangements with other public transport system operators
- Need to give operational priority to transit systems (for example, granting traffic signal priority for at-grade LRT systems or giving priority to rapid transit over lower-capacity modes)
- Degree of tariff integration across different modes of public transport and availability of a collection system and clearinghouse mechanism to allocate systemwide revenues across different operators if the government expects to have integrated tariffs
- Potential changes in fare-setting policy (such as the use of flat versus distance-based tariffs or mechanisms for periodic adjustment)
- Anticipated method of ticketing (that is, prepaid, pay-as-you-go, or electronic credit)
- Requirements for discounted fares (including for students, senior citizens, or low-income users)

- Ability of the private sector to mitigate fare evasion (access-control systems and penalty and infringement regimes, including policing and enforcement powers)
- Broader macro risks that may affect the local economy and adversely affect demand, such as changes in urban population or economic activity

Significant debate remains about the question of whether transferring the farebox or demand risk to the private partner creates VfM, even when limiting the risk factors mentioned above. Private operators are only willing to assume some demand risk if they can manage it adequately. In the case of PPP projects, it is very important to state in the concession contract which party is responsible for what risks and what type of measures will be implemented by the public sector to eliminate competing services and to increase the technological, physical, and fare integration between the urban rail project and other transport systems.

It is convenient to align the objective of increasing the use of public transportation with the economic interest of the private partner by building incentives in the payment mechanism to encourage the private operator to manage the system in a way that maximizes demand. This alignment may be achieved by providing bonuses or by implementing a system in which the public partner does not retain all of the extra revenue accruing from increases in demand above original projections and agrees to share it with the private partner. The demand-band mechanism used for the PPP of São Paulo's Line 4 offers an example of a payment mechanism that encourages the operator to increase farebox revenues, giving it the opportunity to share any additional income resulting from demand exceeding the base-case scenario (see chapter 7). In addition, the best way to incentivize the population to use the urban rail project is to provide excellent service, especially with regard to reliability and punctuality.

The PPP agreement should clearly establish grantor or government control over fare increases (see box 9.6). In PPPs, having an independent tariff regulator that enforces tariff adjustments based on transparent formulas that account for cost increases and limit regulatory risk is fundamental to enabling private financing. Research suggests that the best practice in this regard is to apply a formula-based annual fare adjustment that considers changes in the cost of inputs, users' capacity to pay, ability of metro systems to increase productivity, and future investment requirements (Anderson, Findlay, and Graham 2012).

The PPP agreement should also state clearly who is responsible for the procurement of additional rolling stock and how the service frequency should be altered to accommodate rising demand.

**BOX 9.6.****Setting Fares: Phase 2 of the Manchester Metrolink, United Kingdom**

Phase 2 of the Manchester Metrolink project included a full concession that allocated revenue risks and the ability to set tariffs entirely to a private developer. Following system expansion during this concession, demand for Metrolink's services was robust, and the developer raised fares considerably. Critics speculated that higher fares were an attempt to "price off" demand, that is, to increase pricing to a level that would limit demand and

eliminate the need to purchase additional rolling stock.

However, the Greater Manchester Public Transportation Authority—a public body that sets transportation policy in Manchester—sought to maximize ridership. This conflict in actions and objectives partially contributed to the concession's early termination, which involved a substantial payment to the concessionaire.

*Source:* Mandri-Perrot and Menzies 2010.

Finally, it may be convenient for the private partner to be the owner of the farebox (legally entitled to collect and manage revenues) so that those revenues can be pledged to strengthen the creditworthiness of the project. Private partners in PPP will prefer to have the ability to manage the farebox directly in order to reduce the credit and liquidity risk associated with government payments and to gain the ability to extract value from funds management. This preference exists regardless of whether the tariff paid to the private partner is different from the one charged to riders: some PPP contracts are constructed on the basis of "public payment per user" according to a technical tariff, but fare revenue is collected and retained by the private partner as an advance of the payments to be settled every payment period (advance payment approach). At any rate, the contract should establish clearly the owner of the farebox and, if applying the advance payment approach, how the farebox revenue will be included in the overall PPP payment settlement. When removing demand risk from the private partner, but including a limited exposure to risk-reward in the form of a bonus, the contract will describe what percentage of revenue is earned on top of the service payments.

***Service Payments***

In a PPP contract with a significant amount of private finance, a budgetary payment will likely be required. This payment should be constructed in such a way as to align the interests of the public and private partners. On what basis should these service payments be made? What should be regarded as "performance"?

These questions relate to the objectives of the authority and risk considerations: are these payments assumable, and will basing the payment stream on the volume of users provide VfM?

Performance may be related to the transport service delivery standards as defined in the contract (for example, punctuality, frequency, and comfort), which, in turn, depend to a significant extent on the availability and proper functioning of the infrastructure, but also on the quality of the service operations (how well the operator is managing the fleet). Quality should be incorporated explicitly in the payment mechanism by means of penalties.

Even when the focus of the payment is service level or standards, it is still necessary to define the “unit of payment,” which in payments per volume naturally corresponds to the number of passengers. Other units of payment include time units (payments are earned per day or even per hour) or number of kilometers served per vehicle. Depending on these factors and considerations, there are three main types of payment mechanisms for PPP contracts for urban rail systems: (a) availability or quality payments, (b) technical tariff based on vehicles per kilometer, and (c) payments per user or shadow fares.

With regard to availability or quality payments, a maximum payment is defined on a yearly basis (as per the winning offer). The actual payment is earned on a time-prorated basis and calculated by taking into account the level of achievement of the performance requirements as defined in the contract. The maximum payment is adjusted applying abatements or deductions as a way to impose penalties when performance requirements are not met.

In developing a compensation mechanism based on availability payments, the following issues need to be taken into account:

- How is performance controlled and measured? How is payment linked to the key performance indicators (KPIs)—for example, availability, waiting times, frequency, safety, fare evasion, ambience, cleanliness, condition of platforms, standard of supporting facilities, such as ticketing machines, timetable information, and journey assistance? How are effective payment or deductions calculated?
- What is the maximum level of deductions to be imposed on the private partner and its impact on financing?
- What KPIs are to be used to develop a suitable deduction regime?
- What are the procedures for dealing with recurrent underperformance?
- When is the first payment due, or when does the payment period commence?

- What is the invoice and payment settlement process and the timing of payments?
- How will the payment amount be adjusted over the contract term?
- What is the best way to incentivize the private partner to maximize farebox revenue (including minimizing fare evasion) if the partner is to be paid on an availability basis?

With technical tariffs based on vehicles per kilometer (and affected by availability), bidders calculate their offer knowing in advance the total number of kilometers contracted on a yearly basis as per the project's service plan. The payment is first calculated based on the number of kilometers served in a specific period (for example, days). Kilometers not operated for any reason other than a change by the grantor in the service plan do not count. Not all kilometers deserve the payment or at least not the full amount. Trips that do not meet the performance levels defined in the contract (as in the case of pure availability payments described above) do not earn payment or the payment is partially adjusted.

This system has the advantage of providing flexibility for adjustments in the transport service plan, usually limited by a cap (for example, plus or minus 10 percent of the original number of kilometers), because the change in the amount of service has a predefined price and there is no need for negotiations. For example, this arrangement might allow the grantor to ask for higher frequency in one particular month of one particular year to accommodate a special event, such as an international sports championship.

Payments per user or shadow fares directly link service payments to demand measured as the number of users. The most common approach when using a payment per user mechanism is to also include a minimum volume guarantee or a more sophisticated system of patronage bands (see chapter 7 for examples from the Canada Line in Vancouver and Line 4 in São Paulo). The bidder submits a base shadow fare that is applied to calculate payment for a predefined band of demand (for example, from minus 20 percent to plus 20 percent of the number of passengers over the contractual baseline). Above that band, the payment per user is smaller (for example, 50 percent of the base shadow tariff). Below that band, the payment per user is larger (for example, 150 percent of the base tariff). These volume payment or payment per user mechanisms also allow the authority flexibility when defining tariff policy, as the impact on the finances of the private partner is relatively lower (when the level of tariff may influence revenue by increasing or decreasing patronage depending on the elasticity of demand to tariffs).

### *Frequency of Payments*

Measuring performance and calculating payments is time-consuming, but the private partner has recurrent and periodic costs that have to be met and paid. Availability payment schemes usually consider quarterly payments, but this frequency may put undue financial pressure on the private partner's liquidity. Monthly payments are the highest frequency of payments normally seen, but this frequency is difficult when payment involves assessing the level of performance and applying deductions when the level of service is below requirements.

One solution is to establish a method of provisional monthly payments so that, at the end of each quarter, the grantor finalizes all calculations related to performance and adjusts interim monthly payments to performance within the third month of payment. The monthly interim payments are made considering a provisional deduction that is the same as the one applied in the previous quarter.

### *Payment Actualization*

O&M costs logically vary over the time of the contract due to changes in the price of inputs. The most usual and simple way to capture the effect of changes in the price of inputs is to link service payments to inflation, using the relevant consumer price index (CPI).<sup>7</sup> Some contracts include more complex actualization formulas that include the indexation of single-cost components. Many other contracts define an actualization factor that only affects a percentage of the payment: the percentage that is deemed to be linked to variable costs. Variable costs include energy costs (a fundamental cost of operating an urban rail system) and, to the extent that interest rates are variable, financing cost.

### *First Payment and Early Commencement*

To incentivize the private partner delivering the infrastructure to open the system early, the contract may include a provision whereby any savings generated through early opening (for example, lower financing costs through early servicing of senior debt) could be shared between the grantor and the partner. Alternatively, for PPP contracts that include O&M, the early opening period could be treated as an extension of the project period, and the net additional revenue received (after allowing for the partner's usual operating costs) could be shared between the partner and the grantor.

### **Other Compensation Provisions**

In addition to these sources of compensation, the private partner may derive compensation from other sources of "ancillary revenue" (see chapter 10).

The ability to collect revenue from these other sources should be specified in the contract. It is good practice for the grantor to incentivize the exploitation of ancillary revenues by the private partner and to share in a portion of the additional income generated.

## Performance Management and Control

A wide range of level-of-service parameters are set by the project design and may form part of the “technical” obligations of the PPP contract. Nevertheless, there is generally the need to establish a limited number of KPIs to allow monitoring of the service provided by the partner (see table 9.3). KPIs have to be definable, significant, quantifiable, and able to be monitored and verified. Used to assure compliance with major contractual objectives, they can also serve as

**TABLE 9.3. Examples of Common Key Performance Indicators for Urban Rail Systems**

CATEGORY	KEY PERFORMANCE INDICATORS	DESCRIPTION
Reliability and punctuality	Daily or monthly system reliability	Number of actual trips compared with the number of scheduled trips per day per month
	Early departures	Number of trains leaving earlier than some specified window of time
	Late departures	Number of trains leaving later than some specified window of time
	First or last trains departing early	Number of first or last trains departing earlier than the time tolerance applied to early departures
Customer satisfaction	Performance on satisfaction surveys	Annual, independent, published survey, remedial actions, and delivered improvements
	Receipt of customer comments	Number of responses to customer comments not made within some allowable window of time
	Availability of real-time information	Number of hours when displays were unavailable
	Timetable availability and accuracy	Number of designated timetable locations missing timetables or displaying outdated information
	Availability of customer-facing staff	Availability of customer-facing staff relative to some agreed benchmark (typically measured as a percentage of total staff hours per station per period)

*(table continues next page)*

**TABLE 9.3. Examples of Common Key Performance Indicators for Urban Rail Systems***(Continued)*

CATEGORY	KEY PERFORMANCE INDICATORS	DESCRIPTION
Cleanliness and general upkeep	Cleanliness of urban rail vehicles	Number of cleanings implemented
	Removal of graffiti from urban rail vehicles	Number of incidences removed within period of reporting
	Repair of damaged urban rail vehicles	Number of incidences reported and repaired before returning to service
	Cleaning of stations	Number of cleanings implemented
	Removal of graffiti from stations	Number of incidences removed within some time period of reporting
	Repair of general damage to stations	Number of incidences repaired within some time period of reporting (often includes some number of unreported instances)
	Availability of ticket-vending machines, offices, and gates	Number of devices and hours unavailable or not operational
Access and security	Availability of a passenger alarm system	Number of hours unavailable
	Availability of closed-circuit television	Number of hours unavailable
	Availability of lighting	Number of defects not repaired within some time period after first reported
	Availability of an elevator or escalator	Number of hours unavailable
	Revenue security (fare evasion)	Achievement of some specified level of revenue security (often measured through a comparison of collected revenues against automated passenger counter figures)
Ride quality and noise emission	Ride quality index	Performance on periodic assessments of vehicles
	Noise and vibration (within urban rail vehicles)	Performance on periodic tests of noise and vibration levels inside each urban rail vehicle over the entire system route
	Noise and vibration (within stations)	Performance on periodic tests of noise and vibration levels inside system stations
	Noise and vibration (at locations on route)	Performance on periodic tests of noise and vibration levels generated by each urban rail vehicle at locations along the system route
	Overcrowding	Compliance with limits on density of standing passengers set out in performance specifications



a means of assessing performance levels and are frequently used as a tool to implement incentive schemes in areas where the private developer may be expected to perform beyond the basic contractual norms. Most urban rail PPPs that involve private operations employ performance management systems that include formulas to link performance assessment criteria to compensation.

### Specifying Performance Targets and Weighting Key Performance Indicators

Effectively applying information gathered through continuous KPI monitoring requires a system for normalizing data consistently into a usable form. Normalizing data allows combinations of KPIs that have dissimilar units of measurement (for example, number of occurrences, time, or qualitative rankings). Measuring the percent achievement level for KPIs is one method of normalizing data to a continuous scale:

$$\% \text{ Achievement} = \frac{\text{Measured Value}}{\text{Target Value}} * 100\% \quad (9.1)$$

Using the example above, planners could elect to cap achievement at 100 percent or establish some greater value when performance is in excess of targets. Alternatively, measuring achievement for KPIs could involve a stepwise series of thresholds similar to the following:

$$\% \text{ Achievement} = \begin{cases} X\% \text{ when measured KPI value} \geq \text{target value } A \\ Y\% \text{ when target value } A > \text{measured KPI value} \geq \text{target value } B \\ Z\% \text{ when measured KPI value} < \text{target value } B \end{cases} \quad (9.2)$$

This stepwise methodology may be preferable to continuous measurement when KPIs involve subjective assessments or when planners prefer to provide tolerance bands around a given metric.

Authorities may elect to assign different weightings to certain KPIs that have greater impacts on the quality of urban rail services. One method for incorporating weightings into a total KPI adjustment factor is as follows:

$$\text{KPI Adjustment Factors} = \sum_{\text{KPI}} (\% \text{ Achievement})_{\text{KPI}} * (\text{Weighting Factors})_{\text{KPI}} \quad (9.3)$$

where  $100\% = \sum (\text{Weighting factors for all KPIs})$ .

### Tying Performance Specifications to Payments

Much of the value associated with performance management systems comes from their ability to affect the compensation paid to private operators. Adjusting compensation requires delicate management and some notion of what constitutes an appropriate level of value at risk. Reducing the certainty of cash flows can increase risk premiums, reduce financial viability, and jeopardize project bankability. Conversely, too little value at risk may not provide sufficiently strong incentives for performance. PPP agreements for urban rail operations generally solve this conflict by limiting the reach of the performance management system to some reasonable fraction of total private compensation (see box 9.7). For example, a PPP agreement structured around an availability payment may determine total operator compensation using a formula similar to the following:

$$\text{Compensation Payment} = AP_{\text{Fixed}} + AP_{\text{Variable}} * (\text{KPI Adjustment Factor}), \quad (94)$$

where

- $AP_{\text{Fixed}}$  is the portion of availability payment guaranteed by simply meeting minimum, easily attainable standards for urban rail services.
- $AP_{\text{Variable}}$  is the portion of total availability payment subject to the terms of the project's performance management system.
- *(KPI Adjustment Factor)* represents the combined performance on KPIs as weighted in the system's operating agreement.

Determining an appropriate fraction of private compensation at risk should involve sound analysis and continuous dialogue with prospective private partners. Planners should specifically consider the following:

- Cash requirements for servicing any project debt, covering O&M expenses, and funding required investments
- Minimum sums that private partners consider meaningful
- Level of KPI performance targets that operators should be able to achieve regularly.

When performance management systems place too much value at risk, private partners will charge a risk premium to the public sector. Overreaching performance management systems may even render projects financially unviable when private partners perceive opportunities for unscrupulous public authorities to impose unreasonable and excessive deductions.

**BOX 9.7.****Key Performance Indicators and Performance Management Systems in Public-Private Partnerships: Lima Line 1, Peru and São Paulo Line 4, Brazil****Lima Metro Line 1**

The following indicators of the level of service provided are monitored:

1. *Interval between trains.* Measures whether the contracted frequencies between 6 a.m. and 10 p.m. are respected. It is measured at peak and nonpeak hours: 8 a.m.–1 p.m.: 6 minutes; before 8 a.m.: 12 minutes; 1 p.m.–8 p.m.: 10 minutes; 8 p.m.–12 p.m.: 12 minutes (see image B9.7.1).
2. *Availability of service.* Monitors the speed of movement (commercial speed should not be less than 35 kilometers per hour). It is calculated as the ratio of the effective to programmed travel times and has a minimum value of 0.95. Indicator is measured based on two-month moving averages. However, for assessing quarterly service payments, the calculation is made using three-month averages.

**IMAGE B9.7.1. Passengers Waiting for a Train at Estación Gamarra, Metro de Lima, Peru, 2012**



Source: Jorge Gobbi via Flickr Commons (CC BY 2.0).

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**BOX 9.7.****Key Performance Indicators and Performance Management Systems in Public-Private Partnerships: Lima Line 1, Peru, and São Paulo Line 4, Brazil (Continued)**

3. *Service regularity.* Monitors the punctuality of the service by comparing scheduled and actual train times. It is calculated on moving averages of two months, except for determining the quarterly payment, for which a three-month moving average is used.
4. *Cleanliness of stations and trains.* Indicates the level of cleanliness in the stations and trains and is measured weekly. It is divided into two components of equal weight: cleanliness of stations and cleanliness of rolling stock.
5. *Fraud.* Measures the incidence of unpaid travel. It is calculated monthly using a sample of 5 users per 1,000 users over a period of a week. The expected fraud is 8 percent. It is calculated on three-month moving averages from the weekly inspections.

**São Paulo Line 4**

1. *Interval between trains.* Monitors service regularity. It is defined as the average interval between trains from the first train measured at the beginning of the period to the first train after the end of the period. The actual interval is measured as the time between the opening of doors of a train and the opening of doors of the previous train on the same platform. The indicator is calculated daily by means of the ratio between the average interval measurements between trains.
2. *Average travel time in peaks.* Monitors the speed of travel of users. It is defined as the time it takes the train to travel between the terminal stations of the line. The beginning of the trip is the moment the alarm sounds when the doors of the train at the initial station are closed until the doors of the train are completely open at the final station.
3. *Compliance with the scheduled offer.* Monitors the fulfillment of the daily planning of the offer. It is defined as the ratio of the number of trips made to the number of trips scheduled (complete travel from and to terminal stations).
4. *Accidents.* Measures safety on the metro line. Defined as the ratio between the total number of accidents and the total number of passengers transported on the line, monthly.
5. *Crimes.* Monitors the level of public security on the line. It is calculated as the ratio between the number of crimes and faults and the total number of passengers transported on the line in one month.
6. *Validation of access.* Measures the time spent by users in the payment area. It is defined as the number of measurements showing less than three minutes of time spent in the queue or total number of measurements and is calculated by taking samples.
7. *User satisfaction survey.* Measures the attributes traditionally used to evaluate the quality of transportation service as well as the specifics of the metro system, which are reliability, comfort, public safety, safety, speed, and attention and information to the user.

## Conclusions and Recommendations

*PPPs are relatively more complicated for urban rail than for other transport projects and have had mixed results.* Early urban rail projects developed through PPPs in the 1990s and early 2000s were far from delivering optimal VfM given delays in construction, higher-than-anticipated project costs, or lower-than-expected demand. In many cases, public project-implementing agencies had to take over the remaining development of the urban rail project (Pulido and Hirschhorn 2015). Nonetheless, interest in private participation in urban rail is growing as urban transportation needs exceed the capacity of public sector resources and more countries develop PPP frameworks.

*To capitalize on the benefits of PPPs, project-implementing agencies need to invest in strong project preparation and contract management capacity.* The public sector's goal in creating PPPs is to obtain expertise, efficiency, and capital from the private sector. Those benefits do not come without costs, mainly related to the significant resources required for project preparation and contract management, both functions that cannot be completely delegated. Experience shows that regardless of the scope of the PPP chosen and even when consultants are available, a highly capable public sector with a robust institutional framework and a strong management team capable of evaluating options, issues, bids, and contractor performance is required.

PPPs should be used only when the public sector has the effective capacity to measure and supervise the quality of service (whether infrastructure delivery or operations) contracted. In this sense, the adequate setting and monitoring of KPIs is fundamental for PPPs to be able to deliver the higher quality of service, reliability, and timely delivery expected from private sector involvement.

*Even in complex and risky projects, such as urban rail systems, PPPs can provide benefits.* Large capital investment requirements, high risk, and limited cost recovery all limit the potential for substantial private financing in urban rail PPPs. However, PPPs can provide benefits in the form of efficiency, partial risk transfer, and life-cycle management through an alignment of interests that is difficult to obtain in more conventional project delivery models. In recent urban rail PPP projects, more than the potential for substantial private finance, the main motivations for contracting urban rail projects via PPPs were to reduce the time required for project implementation and to minimize the potential for interface problems between project components.

PPPs in urban rail often have been dismissed on the argument that the relatively high risk of these projects precludes risk transfer to the private partner and therefore limits their benefits. Nonetheless, even the most complex urban rail projects can achieve partial risk transfer by quantifying potential risks and

setting risk-sharing mechanisms (such as risk-sharing bands and financial caps) in contracts. Ultimately, the effective transfer of risks is a function not only of what is written in the contracts, but also of the capacity of the party that bears the risk to manage it effectively. This capacity is a function of the qualifications and financial standing of the private partner and the incentives for adequate risk management built into the compensation mechanism.

***The benefits of private finance PPPs in urban rail could be counterbalanced by the additional cost of capital.*** Assuming an adequate risk allocation that is properly translated in the contract, one way to protect VfM is to diminish the financing cost of the PPP project while keeping sufficient financial tension on the private side. In some of the most developed PPP markets, the public partner cofinances projects with intensive capital needs. Cofinanced PPPs can help to reduce the cost of capital, alleviating the budgetary burden of urban rail development in the long term and making the project more affordable. In addition to public cofinancing, the cost of capital may also be lowered through derisking techniques, always keeping in mind the importance of maintaining sufficient risk transfer to incentivize private partner performance.

***PPPs are built on risk allocation and payment structures that have to be translated into well-crafted and manageable contracts.*** Risk allocation and compensation mechanisms are the building blocks of the PPP contract. Commercial matters such as dispute resolution, rights of lenders, and other financing regulations and penalty regimes, are also crucial for the project's success. Many contracts provide the tools for managing and administering the contract during its life. Above all, rights and obligations have to be described clearly to avoid ambiguities, starting with the technical requirements, service specifications, and related KPIs that will link performance and revenue.

When designing and developing the PPP contract, it is also important to consider its flexibility: “to enable changing circumstances to be dealt with as far as possible within the contract, rather than resulting in re-negotiation or termination ... to create certainty where possible, and bounded flexibility where needed (i.e., boundaries for change)” (ADB et al. 2016).

***The ultimate success of PPPs in urban rail still depends on the existence of a supportive environment.*** For a project to succeed in applying the PPP delivery model, the project and the context (mostly macroeconomic and financial market context) have to be suitable for a PPP. Private participation does not suit all projects and all contexts. It should not be pursued just because it may be helpful to obtain some private financing or to circumvent accounting or fiscal regulatory restrictions. In order for PPPs to deliver value for money, the institutional, legal, and regulatory frameworks at the country and city level have to be supportive of adequate contract structuring and management.

## Annex 9A. Allocation of Risks Related to Public-Private Partnerships for Urban Rail Development Projects

**TABLE 9A.1. Allocation of Risks Related to Project Design and Construction, Including Site Conditions**

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Land (or site) availability and acquisition	<p>Land is needed for depots and other facilities, in addition to right-of-way. This is typically the responsibility of the public authority. The uncertainty of site availability may make it likely that no bidders will participate or financing may not be closed. Land will usually be owned by municipal authorities, so for projects procured by other administration levels such as a state or province, the procuring authority will need to acquire or to ensure that the desired site is reserved or dedicated to the project. The authority is usually the only party with powers to expropriate land from the existing landholders, although in some countries this power can be delegated to the private partner (giving it the title of “expropriation beneficiary”).</p>	X		The standard good practice is that the site is available when the project tender is launched, but even if the private party has to do some expropriation work, the procuring authority should retain the risks related to both the cost and availability of land, including the cost of relocating current occupants (if needed).
Environmental (and environmental assessment) risk	<p>The preparation of an environmental impact assessment (EIA) and an environmental management plan (EMP) approved by the relevant authority is a requirement for project development. The EIA identifies the environmental impacts and may recommend changes in the project design. The EMP outlines the measures required to mitigate the impacts identified in the EIA. These measures have implications in terms of costs and implementation schedule (see chapter 15).</p> <p>The project specifications defined when the tender is issued have to comply with environmental regulations and impacts addressed, and the project’s preliminary design or outline should have been tested with the appropriate environmental agency. In some countries, it is common to request a preliminary environmental assessment. These risks are usually categorized in the construction phase. However, the risk may also affect O&amp;M costs (for example, noncompliance with environmental legislation that is detected during operations or changes in environmental law).</p>	(X)	X	<p>The risk of inadequate implementation of the EMP is borne by the private party, which is usually in charge of developing and implementing the plan based on the EIA. The public party usually retains risks originated in changes to the project design caused by environmental issues outside the boundaries or guidelines provided by the EIA.</p> <p><i>When or to what extent assumed or shared by public authority</i></p> <p>The authority needs to anticipate environmental impacts to the largest extent possible in order to limit or mitigate this risk for the benefit of both parties. The authority should remain responsible for adverse assessments related to the specifications settled in the contract.</p>

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**TABLE 9A.1. Allocation of Risks Related to Project Design and Construction, Including Site Conditions (Continued)**

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Other permits	Delays in obtaining the needed permits for construction will cause delays in starting construction, and the clearance of those delays is usually a condition for the effectiveness of most financing agreements.		X	Generally, the private partner should anticipate the permits needed and assess the implications and related risks. It is also good practice for the public authority to commit to supporting on a best-effort basis the private partner in obtaining the permits required for construction or to build some protection into the contract for cases of unreasonable behavior of the authorities granting the permits.
Design risk	<p>Broadly speaking, design risk refers to two types of events:</p> <ul style="list-style-type: none"> <li>• Defects in the design that result in the asset being built but failing to meet the prescribed standards, legal requirements, and any conditions imposed by environmental or any other stipulations. Such circumstances mean that the project has to be changed, causing delays and above all cost increases.</li> <li>• Defects or failures in the design that result in the project not meeting the service standards requested in the contract or that result in an increase in O&amp;M costs in order to meet the service requirements.</li> </ul>		X	As the design in PPPs is developed commonly by the private party, the private party should generally bear the design risk.
Construction risk (general)	<p>Construction risk refers to the possibility that, during the design and construction phase, the actual project costs or construction time exceed those projected. The delay in the completion or commissioning is a separate or ad hoc category of risk.</p> <p>Broadly speaking, construction risks can be caused by defects or mistakes in design, lack of appropriate planning, lack of proper project and schedule management of the construction program, defects in the methods used, or other causes related to underperformance or even negligence by the private partner (or its contractors), including external factors that should have been anticipated but were not.</p>		X	This risk is to be borne by the private partner. However, the contract should provide relief (excuse from obligations and potential related penalties) or compensation for certain risk events that might occur, the main categories of which are explained in table 9A.4.

*(table continues next page)*



**TABLE 9A.1. Allocation of Risks Related to Project Design and Construction, Including Site Conditions (Continued)**

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Construction delay and commissioning (general)	Delay in completing construction and, therefore, in commissioning will delay the commencement of service and, therefore, increase the financial costs accrued and produce missed or delayed revenues. "Completion" refers to finalizing the construction works, while "commissioning" refers to authorizing to commence operations. The transition from completing the works to commissioning is very important and can be demanding in some projects. There will be a trial period to test that the service works as expected, before granting the final acceptance.		X	As a general rule, construction or design risk has to be borne by the private partner, subject to the exceptions that the contract may provide, based on some specific risk event covered in table 9A.4. The risk will be transferred naturally to the private party by means of missed revenues and also explicit penalties (up to potential termination for default).
Site and ground conditions: geotechnical	The risk of unexpected geological or geotechnical conditions is commonly allocated to the private partner in a conventional project, that is, in projects where geotechnical conditions do not represent a significant challenge or information on ground conditions can be effectively tested, like most surface urban rail projects (typically light rail).  In underground urban rail projects, geotechnical risks are significant. A change in the anticipated geotechnical conditions or the inability to anticipate those conditions will produce a serious cost increase (an extreme example is when a tunneling machine has to be replaced because it cannot bore the tunnel due to unanticipated geological conditions).	(X)	X	Geotechnical risk should be allocated to the private partner as a general rule, with the exception of underground projects with significant risk and uncertainty.  <i>When or to what extent assumed or shared by public authority</i>  In projects with significant risk, it is common practice to share the risk or to limit the risk exposure to the private partner. Best practice includes defining a baseline of geotechnical conditions, which will be used to assess the materiality of adverse conditions that entitle the private party to financial relief or compensation (or both parties may terminate the contract under similar conditions or consequences as for force majeure).

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**TABLE 9A.1. Allocation of Risks Related to Project Design and Construction, Including Site Conditions (Continued)**

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Site and ground conditions: latent defects (Note: only relevant in very specific projects)	When part of the asset is already built or existing (assuming rolling stock material already in use or assuming the responsibility to manage existing infrastructure in a contract for expanding the system), there is the risk that latent defects will emerge in the future and cause the private partner to invest unexpected amounts to repair or substitute.	(X)	X	The risk of latent defects (defects in the site or in the infrastructure as previously built and maintained) should be assumed by the private party as long as meaningful information is available to enable prospective bidders to investigate and assess the asset condition before submitting the bid.  <i>When or to what extent assumed or shared by public authority</i>  When there is inadequate or insufficient information, it is good practice to share this risk to some extent, by limiting or capping the exposure of the private partner. If a defect arises and was not reasonably foreseeable according to good professional practice and as long as it has a significant adverse impact, the risks will be shared or partially compensated by the authority, treating the event as a compensation event in the contract.

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**TABLE 9A.1. Allocation of Risks Related to Project Design and Construction, Including Site Conditions (Continued)**

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Site and ground conditions: archeological findings	<p>Archeological findings may cause significant impacts on project costs and time:</p> <ul style="list-style-type: none"> <li>• They may severely affect the project if, for example, a change in the alignment is necessary.</li> <li>• They may require works to preserve or protect the findings or to relocate the findings.</li> <li>• At any rate, works will be paralyzed until a detailed assessment is done, which may cause great delays (as long as the finding affects the critical path of construction).</li> </ul> <p>When archeological findings are a significant risk at the particular project site, it is essential for the authority to develop archeological site studies (archeological maps), including digging tests, in the course of its preparatory activities.</p>	X	X	<p>Archeological findings are a risk that is typically assumed to some extent by the private partner, with exposure capped or shared by the public party if uncertainty is regarded as significant.</p> <p>Findings that were not anticipated vary significantly depending on the country practice and legal framework:</p> <ul style="list-style-type: none"> <li>• It is common and good practice for the private partner to be exposed to some extent, as the risk is, above all, a time-related risk (potential delays in construction) and may be significantly mitigated by means of proper management of construction schedule.</li> <li>• It is also good practice for risks with severe impacts on the project, as long as they were not anticipated in surveys or other information available, to be taken back by the public party, at least under a shared-risk mechanism—for example, granting relief with respect to time delays beyond a certain delay period. Unanticipated risks should be evaluated on the basis of a baseline of conditions (archeological maps) or linked to some extent with objective information so as to assess whether a risk was, or was not, a foreseeable event under due diligence.</li> </ul>

(table continues next page)

**TABLE 9A.1. Allocation of Risks Related to Project Design and Construction, Including Site Conditions (Continued)**

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Site and ground conditions: utility reallocation	This risk is related to additional costs and implementation delays caused by unexpected interference with public utility networks. As in the case of environmental and archeological risks, it is essential for the public partner to mitigate the risks by investigating and assessing utility locations in advance of the contract tender. In the context of urban rail, this risk is usually significant if the information on utility locations and physical state is not available.	(X)	X	In general, the granting authority may transfer this risk to the private partner when an adequate survey of utilities is available.  <i>When or to what extent assumed or shared by public authority</i>  When information on the location of utilities is unavailable or deficient, it is not uncommon for the public authority to share this risk and set a limit or cap on the risk exposure of the private partner in terms of both delays and additional costs.

Source: Information compiled by K-infra based on publicly available information.

Note: EIA = environmental impact assessment; EMP = environmental management plan; O&M = operation and maintenance; PPP = public-private partnership.

**TABLE 9A.2. Allocation of Risks Related to Project Operations**

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Revenue risk: demand-volume	Refers to the potential impact of lower-than-anticipated demand or use. A general rule for deciding the allocation of use or demand is the scope of the project. If the contract does not provide the management tools for managing the demand risk (when it does not include the operations), the risk should not be transferred. Conversely, when operations are included (vertical integration), some risk and reward linked to volume or patronage should be transferred.	X	(X)	Even assuming vertical integration (operations provided by the private partner), it is expected that the public partner would need to assume a significant part of the demand risk (via availability payments). Assuming that the project contract includes operations, the most common good approach is limited risk transfer by basing revenues mostly on availability payments (and only partially on demand) or by paying on the basis of demand, but under a system of bands (as in a number of LRT schemes in Spain) or minimum revenue guarantees, as described in some examples in chapter 7.  <i>Note:</i> Some aspects of demand risk are to be retained by the public authority, and the private partner should be properly covered against them. The most common cause of lower demand is economic downturn, which as a general business risk should be borne by the private partner to some extent. However, lower demand may also be caused by competing facilities, a competing offer (for example, bus transportation), network risks, or other subtle risk events. If a competing facility promoted by the authority (or by the government in general), which was not announced or planned at the time of the tender, causes a downturn in traffic compared with previous projections, this is commonly (or should be) considered a retained risk event. This is a similar situation to when government bases the patronage projections and the financial feasibility of the project on reorganization of the existing bus network. The private partner receives the right to compensation if the reorganization is delayed or not implemented in due time.

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**TABLE 9A.2. Allocation of Risks Related to Project Operations (Continued)**

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Revenue risk: tariff levels (regarding user revenues)	The private partner is not in control of the level of fares in most of the urban rail projects; therefore, tariff increases may divert from the CPI, or the authority may need to actualize the tariff at a different pace than originally agreed (for example, keeping it constant in current terms). As a result, the private partner would suffer the risk of lower-than-expected increases, and this risk has to be eliminated or retained in order to allow the authority to retain some flexibility to review the tariff policy. This is crucial when the private partner will be paid on the basis of demand (partially or totally) and will retain the revenue of the farebox.  When the farebox is retained by the government (reimbursing the private partner completely by means of service payments linked to volume or availability) this risk is naturally retained by the public authority.	X		As the private partner is not in control of the level of tariff (in the vast majority of the projects), the private partner should be entitled to compensation to the extent that it is affected by lower-than-expected tariff increases or actualizations.  One common approach is to define a baseline for tariff levels in the contract, including a defined profile of the tariff with an indexation method “in the shadow” (for example, CPI), so as to calculate the loss or the extra profit by comparing the baseline curve and the actual tariff. This has the complexity (especially in transportation projects) of considering elasticity of demand, as a lower-than-expected actualization of tariff will produce a loss in revenues, but this loss may be partially corrected by a potential increase in use/demand due to the lower price.  The principle is that regardless of the actual tariff settled on each year for the user payment, the private partner receives the same amount per user. This is done through a settlement mechanism where government pays the difference between the actual revenue and the deemed revenue, calculated by applying the shadow tariff, or receives a payment from the private partner when the actual tariff is above the baseline tariff curve.

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**TABLE 9A-2. Allocation of Risks Related to Project Operations (Continued)**

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Revenue risk: fraud risks	Fraud commonly refers to willingly avoiding payment and may represent a serious impact on the finances of project (or on the budget of the public authority when retaining the farebox) when not duly controlled.	X	X	Assuming operations are included, to be incentivized to control or manage proactively, the private partner should be exposed to this risk to some degree, regardless of whether the private partner or the authority retains the farebox revenue. The private partner is the party best positioned to manage the risk, which it can mitigate by controlling access and ticketing.  The private partner will have a natural incentive in those projects to diminish fraud when it is receiving user revenue, but even in these cases, it may be convenient for the public authority to share risks, especially when the risk is highly significant because of the design of the vehicles (for example, open vehicles). In these cases, it is not uncommon to limit the risk so as to share it against a fraud benchmark (for example, fraud above 5 percent will be shared at a 50 percent level, while fraud above 10 percent will be considered extraordinary and full compensation is provided above that threshold).  Many metro and LRT projects are structured around availability or quality payments. In these cases, government should include fraud management in the availability criteria to explicitly incentivize the private partner to control fraud.

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TABLE 9A.2. Allocation of Risks Related to Project Operations (Continued)

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Revenue risk: inflation (regarding government service payments)	<p>Contracts must provide clear rules as to how payments will be indexed to reflect cost inflation. Generally, the private partner assumes the risk of cost inflation not being compensated by revisions to pricing.</p> <p>When considering not only revenue but also costs, inflation is a two-faced risk: higher inflation affecting costs will result in lower operational margins, but provided it is neutralized by a revenue indexation mechanism, it may result in higher nominal cash flows to debt service and to shareholders, increasing the equity internal rate of return in nominal terms.</p> <p><i>Inflation risk</i> refers to the risk of the value of payments received by the private partner being eroded by inflation. If inflation is not captured in the payments, the real value of the revenues will be significantly eroded when inflation is higher than anticipated, which may be exacerbated by cost inflation resulting in a lower operational margin.</p>	X	X	<p>Inflation risk is naturally a shared risk, with the authority providing protection to the private partner by indexing (to some extent) the payments to CPI (or another price benchmark), and at the same time being exposed to inflation of the price of the service.</p> <p>The private partner will assume the risk that the indexation mechanism, established in the contract, does not effectively protect the private partner's cash flows. This may be because cost inflation is higher than expected and, therefore, not neutralized by the indexation mechanism, or simply because CPI movement (as captured by the indexation) differs from what was anticipated—also eroding the expected nominal value of operating cash flows.</p> <p>Inflation risk is generally borne by the private partner, which can manage the cost inflation risk by transferring it to the contractors, fixing or limiting the price of the O&amp;M tasks, or linking it to an inflation index correlated to the index applied by the authority in the PPP contract.</p> <p>Any PPP requires a clear set of rules to index the payments and capture the natural movement of inflation in costs and price of services.</p> <p>Provided it is clear how indexation to CPI (or a similar benchmark of price) provides value for money, the question is the extent to which the payments should be linked to inflation to avoid overprotection of the inflation risk.</p>

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**TABLE 9A.2. Allocation of Risks Related to Project Operations (Continued)**

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Revenue risk: availability and quality	In most urban rail projects, revenues will be partially or totally linked to availability or quality. When the performance requirements and performance target levels are not met, this will logically affect the revenue and must be the responsibility of the private partner. Failure to meet these requirements may affect the revenue directly (abatement of payments) or indirectly (imposition of penalties or liquidated damages).		X	This risk is borne by the private partner as it is the essence of the PPP objectives. This risk is also referred to as performance risk. Governments need to consider the level of risk they want to transfer. It is common in low- and middle-income countries for the risk to be tempered by considering a portion of the payment fixed (not subject to deductions) or limiting the amount of deductions. Governments also need to request a level of performance or output that is challenging but achievable.
Ancillary revenues	The risk related to revenues such as advertising, renting of spaces in stations, and other similar commercial activities is normally transferred in full to the private partner.		X	Private partner. However, some contracts may provide for the sharing of ancillary revenues above a baseline established in the winning bid. This sharing of revenues provides an upside to the government, while giving the private partner an incentive to adequately exploit commercial activities.

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TABLE 9A.2. Allocation of Risks Related to Project Operations (Continued)

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Revenue risk: government pays counterparty risk and appropriation risks	To the extent that payment is the main obligation of the public partner, the government assumes revenue and affordability risk. This discussion about risk allocation is based on the perspective of the private partner (events that may affect its financial standing related to risks that may or may not be shared or retained by the public party).  <i>Revenue risk</i> refers, therefore, to the probability and potential consequences of lack of payment from the public party.	N/A	N/A	Each party assumes this risk from its own perspective. Government assumes the risk from the perspective of affordability and funding availability.  In government-pays PPPs, the risk of default by the authority is obviously a private-side risk, inherent in the strategic decision to invest in a particular country's market or in the projects promoted by a particular authority. Credit risk is more an issue in subsovereign PPPs. To the extent that it relates to appropriations in the budget or to the risk of affordability issues, the public party may pursue various actions to mitigate this risk.  For low- and middle-income metropolitan regions entering into subsovereign PPPs, especially those of a government-pays type, it is good practice to provide credit enhancement from the central government to ensure access to the investors market (letters of credit, guarantee by the treasury, or guarantee funds). The private partner will also have the chance to contract political risk guarantees (such as with MIGA or private insurers) and other mechanisms from MDBs, such as partial guarantees to cover the debt to be raised.
Rolling stock fleet increases	The risk of additional investment to meet higher demand may occur in later years of the contract with no material time to amortize the investment.	X		When farebox is retained by the public authority or is a marginal part of total revenue, this risk should be retained by the public authority.

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**TABLE 9A-2. Allocation of Risks Related to Project Operations (Continued)**

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Maintenance and operating costs	<p>Maintenance risk may refer to the risk of improper maintenance resulting in a lack of performance, which is implicit and covered in availability and performance risk analysis.</p> <p>Maintenance risk also refers to the risk of higher costs for maintenance operations and plans (including ordinary maintenance and renewals as well as upgrades). This is the focus of the risk in this category.</p> <p>The risk may correlate with the design risk, as improper design may drive maintenance costs higher, especially major maintenance and renewals (life-cycle costs), and may be due to improper maintenance planning and management. It is not uncommon to consider some exceptions to the general transfer-of-risk rule for some particular risks and cost elements in specific projects: utility costs (especially energy), insurance premium costs, and “inverse risk of usage” (that is, when the payment is not linked to volume, there is a need to compensate for risks of maintenance cost overruns due to higher-than-expected demand).</p> <p>The purchase of new vehicles is an extreme case.</p>	X	<p>This is a natural risk to be allocated to the private party because the maintenance obligation is a core element of any PPP contract scope.</p> <p>Technology obsolescence is another subset of risk that generally has to be assumed by the private party, unless related to discriminatory or specific “change in law” (regulations that may imply mandatory technological enhancements), which are a subset of changes in law. <i>Some limited exceptions</i></p> <p>In some cases, the financial impact of maintenance risks on private partners may be limited. For instance, certain contracts provide for the sharing or/capping of the private partner’s exposure to higher electricity costs and, less commonly, increasing insurance costs (capping the risk of premium increases at a threshold, commonly 100 percent of the initial premium actualized).</p>	

(table continues next page)

**TABLE 9A.2. Allocation of Risks Related to Project Operations (Continued)**

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Residual value and hand-back conditions	Hand-back risk is the risk of investment needed by the contract expiration date to ensure a reasonable extension of the operational life of the asset beyond the contract term. When, as is the case in most PPPs, the asset is "handed back" to the authority at the end of the contract, it should be in an appropriate physical state. The authority should not be exposed to the risk of the asset having a short remaining life, having a low residual value, or being in an improper technical state. The contract should clearly define the technical state that the asset has to meet at the contract expiration date (noting that some specific assets—for example, those subject to a fast technological obsolescence—would be excepted, but this should be clearly established in the contract as part of the hand-back requirements or specifications).	X		This risk is borne by the private partner, but taking into account that the hand-back will happen at the end of the contract (unless terminated early, in which case the provisions are specifically provided in the contract), the partner may have less of an incentive to manage the residual value risk so as to meet the specified standard. The mechanisms for handling this risk are in the contract itself, through incorporation of "hand-back," "hand-over," or "transition" provisions.

Source: Information compiled by K-infra based on publicly available information.

Note: CPI = consumer price index; LRT = light rail transit; MDB = multilateral development bank; MIGA = Multilateral Investment Guarantee Agency; O&M = operation and maintenance; PPP = public-private partnership.

**TABLE 9A.3. Allocation of Financial Risks**

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Availability of finance	This represents the risk of financing (especially third-party financing) not being available at commercial close or before construction starts or only being available on prohibitive conditions.		X	This risk relates to an essential obligation of a PPP and should generally be assumed by the private partner. However, the government has to mitigate the risk proactively by proper preparation and appraisal and potentially (in some projects in low- and middle-income countries) by providing financing support using some of the mechanisms described in chapter 10 (grant financing, public loans, derisking, and credit enhancement measures).
Financial costs or interest rates	Changes in interest rates affect project costs (increasing investment costs as a result of higher interest capitalized during construction and higher debt service payments).		X	This risk is generally taken by the private partner and can be mitigated using hedging mechanisms. In some cases, the public authority may completely or partially assume the risk that the base rate changes between the time of bid submission and the time of financial close.
Foreign exchange risk	Risk of currency exchange is generally assumed by the private partner, especially when related to the real cost of capital or operating expenses. However, the specific risk related to cross-border debt in hard currency is a very specific and major issue. Devaluation of the local currency, when it is the currency of the revenues of the project (payments from government or from users), increases the value of the debt and the burden of debt service. For that reason, governments often assume (or share) devaluation risks. Risk may be assumed by different means.	(X)	X	The default position in PPPs is for foreign exchange risk to be assumed by the private partner. However, in some low- and middle-income countries, access to long-term finance in local currency is not possible, and cross-border financing in hard currency is needed. In the context of hard currency, cross-border financing of foreign exchange risk is a major issue.  <i>When or to what extent assumed or shared by public authority</i>  In some specific projects and countries, the public authority will assume currency risks by committing a part of the contractual payments in hard currency or by providing compensation to the private partner for devaluations above certain thresholds.

Note: PPP = public-private partnership.

**TABLE 9A.4. Allocation of Other Risks Affecting or Occurring throughout the Contract Life**

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Uninsurable risks	A risk originally insurable (at the inception of the contract), and for which a requirement to be insured has been included in the contract, may become uninsurable during the life of the contract.	X		Unless specifically imputable to the private partner, this risk should not be borne by the private partner; instead, the contract should provide for the ability to change the specific insurance requirement or for an automatic waiver of that specific obligation.
Changes in law: general	Changes in general laws such as on labor, business regulations, including general accounting and tax rules.		X	Any change in law or regulation that generally affects all business should be borne by the private partner. <i>Limited exceptions</i> Some countries provide for protection or compensation in reference to changes in value added taxes.
Changes in law: specific and discriminatory changes in law	Discriminatory changes in law (affecting the specific project), as well as specific changes in law (affecting only the sector in which the project company carries out its activity, in this case, public transport or specifically rail or metro projects) may affect the project by increasing investment or O&M costs.	X	(X)	<i>Discriminatory</i> This risk should be fully retained by the granting authority by assuming the responsibility to compensate the private partner for any discriminatory change in law. <i>Specific</i> Usual approach is to share the risk, but always providing a cap on the overall exposure of the private partner, so the risk is quantifiable. For example, the first X percent of the risk impact of a single event may be borne by the private partner. Beyond that threshold, the contract may establish that the parties each will assume 50 percent of the impact up to the upper limit of the risk, which may be defined as a percentage of cost deviation. In addition, it is common to provide for an overall cap, as a sum of the impact of all potential events, established as a percentage of the original investment or an absolute figure.

(table continues next page)

**TABLE 9A.4. Allocation of Other Risks Affecting or Occurring throughout the Contract Life (Continued)**

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Changes in services: scope of work or financial need	An authority should have the ability to ask for or order changes in the scope of services or works (under the legal limits established by the respective legislation), but this may financially affect the private partner as long as the change imposes new investments or more onerous performance requirements.	X		Setting aside the potential limits established by the procurement regulations in some countries, changes in design or scope of works and changes in service requirements are always a risk event to be allocated clearly to the public partner. This is an area of risk where the contract should not just state what the risk allocation is, but also contain clear and transparent provisions governing how the process will be handled in the case of a change occurring, including how the price or cost will be defined and how compensation will be granted.
Vandalism	Vandalism is the risk of intentional acts against the asset or parts of the asset.		X	Generally, vandalism is a risk to be allocated to the private partner, as it is the economic owner of the asset and has the first responsibility to protect the asset's physical and operational state. <i>Some limited exceptions</i> In some specific projects, this risk is shared. This may be a sensible approach when the likelihood and consequences of acts of vandalism are high and where asset protection may be difficult or costly.
Early termination by default: related to bankability	The risk of early termination, from the perspective of the private partner, is the risk that the compensation amount due at early termination is insufficient to meet its financial obligations. This risk (as perceived by the private partner) is relevant for the authority in terms of commercial feasibility since a compensation method perceived as unfair or unbalanced or one that is ambiguous or difficult to assess may involve losing bids or even facing a no-bid situation.		X	Technically speaking, this risk is assumed by the private partner. <i>Limited exceptions or nuances</i> Public authorities should mitigate this risk at least by objectively defining the causes related to each type of termination and the calculation of the related compensation, under clear rules and including, potentially (in some low- and middle-income countries), some protection to the lenders even in the event of termination by default of the private partner ("debt underpinning" or guaranteeing a percentage of the debt that will be paid as a floor to lenders in case of early termination).

(table continues next page)

**TABLE 9A.4. Allocation of Other Risks Affecting or Occurring throughout the Contract Life (Continued)**

RISK	DESCRIPTION	ALLOCATION		COMMENTS
		PUBLIC	PRIVATE	
Force majeure	<p>Force majeure may have different meanings in different jurisdictions and may even be a legally defined term of direct application to PPP contracts (especially in civil code countries where the administrative legal corpus regulates the procurement and public contracts).<sup>a</sup> Force majeure typically includes “acts of god,” including natural disasters or other natural events with potential extraordinary impact, such as hurricanes, earthquakes, storms, and so on, that are not controllable by either party and that should be shared (and specifically defined as such, if possible, in the contract).</p> <p>It also includes certain political events with low likelihood, but unmeasurable effects, such as wars, terrorism, nuclear contamination, and so on, that are uncontrollable by either party. Some countries or some specific contracts may also include malicious damage (and more exceptionally strikes or riots)<sup>b</sup> under the force majeure concept.</p> <p>Force majeure causes inability to perform (and as such should be considered exempted in terms of declaring breaches or default) and raises the need for additional investment, possibly concluding in the right to terminate by either party.</p>	X	X	<p>Technically, these are shared risks, as the contract will impose the obligation for the private partner to contract out certain insurance policies, which will commonly cover some events potentially regarded as force majeure events; the first loss in such events will be borne by the private partner who in turn (and as prescribed in the contract) will be compensated by the indemnity claimed under the insurance policy. The risk of the indemnity being accessible is a risk of the private partner, unless the risk has become an uninsurable risk in the course of the contract (see “uninsurable risks”).</p> <p>Force majeure risks are not only to be treated as compensation, defining who should bear a loss and when; the contract should also define how to handle the risk of the service not being available during a certain period of time because of a force majeure event, including provision for either party to renounce the contract and ask for an early termination (in which case the financial impact should be neutral, with the private partner only and potentially exposed to the loss of opportunity costs). When the contract terminates for a force majeure event, the contract should indicate a clear termination compensation sum.</p> <p>A relevant aspect in considering a force majeure event, also applicable to most of the compensation events defined in the contract, is that the event should not provide undue protection if the private partner fails to behave as expected. The contract should establish clearly that the private partner, as economic owner of the asset, must exercise all of its due diligence so as to avoid a risk and mitigate its consequences.</p>

Source: Information compiled by K-infra based on publicly available information.

Note: O&M = operation and maintenance; PPP = public-private partnership.

a. The Public Private Partnerships in Infrastructure Resource Center provides an interesting description of the variety of approaches to defining force majeure and advises on how to incorporate the concept in the PPP contract. See <http://pppworldbank.org/public-private-partnership/ppp-overview/practical-tools/checklists-and-risk-matrices/force-majeure-checklist>. See also EPEC (2012b) that describes the approach in some European countries.

b. When strikes are not general strikes, but only affect the specific project, the risk is generally borne by the private partner.



**TABLE 9A.5. Risk Allocation in Recent Public-Private Partnerships in Urban Rail in Latin America**

TYPE OF CONTRACT	TYPE OF RISK	RESPONSIBILITY		
		PUBLIC	SHARED	PRIVATE
EPC contract for civil works + EOT concession with partial demand risk transfer (São Paulo Line 4)	Construction	X		
		Government compensates concessionaire for delays, but is protected through fixed-price, date-certain EPC		
	Geological	X		
	Demand		Band system: +/-10%-20% +/- 20%-40%	Private sector partially assumes demand risk (+/-10% relative to base case)
	Foreign exchange		X	
	Environmental	Government secures environmental license		Private sector is responsible for environmental management
	Legal			X
	Utility interference	X		
	Archeological finding	X		
	Resettlement	X		

(table continues next page)

**TABLE 9A.5. Risk Allocation in Recent Public-Private Partnerships in Urban Rail in Latin America (Continued)**

TYPE OF CONTRACT	TYPE OF RISK	RESPONSIBILITY		
		PUBLIC	SHARED	PRIVATE
Vertically integrated PPP with partial demand and geological risk transfer (São Paulo Lines 6 and 18)	Construction			X
	Geological	Unknown up to R\$40 million	Unknown > R\$40 million: renegotiation	Known + unknown ≤ R\$40 million
	Demand		> 140%: renegotiation; 115–140%: shared upside; 60–85%: shared downside; < 60%: renegotiation	85–115% of projected demand
	Foreign exchange			X
	Environmental	Issues environmental license		X (unknown environmental liabilities, not contemplated in license, can trigger renegotiation)
	Legal			X
	Construction			X
	Geological			X
	Demand			X
	Foreign exchange			X
Vertically integrated PPP without demand risk transfer (Lima Metro Lines 2 and 4)	Environmental	X (licensing and preexisting liabilities)		X (regulations)
	Legal	X		
	Utility interference	X		
	Archeological finding	X		
	Resettlement	X		

Note: EPC = engineering, procurement, and construction; EOT = equip-operate-transfer; PPP = public-private partnership.

## Notes

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1. In a private finance PPP with no public cofinancing, no payments would be made during construction, but payments during the operating period would be higher, covering O&M expenses and remunerating private capital investment (projected debt service and dividends to equity investors).
2. For an example of an VfM analysis report for a light rail transit project in Canada, see KPMG (2016).
3. Until fairly recently, fully bundled PPPs had been used for developing simpler projects such as elevated or at-grade trams or light rail projects that did not involve underground construction. However, this trend is changing as some notable large urban rail projects are currently being carried out under bundled PPPs. The São Paulo Line 6 and Lima Line 2 projects in Latin America and Hyderabad Metro project in India are being developed through single PPP contracts that encompass all project components.
4. Minimum or maximum contract terms may be defined in general policy guidelines or, mostly in civil code countries, in specific PPP legal frameworks.
5. Some governments may decide to finance directly all works under a separate contract and will limit the scope of the PPP contract to operations, usually including the provision and maintenance of rolling stock (EOT contracts).
6. This situation will generally only arise in project contracts with no intensive capital requirements (only operations) or in contracts with some operations and rolling stock (EOT) and strong revenue generation.
7. In addition, it is possible to include in the arrangement periodic value or market testing of certain services provided by the developer. Value testing refers to benchmarking in which the developer compares its costs for providing certain services against the market price for the services. Market testing requires the partner to retender a service in order to gauge the market price for it. After this test, any increase or decrease should be reflected in the price charged to the authority.

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Contemplation

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6:55

## MAXIMIZING FUNDING AND FINANCING

Daniel Pulido and Cledan Mandri-Perrott

The current gap in global infrastructure investment is estimated at US\$1 trillion per year and is expected to widen over the next couple of decades (Maier 2015). In order to bridge this gap, governments will need to use public resources better and to mobilize private capital from traditional and new sources.

Urban rail projects bring enormous benefits to city dwellers, but they are costly. In low- and middle-income countries, they often are the largest infrastructure investments undertaken by the government. Obtaining funds to pay for projects of such magnitude can be difficult and onerous. The failure to mobilize appropriate funding (and financing) is one reason why many urban rail projects fail to advance beyond initial planning. The willingness and capacity of the government and users to commit funds to mass transit ultimately determine a country's ability to invest in new urban rail projects.

Increasingly, governments in low- and middle-income countries are resorting to public-private partnerships (PPPs) to deliver large infrastructure projects with financing from the private sector. Mobilizing private resources in a cost-efficient manner requires an important up-front effort to design a financing structure that mitigates key risks and taps into different sources of capital according to their suitability for financing different project components.

*Photo:* Active Commercial Space in Po Lam Station, MTR, Hong Kong SAR, China, 2009. *Source:* Lip Jin Lee via Flickr (CC BY-NC 2.0).

This chapter explains the difference between funding and financing, describes where implementing agencies can get the funding and financing needed for project development, and discusses the suitability of different financing vehicles. It then provides useful information and considerations for making urban rail projects bankable—that is, able to obtain the long-term financing needed for their development. Although the subject of funding and financing is explained irrespective of the project delivery method (public procurement or PPPs), this chapter focuses on the challenges associated with mobilizing private finance—one of the objectives of pursuing a private finance PPP (as defined in chapter 8). Finally, it offers recommendations to develop an adequate financing plan.

### Funding versus Financing

When it comes to developing urban rail (or any other infrastructure project), it is critical to understand the difference between “funding” and “financing” and to avoid the trap of focusing only on the latter. “Funding” refers to who pays for the increased accessibility brought about by an urban rail system (that is, taxpayers and users), while “financing” refers to who provides the capital to deliver the infrastructure required to develop the system in the first place. From another vantage point, “financing” provides the money required up-front to meet the costs of constructing or developing the project, while “funding” is the long-term revenue stream used to cover payment obligations, including debt service (ADB et al. 2016).

In a project developed via traditional public procurement models, the government finances the infrastructure by making payments directly to contractors during construction. It funds these payments mainly from taxes and other sources of government revenue, which can also be used to secure loans or to back bonds if additional financing is needed.

In a PPP that involves private finance, the private sector (commercial lenders and equity investors) finances part of the project, while funding to repay such financing comes from farebox, ancillary, and sometimes even real estate development revenues (exploited directly by the private partner under the terms of the PPP or by the public sector) or from the government’s budget (that is, output based or availability payments). Regardless of the method of delivery or source of finance (public or private), funding is key to making a project happen. The level and stability of project funding also significantly influence the availability of financing, especially in privately financed projects. Therefore, financing alone cannot fix a funding problem; reliable funding sources are required to



make the debt issuance affordable and to ensure the long-term financial viability of the system.

Indeed, the sustainability of urban rail operations also depends on having reliable and sufficient funding. Public authorities that are considering developing rapid transit systems need to do a lot of up-front work to ensure sufficient funds to repay the loans obtained from financiers or to compensate the private partner (under a PPP) for operation and maintenance (O&M) services and for its share of the investment. The search for additional sources of funding becomes critical given the large size of urban rail projects relative to low- and middle-income countries’ budgets and the sector’s limited capacity to cover costs with user fees.

Regardless of the type of financing, the sources of funding are always the same: the government budget, farebox revenues, nonfare commercial revenues (such as advertising, merchandising, and leasing of commercial spaces), and development or tax-based land value capture (LVC). Although less prevalent, other user charges or dedicated taxes may also be used in some jurisdictions. Table 10.1 summarizes the sources of funding and financing, which are described further in subsequent sections of this chapter.

**TABLE 10.1. Sources of Funding and Financing for Urban Rail Projects**

FUNDING		FINANCING	
TYPE	SOURCE	TYPE	SOURCE
Government revenues	• General taxes	Public finance	• Multilateral development banks
	• Intragovernmental transfers		• Bilateral development institutions
User revenues	• Farebox revenues		• Public or municipal debt
Commercial revenues	• Advertising		• Tax exemptions
	• Leasing of commercial spaces		• Government-backed securities
	• Naming rights		Private finance
• Merchandising	• Equity investors		
LVC revenues	• Development based	• Capital markets	
	• Tax based	• Equipment suppliers	
Other revenues	• User charges		
	• Dedicated sales or payroll taxes		

Note: LVC = land value capture.

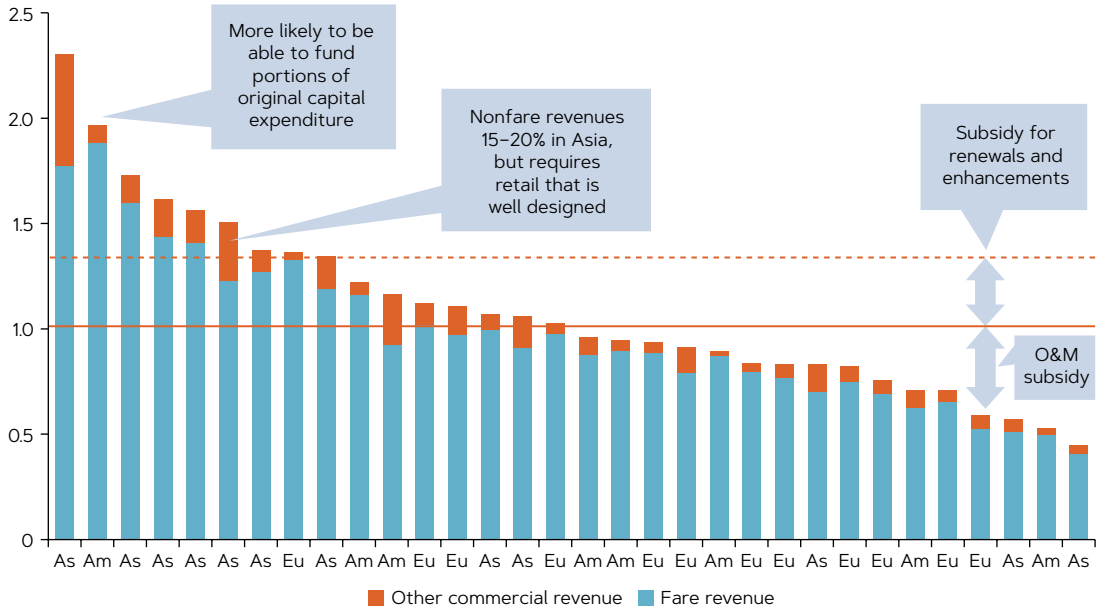
Financing new urban rail projects should form part of an overall strategy to finance urban transport, which also includes other modes that serve as feeders for rail lines. Ardila-Gómez and Ortégón-Sánchez (2016) provide an analytical framework for assessing and designing urban transport financing based on the concept of “who benefits pays.”

### Sources of Funding

Most urban rail systems around the world are unable to cover their operating costs with farebox revenues, let alone capital expenditures. Using 15 years of data from 26 metros around the world (mostly in high-income countries), international metro benchmarking programs CoMET and Nova have shown that, on average, metros only cover 89 percent of operating expenditures from commercial revenues (farebox and ancillary revenues) and spend around 54 percent above their operating expenditures on capital renewal programs, excluding extensions (Anderson, Findlay, and Graham 2012). This means that metro companies would need almost two times their commercial revenue to meet operating expenditures and asset renewal needs. Although these data can vary depending on the period analyzed and the number and characteristics of metros included in the sample, one thing is clear: all capital renewals and expansion projects are funded out of government budgets (see figure 10.1). When public financial resources are limited, project-implementing agencies are faced with funding restrictions that can lead to suboptimal project scopes and funding gaps.

A funding gap occurs when the urban rail system’s revenues are not enough to pay for operational costs and investments in capital improvements. A funding gap is a significant impediment for maintaining service quality and addressing increasing urban mobility needs. However, closing the gap is no easy task when public budgets are under growing pressure and the most direct solutions for increasing revenues (that is, increasing fares or implementing congestion charges) are politically difficult to implement. The situation is worse in low- and middle-income countries where there is little experience with rapid transit, capital investment needs are even larger than in high-income nations, and farebox revenues are constrained by the limited scale and poor quality of urban transport systems. The funding gap in these cities is widened further by the implicit subsidies for the use of private cars, which represent only a minority of trips, but generate very large costs for society in the form of congestion, air pollution, and accidents (Ardila-Gómez and Ortégón-Sánchez 2016).

**FIGURE 10.1. Farebox Ratios for Urban Rail Systems around the World**



Source: World Bank and RTSC 2017.  
 Note: Am = Americas; As = Asia; EU = Europe; O&M = operation and maintenance.

This section describes the sources of funding available for urban rail projects, including government subsidies, fare revenues, and alternative sources. These alternative sources of revenue include nonfare commercial or ancillary revenues, LVC, dedicated taxes, and user charges. Planning for the use of alternative sources of revenue early in project development can provide project-implementing agencies with more time to incorporate them into the business model, closing the funding gap to better leverage financing or ensure more robust coverage of O&M (and capital maintenance) costs.

**Government Revenues**

Most of the funding for large infrastructure projects has historically come from national and local government budgets. Urban rail is no exception. Under traditional procurement models, government tax revenues and borrowings serve to pay for construction works, repay the loans taken by project-implementing agencies, or subsidize public operators.

Generally, the source of revenue for public funding of urban rail projects comes from some form of tax collected by the national government (such as income taxes) or by local governments (such as property taxes). These taxes are

general in nature and differ from other dedicated tax instruments that can be applied to direct or indirect beneficiaries of urban rail projects. Public funding dependent on annual government budgets is subject to appropriation risk and is, therefore, neither predictable nor stable from one year to another. Reliable funding from public sources requires multiple-year budgeting arrangements (see chapter 12).

In PPPs, government budgets are used to make payments to private partners during the operational period in compensation for the provision of urban rail services. Private partners, in turn, raise financing secured by these payments. When receiving payments from the government, private partners and financiers are exposed to the associated credit and liquidity risks. Payment mechanisms under PPP structures are explored in detail in chapter 9.

### **Fare Revenues**

User fare revenue is an essential source of funding for urban rail systems. However, it is rarely enough to cover even O&M costs. On average, user fare collection covers only about 75 percent of the operating costs of metro systems globally<sup>1</sup> (Pulido and Portabales 2015). Some metro systems do recoup their operating costs, such as those in Santiago, Chile; and Hong Kong SAR, China; but others, like the Mexico City Metro, only cover half of their operating expenses with fare revenues. Urban rail operators have reported that the most effective strategies to increase fare revenues that are within their control include (1) bus feeder services integrated with urban rail service; (2) integrated ticketing, station expansions, and upgrades that facilitate access to new demand generators; (3) targeted fare products; and (4) services to open new markets, such as off-peak frequency improvements (CoMET and Nova 2015).

Fare revenue from riders depends, in part, on ridership levels. Therefore, this revenue depends on factors that are outside the control of project-implementing agencies and operators, including population changes, economic growth, and employment levels. Other factors that drive demand are within the control of governments, but often are poorly integrated with urban transport planning and management, including land use policy, urban transportation pricing, and government regulations (see chapter 3). Of these factors, effective fare and physical integration across transportation modes is the most important one for increasing demand and maximizing farebox revenue. This integration may require an institutional framework with a transport authority that takes responsibility for coordinating services and that distributes fare revenues among different operators (public or private) (see chapter 12).

In addition to demand, fare policy—including the level at which the tariff is set and the mechanism through which it is adjusted—is a fundamental factor

in ensuring adequate funding from fare revenues. Most urban rail tariffs are set below the cost of service provision (below both operating expenses and capital renewal needs), resulting in underfunding. The rationale behind this decision is often to keep tariffs affordable and encourage demand. However, keeping tariffs low may not allow the funding of investments in capacity and service-level improvements that can have a more positive effect on demand and farebox revenues than low tariffs (Brage-Ardao, Graham, and Anderson 2015). In addition, when tariff levels are not adjusted frequently to keep up with the rising costs of service (labor and electricity costs mainly), they fall in real terms and eventually generate larger deficits that need to be covered by one-off increases that are politically costlier. Government authorities need to define early a tariff structure and adjustment mechanisms that promote financial sustainability (see chapter 12). Tariff setting and adjustment become more difficult once the system is in operation, especially if tariffs are not revised frequently.

Regarding tariff structure, research has found that urban rail systems with a fare structure that varies pricing by time of day (that is, peak versus off-peak) and distance are better able to cover their costs from farebox revenues. Although differentiated tariff structures may be more difficult to understand for riders and may increase transportation costs for riders having to travel longer distances (often the lowest-income users in developing cities), both of these issues can be addressed using smartcard technologies and targeted demand subsidies (see chapter 2).

### **Nonfare Commercial or Ancillary Revenues**

Considering that fare revenues are insufficient to cover operational and capital costs, some urban rail systems around the world supplement their funding with nonfare commercial or ancillary revenues. In some urban rail systems, these alternative sources of revenue have become significant, even approaching 20 percent of fare revenues. Commercial activity by urban rail systems is concentrated in high-income economies, with many of the most lucrative in Asia. But systems in low- and middle-income countries are increasingly looking for ways to increase their nontariff revenues, often in collaboration with the private sector.

The goal of maximizing revenues from commercial activities has to be embedded in project planning from the beginning, regardless of the project delivery model. The exploitation of additional revenue sources must be incorporated up-front into the mandate and business model for the eventual operator of the system, whether public or private<sup>2</sup> (see chapter 12).

The most common sources of nonfare commercial revenues include advertising, commercial space leasing, naming rights, and merchandising.

### *Advertising*

High passenger densities and frequent service present an opportunity for marketing to captive audiences through well-placed advertising messages in vehicles or in stations (see image 10.1). In 2016, the Madrid Metro implemented an innovative dynamic in-tunnel advertising system on a section of Line 8 that is expected to generate new revenues of about €200,000 per year. Considering that this is only for a section of one of the lines, the revenue mobilization potential of this system for the whole network is significant.

### *Commercial Space Leasing*

Urban rapid transit systems in low- and middle-income countries can lease commercial space at stations, particularly important integration hubs (see image 10.2). In Lima, Estación Central is an underground bus rapid transit (BRT) station (Ave. Grau and Paseo de la República) that will be physically integrated

**IMAGE 10.1.** Advertisements along the Platform of the Gloucester Tube, London, United Kingdom, 2012



Source: Brent Flanders via Flickr Commons.

**IMAGE 10.2.** Commercial Activity among Restaurants and Shops in Hua Lamphong Station: Bangkok, Thailand



Source: Tatsuya Fukata via Flickr Commons.

with Metro Line 2. Currently, it offers approximately 60 commercial spaces, and passenger volume is expected to rise significantly once Line 2 is operating. Such integration has great potential to increase revenues from the leasing of commercial spaces. In São Paulo, for example, franchising consultants have reported that rents for commercial spaces in the urban rail systems are approximately 30 to 60 percent below the rates charged at shopping malls, showing that there is substantial potential for increasing revenue by adopting market prices for the lease of commercial space in and around rail stations (Pulido and Portabales 2015).

### *Naming Rights*

Cities in many countries are selling station names to private companies in order to complement user fare revenues. In addition to adding revenue, some naming rights contracts can stipulate that the private sponsor help with remodeling of the station or providing passenger amenities like improved mobile phone service coverage or free Wi-Fi. The first successful example took place in Dubai, earning well over US\$100 million in revenues per year (for the period 2010–15). Other cities followed, including Delhi, Kuala Lumpur, Mumbai, and New York City. Mumbai Metro sold 12 station names and raised between US\$250,000 and US\$1 million per year for a period of five years (Pulido and Portabales 2015).

While naming rights for stations can be a weighty and relatively stable source of commercial revenue, it may detract from the placemaking that urban rail stations can provide (see chapter 16). Often, rail stations—named after important landmarks or areas—mark the center of urban neighborhoods and provide important community hubs. By naming stations after sponsor companies rather than their location, wayfinding for passengers (especially tourists) can become more confusing and the urban rail station may be less integrated into the urban fabric.

### *Merchandising*

Urban rail systems, especially those that have existed for a number of years, can capitalize on easily recognizable logos, maps, and slogans. The London Underground is a remarkable example of an urban rail system that uses merchandising for additional revenue. Using the “Mind the Gap” slogan and their trademarked London Underground logo and system map on souvenirs, London Metro raises approximately US\$4 million annually. Other systems, including Madrid Metro and São Paulo Metro, have also begun to capitalize on their brand image. In 2014, São Paulo Metro reported revenues from merchandise, products, and services of close to US\$1 million (São Paulo Metropolitan Company 2014).

### **Land Value Capture**

The implementation of rapid transit increases accessibility and improves mobility for residents adjacent to stations. This increase in accessibility, in theory, increases the willingness to pay for land around transit stations, creating an increase in land value. Cities around the world are capturing such value increases and using the resources to fund infrastructure projects and service provision, including covering transit O&M costs.

This section presents a basic account of how LVC has great potential for funding urban rail projects. Chapter 16 presents a more detailed discussion of LVC and its impacts on accessibility and mobility. In particular, chapter 16



discusses some of the strategies for increasing land value as part of an urban rail project, including (1) changes in regulations (land uses, for example) that result in a potential increment in the profitability of land use, (2) investments in infrastructure or neighborhood improvements that result in higher demand for land in those neighborhoods, and (3) implementation of property and betterment taxes (Suzuki et al. 2015).

Various studies in high-income and in low- and middle-income countries have investigated the impacts of urban rail development on land value. A report on several cities in Europe and North America found that, on average, being within 400 meters of a commuter rail station increased commercial property values by about 16.4 percent. For residential property, the increase was 4.2 percent (Goetz et al. 2010). Other studies in high-income countries (mainly in the United States) indicate that, depending on the specific land use and type of urban rail project, the value of commercial property near rail stations has a potential increase of up to 150 percent, while residential property value has a lower, but significant, potential increase of 0–45 percent (Center for Neighborhood Technology 2013). A recent World Bank study has analyzed the estimated land value increases for select rapid transit systems around the world (see table 10.2).

There are two main types of LVC instruments: development based and tax based.

**TABLE 10.2. Estimation of Land Value Increase Resulting from Rapid Transit Investments in Selected Cities**

REGION, COUNTRY	YEAR	TYPE OF RAPID TRANSIT PROJECT	ESTIMATED VALUE INCREASE	DESCRIPTION OF IMPACT
Massachusetts, United States	2006	Commuter rail	9.6–10.1%	Property price differential between municipalities with and without rail service
Santiago, Chile	2005	Metro Line 4	3.3–4.4%	Increase in prices after construction of Line 4 was announced
Seoul, Korea, Rep.	2003	Metro	US\$1.69–US\$7.64 per square foot	Applies to commercial property
Bogotá, Colombia	2016	Metro Line 1	10–20% and 5–10%	Between 10 and 20% for properties closer to 0.5 kilometer from a station and between 5 and 10% for properties between 0.5 and 1.5 kilometer from a station
	2007	Bus rapid transit	6.8–9.3%	For every 5 minutes closer to a station by walking in a radius of 1.5 kilometer

Source: World Bank 2015.

### *Development-Based LVC*

Development-based LVC harnesses the increase in property value that comes with infrastructure investment, whether owned by a private or a public entity. Property development around stations is a common example of an external benefit that results from investments in rail. Once the rail infrastructure and adjacent improvements are completed, the project owner can sell the land that has benefited from urban rail service provision for a higher price, capturing the value increment during the sale of either the property or the rights to exploit the property. In order for project-implementing agencies to capitalize on LVC, they must be staffed with the required skills and knowledge of the real estate business, and this mandate has to be built into their enabling legislation and institutional structure.<sup>3</sup> When project-implementing agencies do not have this expertise or authority, they can consider partnering with other public and private institutions active in the property development business.

One particular type of development right that often accompanies the development of urban rail projects is “air rights,” whereby a developer, through owning or renting property, gains the right to use and develop the empty space above the property. Building over tracks, platforms, depots, or stations (or even creating new in-fill stations) is potentially very profitable for owners of urban rail systems. Several urban rail projects have attempted to internalize the value of property development in order to offset operating losses resulting from insufficient fare revenues. For example, in New York in 2015, the Metropolitan Transportation Authority sold air rights to a parcel on Queens Plaza Park in Long Island for the construction of a new 229-meter tower that will provide 1,000 rental apartments. This real estate transaction helped to reduce pressure on fares, tolls, and taxes. Other successful examples of development-based LVC include land transactions in the Arab Republic of Egypt, India, South Africa, and Turkey to finance transport infrastructure projects (Peterson 2008).

Real estate development, however, comes with an opportunity cost of other potential uses of the land for system expansion or other revenue-generating opportunities. Therefore, it is not the ultimate solution for urban rail’s funding challenges, and project-implementing agencies should remain sufficiently focused on improving transport services and operational efficiency. In some instances, project partners whose interests lie primarily in real estate may have perverse incentives to promote urban rail with little regard for sound operations planning. In the case of a PPP, including the exploitation of real estate opportunities as part of the scope of the contract changes the nature of the business, requiring the private partner to incorporate this experience and the project-implementing agency to develop the required management capacity. If interested bidders do not have the expertise, they may undervalue LVC

opportunities in their bids to reduce their exposure to any risk that could arise from this business.

#### *Tax-Based LVC*

Tax-based LVC is the most common form of capturing value that comes with urban rail implementation and neighborhood improvements. Tax-based LVC leverages property taxes as an independent revenue base for local governments. Tax-based instruments used in both high-income and low- and middle-income countries include (Suzuki et al. 2015):

- *Land (parcel) and building (actual construction) values.* Most land taxes are based on the value of the combination of land and buildings occupying that land.
- *Special assessments and betterment charges.* These taxes and charges finance improvements through additional taxes on properties that receive such improvement.
- *Tax increment financing.* This instrument is frequently used to finance neighborhood-level improvements in transport infrastructure and other basic service provision in the United States. For example, Chicago, Illinois, has as many as 130 tax increment financing districts covering more than 30 percent of the city. However, this instrument has not been widely adopted in low- and middle-income countries.

Independent of the type of instruments used, four preconditions are needed to mobilize increased land value for the benefit of the general public: (1) collect and maintain relevant data on land use and property values, (2) implement public (or public and private) investments in infrastructure that increase potential value, (3) implement changes in land use regulations that increase potential value, and (4) carry out selling or leasing transactions that permit capturing the value.

#### **Other Revenues**

Aside from fare, nonfare commercial, and LVC revenues, project-implementing agencies can consider other sources of funding to pay for capital and O&M costs of urban rail projects. These other sources of funding include sales taxes, payroll taxes, climate funds, and user charges.

#### *Sales Taxes*

In many cities, dedicated sales tax increments are used to fund new transport projects or the O&M costs of existing transport systems. These tax increments

can be temporary in nature and have high political acceptability in high-congestion situations. In Los Angeles, a combination of successive sales tax increments of 0.5 percent that total about 1.75 percent has been used to extend the Gold Line, open the Silver Line, extend the Orange Line (BRT), and extend the Expo Line to Santa Monica. An additional 0.5 percent increase in sales tax approved in 2016 is also expected to pay for new rapid transit capital spending, O&M, and other transport improvement projects.

### *Payroll Taxes*

Payroll taxes raise funding from employers as indirect beneficiaries of transit improvements. This stable source of funding has been found to have a high impact at a low cost for government (Ardila-Gómez and Ortégón-Sánchez 2016). In the United States, the state of Oregon has a transit payroll tax of 0.7 percent that is applied to gross salaries and used to finance transit projects. The state of New York also has a payroll tax for the New York metropolitan region that ranges between 0.11 and 0.34 percent and is allocated to the Metropolitan Transportation Authority. Perhaps the most well-known payroll tax is the *versement transport*—a payroll tax levied in more than 85 percent of urban areas in France. This payroll tax has been in place since 1971 in Paris, where it ranges between 1.4 and 2.6 percent for companies of more than 10 employees and produces revenues that surpass transit ticket sales (National Academies of Sciences, Engineering, and Medicine 2015).

### *Climate Funds*

Although only used in a few rapid transit systems in low- and middle-income countries, climate funding can help to fund urban rail transport. Carbon funding—from multilateral and bilateral sources such as the Clean Development Mechanism, Global Environment Facility, and Clean Technology Fund—involves selling carbon emissions (reductions) resulting from the implementation of rapid transit systems. In the United States, the state of California Department of Transportation recently announced funding of US\$34.5 million for 125 local projects from the Low Carbon Transit Operations Program. This program is funded through auction proceeds from the California Air Resources Board's Cap-and-Trade Program (State of California 2017).

### *User Charges*

In the past decade, an important paradigm shift has occurred toward more sustainable urban transport as urban transportation planners recognize that unrestricted use of private vehicles causes overwhelming negative externalities in the form of traffic congestion and air pollution. Low-occupancy private vehicles

are an inefficient use of urban space and their use of fossil fuel is problematic for public health and climate change. New user charging schemes—“pay-for-use” charges and “polluter-pay charges”—can better price private vehicles for the cost of their externalities, incentivizing more sustainable and efficient forms of transport. Furthermore, the revenue generated from these economic tools can be used to support rapid transit investment.

Although many national and subnational governments already have some form of user charges in their overall budget, in general, these charges are not enough to cover the cost of the negative externalities associated with the use of private vehicles. In this sense, governments are implicitly subsidizing private vehicle use and are not maximizing the potential funding that could be generated by charging users for the true cost of private transport. If new sources of revenue were generated, the portion of the budget that goes to maintaining the road network could be directed to funding rapid transit investments, including urban rail. User charges vary by country and city, but the most common types include:

- *Parking charges.* Parking charges have great potential to shift travel away from private vehicles and the associated revenues can fund transport improvements. In the United States, more than 90 percent of car trips begin and end with free parking; charging for parking would make private car trips more expensive and could promote shifts to more sustainable modes (Shoup 2005). In Mexico City, the EcoParq parking pricing system sets aside 20 percent of monthly revenues to invest in public space improvements. In France, part of the revenue from parking fines is allocated specifically to the financing of public transport facilities.
- *Congestion charges.* Congestion charging schemes charge road users for the additional congestion that they impose during peak demand. Congestion pricing encourages the redistribution of demand in space or in time and forces users of private vehicles to pay for their negative externalities, which creates needed revenue that can be invested in more sustainable transport alternatives. London uses cordon pricing, which is a pricing mechanism that charges vehicles to enter London’s city center, creating a disincentive to enter the congested central business district (see image 10.3). The price is about US\$12.60 and the penalties for avoiding payment are quite high. More than 30 percent of revenues from the scheme are used to improve alternative transport modes, such as buses, walking, and cycling, as well as to repair the road network. Congestion pricing schemes also exist in Singapore, Stockholm, Milan, and Gothenburg.
- *Gasoline taxes.* Gasoline taxes offer a very large source of potential funding in jurisdictions where they are not yet in place, but they are often

**IMAGE 10.3.** Signs Indicating the Congestion Charge Central Zone: London, United Kingdom

Source: mariordo59 via Flickr Commons.

politically difficult to implement or increase. In the United States, the Highway Trust Fund administers a national gas tax of 18.3 cents per gallon and allocates a portion of this funding for rapid transit projects. In Bogotá, more than 50 percent of the gasoline tax has been used to pay for the TransMilenio BRT. In Germany, a gasoline tax increment originally dedicated to road financing has been reallocated to public transport investment and O&M expenses.

- *Vehicle registration charges.* Private vehicle registration charges can also be a potential source of funding for rapid transit systems if they are high enough to account for the negative social costs of vehicle ownership. For instance, in the United States, most states set motor vehicle registration fees at a level that covers only the cost of administration, wasting the opportunity to mobilize a good source of funding for mass transit projects (National Academies of Sciences, Engineering, and Medicine 2015).

## Private versus Public Financing

For the purpose of this handbook, financing refers to the resources or capital required to implement a new urban rail project or to extend an existing one before the project-implementing agency generates the necessary revenue to pay for the investment. Sources of financing for an urban rail project are classified into two broad groups: private and public.

Private financing refers to a loan that is provided by a private entity<sup>4</sup> and is bound by market discipline, meaning that its repayment is subject to project performance risk and its rate of return or price corresponds to that risk (ADB et al. 2016). The financing is considered private when financiers provide resources (be it to a public or a private borrower) on the basis of future cash flows generated by the project, with loan repayment linked to or affected by its performance. For the purpose of this handbook, a loan from a public institution with pricing and repayment conditioned by the performance of the project (for example, when a public financing agency lends money to a PPP project with market conditions) is considered private finance.

Public financing refers to finance provided by any entity (public or private) to state-owned enterprises—such as metro companies in charge of developing new urban rail projects—or governments without exposure to project performance risk. Financing of state-owned enterprises is only considered private finance if its repayment depends on the performance of the system and not on an implicit or explicit guarantee from the public owner of the state-owned enterprise. In this sense, debt issued by public metro companies, such as the Metro de Santiago, is not considered private debt if the obligation is backed or guaranteed by the state.

An alternate definition of public and private finance is related to the recognition of obligations on the government's balance sheet. From a national accounting and reporting perspective, private finance means financing that is not regarded as public debt. It is not, for example, consolidated in the government's balance sheet for the sector. Public finance is recognized in the government's balance sheet for accounting purposes, regardless of who provides the financing (ADB et al. 2016).

These definitions are useful when explaining the different sources of finance for an urban rail project and the main factors to consider for enabling their effective and optimal mobilization. These definitions also help to understand the critical factors necessary to facilitate different forms of financing and the differences in pricing and conditions.

## Public Financing

In the context of developing new urban rail projects or extensions, government funds are used to provide financing to local governments, to public metro companies, and, when projects are delivered through PPPs, to private companies. Public finance can be mobilized for projects delivered via traditional procurement or using PPPs. Under public procurement, public finance takes the form of government payments to the contractor as construction progresses or payments to contractors that provide financing (that is, under the design-build-finance [DBF] model discussed in chapter 8) and are not exposed to project risk, but only to the credit and liquidity risks associated with the entity making the payments. In a PPP project, governments may provide financing or grants (monetary or in-kind) that reduce the need for private partners to mobilize private finance. In both cases, public finance may come from the national government as a transfer or from the local government's budget.

The Organisation for Economic Co-operation and Development (OECD) estimates that total infrastructure investments in low- and middle-income countries reached US\$1 trillion in 2013, of which more than half was financed by governments and only one-third by the private sector (OECD 2015). Therefore, the successful delivery of urban rail projects still relies heavily on the appropriate mobilization of different sources of public financing. Project-implementing agencies should assess the availability of different sources of public financing (discussed in the following subsections) and plan early to mobilize them in an efficient manner.

### Municipal or Subnational Finance

Subnational governments (states and municipalities) can raise financing for the development of urban rail projects backed by their own credit. The repayment of such municipal financings does not depend on the revenue-generating capacity of the urban system, but rather on the overall capacity of the municipality to generate revenue in a direct or indirect manner. Reliance on the credit of the subnational government is direct when the subnational government is the borrower. It is indirect when the subnational government provides a guarantee of the indebtedness assumed by an urban rail agency or company entirely or partially owned by that government. Box 10.1 presents examples of subnational financings provided by the International Finance Corporation (IFC) alongside commercial banks.



**BOX 10.1.****International Finance Corporation Municipal Financing for Urban Rail Projects: Turkey**

The International Finance Corporation (IFC) financed the Istanbul Metro Lines 4 and 7 through senior loans of €50 million and €65 million, respectively, under subnational lending processes. Given that Turkey chose not to issue sovereign guarantees, the IFC was the World Bank Group's most suitable institution to participate in the projects because of its ability to lend directly to creditworthy subnational entities on commercial terms, while also sharing its experience and best practices from similar projects. The lending was structured as a corporate loan to the municipality to avoid exposing the IFC to farebox or ridership risk and to be able to offer very competitive financial terms in view of the municipality's relatively strong credit standing.

Similarly, the IFC financed the Konak and Karsiyaka tramways in Izmir through a corporate loan of €55 million to the Izmir Metropolitan Municipality. The French Development Agency and ING Bank were the other cofinanciers of the project. In a separate follow-on project, the IFC provided a corporate loan of up to €20 million to the Izmir Metropolitan Municipality to help to finance the purchase of 85 vehicles for the Izmir Metro system. Other cofinanciers for the project included the European Bank for Reconstruction and Development (EBRD) and the French Development Agency. The lending to Izmir was once again in the form of corporate loans in view of the municipality's relatively strong credit standing and so that lenders were not exposed to any farebox or ridership risk.

**Green Bonds**

Green or climate bonds are debt securities issued to raise capital specifically to support climate-related or environmental projects. Subnational governments and other public institutions use green bonds to finance or refinance projects that address climate change. As a more sustainable form of transportation, urban rail projects can be eligible for these green bonds. Although private corporations and projects can issue climate bonds and have increasingly done so since entering the market in 2013, issuances supporting urban rail projects have come mostly from subnational governments, as well as from multilateral development banks (MDBs). Most green bonds are purchased by institutional investors in the capital markets. Green bonds issued by subnational governments have grown from US\$4 billion in 2014 to US\$10.5 billion in 2016, with the United States as the largest market, followed by Europe (see box 10.2).

**BOX 10.2.****Using Green Bonds to Finance Urban Rail Investments**

In December 2016, Mexico City became the first subnational government to issue a green bond in Latin America. Offering a 6 percent coupon and a term to maturity of five years, the issuance was two-and-a-half times oversubscribed (Climate Bonds Initiative 2017). The bond proceeds of US\$50 million were used to finance sustainable transport projects, including the city's metro system.

That same year, Hong Kong SAR, China's public rail network operator Mass Transit Railway Corporation (MTRC) Limited issued its first green bond for an amount of US\$600 million with a 10-year term. The bond was used to finance the company's sustainable projects, including its metro operations and the installation of energy-efficient lighting in its vehicles and stations.

**National Government Finance**

Project-implementing agencies often receive transfers from the national government that can be used to pay for capital investments. From the point of view of the project-implementing agency (often a subnational entity), these transfers constitute another source of financing for urban rail projects. Under this type of arrangement, it is critical for the project-implementing agency to fulfill all the cofinancing requirements, secure these early, and protect the financing commitments from political risk via long-term formal agreements. One example of such an arrangement is the financing structure for the National Urban Transport Program in Colombia (Law 310 of 1996), which calls for the national government to finance 70 percent of the cost of rapid transit systems, with the remaining 30 percent coming from the local governments implementing these projects.

In a limited number of cases, project-implementing agencies are under or wholly owned by the national government, in which case an important share of the financing comes from loans or bonds backed by the credit of the sovereign government. This is the situation of the Lima Metro Line 2 project in Peru, a PPP with public cofinancing completely provided by the national government without financial participation of the local city government. The government of Peru issued bonds for the project.

**Official Development Finance**

In 2013, official development partners, including multilateral and bilateral sources, financed around 6 percent of global infrastructure investments, amounting to US\$60 billion. Of this amount, approximately US\$27 billion went to the transport sector, of which around US\$8 billion went to railway development projects and sustainable urban transport systems (OECD 2015).

In 2015, the United Nations Framework Convention on Climate Change Conference of Parties strongly urged high-income countries to scale up their level of financial support, adopting a concrete road map to mobilize US\$100 billion in climate finance per year by 2020. Bilateral and multilateral development finance institutions are expected to provide a large share of this amount.

### *Multilateral Development Banks*

Public multilateral development institutions, including the World Bank, can support the financing of urban rail transport projects. Generally, these institutions finance public sector contributions through long-term loans guaranteed by the national government.

Project-implementing agencies can capitalize on the increased commitments of MDBs to support climate-change-mitigation projects, including rapid transit. In 2012, at the United Nations Conference on Sustainable Development in Rio de Janeiro, the world's largest MDBs<sup>5</sup> vowed to provide US\$175 billion over 10 years to help finance sustainable transportation systems. In 2015, in the context of the Paris Climate Conference, MDBs also pledged to increase climate finance significantly by 2020 (UNFCC 2016). In particular, the World Bank Group announced that it would expand its climate-related lending by a third to 28 percent of annual commitments by 2020. This pledge implies an increase in direct financing for climate action from the current average of US\$10.3 billion a year to US\$16 billion.

MDBs help to finance construction works, equipment, and planning, design, and technical studies by providing loans (to both national and subnational governments). They also provide financial guarantees that reduce the risk of projects and loans, improving access to credit, reducing interest cost, and extending financing terms. Loans to governments may be used in conventional procurement (government borrows to make payments to contractors) or in a PPP context (government borrows to make payments to the private partner). In addition to financing, MDBs also provide technical assistance and capacity building on institutions and governance, engineering, social and environmental risk mitigation, and technical, economic, and financial structuring of projects through grants (nonrefundable) and reimbursable advisory services.

Involving MDBs in the financing of urban rail projects can add value by strengthening technical, fiduciary, environmental, and social due diligence and monitoring during implementation. The value brought about by MDBs is greater when they are involved from an early stage in the project and when project-implementing agencies consider the requirements from these financiers in project planning and design.

### *Bilateral Finance*

Certain national governments provide financing of rail projects through loans from development or export-import banks. Loans from bilateral development institutions are considered official development assistance and are provided at concessional rates with long terms to maturity. Export-import bank financings are tied to project delivery by companies originating in the countries of these government entities. Countries such as China, France, and Japan are large providers of financing for the development of urban rail projects in low- and middle-income countries.

For example, in 2016, the government of Japan, through the Japan International Cooperation Agency, announced concessional financing for development of the Ahmedabad Metro project in the state of Gujarat in India. In 2011, the Export-Import Bank of China provided a loan to the government of Ethiopia for development of the first light rail line in Addis Ababa by the China Railway Engineering Corporation. The loan financed approximately 85 percent of the total project cost of US\$475 million. The French Development Agency is also financing metro projects in Latin America and other developing regions.

### **Government-Backed Securities or Structured Public Financings**

Urban rail projects can also be financed by issuing securities backed by direct or indirect obligations of a government agency—namely, government-backed securities (see box 10.3). Investors in government-backed securities associated with an urban rail project contribute to the financing of construction or operations, but they are not exposed to any project completion or demand risks. In such a structure, the debt service of the urban rail project is supported directly by a government entity through future budget allocations or explicit guarantees, regardless of the project's performance.

Given the complexity of urban rail projects and the uncertainties associated with future ridership, investors and lenders tend to place high price tags on risks, leading to financings that are more expensive than straight government financings. By removing risks from the equation, the financing of projects under this modality becomes structured public financing, rather than project financing. However, using this financing instrument for projects structured as PPPs has the drawback of eliminating the exposure of financiers to performance risk and reducing the incentives for greater efficiency, life-cycle benefits, and market discipline that come with financings secured by the project's expected revenues net of operating costs.

**BOX 10.3.****Financing Using Government-Backed Securities: Lima, Peru Metro Line 2**

According to the contract for the Lima Metro Line 2 project, the granting authority (Ministry of Transport) remunerates the private concessionaire's investments through payment certificates provided at the substantial completion of capital investment milestones for construction and provision of rolling stock. These certificates, known as RPI-CAO (*retribución por inversiones-certificado de avances de obras*), give the concessionaire the unconditional right to receive a stream of payments of a fixed amount denominated in U.S. dollars over a period of 15 years.

RPI-CAOs constitute unconditional and irrevocable contractual payment obligations of the granting authority and have to be paid regardless of the performance of the project as a whole. Therefore, this form of financing is considered to be

government-backed securities (structured sovereign financing). Although the granting authority first funds RPI-CAO payments from fare revenues, the government of Peru is contractually obligated to make up for any shortfall in the amount required to make the payments, protecting the concessionaire from demand risk.

In 2015, the Lima Metro Line 2 concessionaire raised US\$1.15 billion through a financing structure involving the issuance of securities backed by RPI-CAO. Under this financing structure, the concessionaire sells its RPI-CAO to a bankruptcy-remote special-purpose vehicle that simultaneously borrows money to purchase RPI-CAO from the concessionaire (under a sale and purchase agreement). This structure has proven successful for financing PPP projects in Peru.

**Tax Exemptions**

Exempting urban rail projects from selected tariffs and taxes can also be a form of public financing. Early planning for exemptions and their associated legal requirements is essential to using this form of financing effectively. In most cases, such tax exemptions or devolutions will require legislative changes and close coordination between the taxing authority and the entity developing the project (see box 10.4).

In cases where the obligation to devolve taxes is sufficiently strong, projects can even structure financings backed by the tax devolutions. When projects are developed as PPPs, decision makers and project-implementing agencies should consider carefully the benefits associated with long-term tax exemptions (especially on corporate income). Existing tax laws and accounting practices may already provide large tax shields in early years through depreciation and

**BOX 10.4.****Tax Exemptions for Urban Rail Projects in Brazil and Ecuador**

In Brazil, the state of São Paulo levies a tax on operations related to the movement of goods, transport communication services, and the supply of other general goods and services. The state government offered exception to this tax to the concessionaire in charge of developing and implementing Lines 6 and 18 of the São Paulo Metro. At the time of project evaluation, exemptions represented cost savings of an estimated US\$198 million for Line 6 and

US\$82 million for Line 18. The state government intends to develop both of these projects as PPPs.

In Ecuador, the national and city of Quito governments agreed to exempt the Quito Metro project from import and sales taxes for project construction and equipment provision. These tax exceptions represent savings of approximately 12 percent of the total project cost. The project is being developed via public procurement.

interest expense deductions. Providing tax breaks in later years as well may reduce the incentives for further capital investments and reduce potential public revenues (Mandri-Perrott and Menzies 2010).

**In-Kind Contributions**

Public provision of land, facilities, or rolling stock as in-kind contributions can help to reduce the up-front costs of projects. This is a source of financing for projects in which the government uses real assets to pay indirectly for the works or to decrease the need for resources. By providing in-kind land contributions, the government assumes the opportunity cost of the value of alternative uses of the properties.

When the public sector provides in-kind contributions to a contractor under a traditional public procurement model, there may be challenges related to asset ownership and integration between contracts and assets (see the case of Quito Metro in box 10.5). In-kind contributions may also be directed to a PPP company (in which case, they are regarded as in-kind grants) and represent a form of cofinancing (see the case of SuperVia in box 10.5).

**BOX 10.5.****In-Kind Contributions for the Development of Urban Rail Projects****Quito Metro Line 1**

For the implementation of Line 1 of the Quito Metro, the municipal government provided the majority of the land necessary to build the stations. Out of 15 stations, 13 will be built under land owned by the municipality and will be returned to public use once the project commences operations. Only three stations required land acquisition, and no resettlement operations are expected. Using public land is a form of public financing and can significantly reduce the total project cost.

**SuperVia Suburban Rail, Rio de Janeiro**

In the public-private partnership (PPP) context, Rio de Janeiro, Brazil, employs in-kind grants as public support of the suburban rail concessionaire, SuperVia. In this project, the state of Rio de Janeiro (granting authority) has financed the provision of rolling stock in exchange for railway and station modernization investments financed by the private concessionaire that is operating the system.

**Private Financing**

Increasingly, infrastructure projects are making use of private financing in addition to public financing. Unlike public financing, private financing comes with an expectation of a reasonable return. Rational, profit-maximizing developers and investors are prepared to take potentially high risks only if they expect to earn commensurate rewards (Mandri-Perrott and Menzies 2010). Project-implementing agencies need to have a clear understanding of how private developers will make the expected returns through development and implementation of the project. This will help them to anticipate and understand the revenue-making objectives of private partners and the sources and cost of private financing potentially available to them. In particular, governments proceeding with a PPP need to be familiar with common sources of private financing (discussed in the subsections below) when structuring the project to ensure financial viability.

Private financing may come in the form of debt, equity, or quasi-equity. Debt may be in the form of loans or bonds that have a higher repayment priority than the dividends expected by equity investors in return for their capital investment (senior debt). Equity may take the form of pure equity or capital shares and quasi-equity products (junior or subordinated debt). Subordinated debt has a

higher repayment priority than (is senior to) equity, but it is paid only after senior debt. Senior debt may be structured in different tranches with different levels of seniority. The following sections discuss these sources of private finance and highlight their key advantages and disadvantages for private financiers of urban rail projects.

### **Equity Investors**

Equity investors can be divided into two groups: (1) sponsors or developers with an interest in construction, equipment provision, and O&M of infrastructure assets and (2) financial investors with a focus on infrastructure sectors—typically, infrastructure funds or other risk capital investors, including, in some cases, institutional investors—that may co-invest with project developers.

As project sponsors or developers, the government may invest in equity shares in the special-purpose vehicle, acting as a financial partner. Government-backed agencies may also provide subordinated debt (quasi-equity) to protect commercial debt providers (see the section on credit support and enhancement).

Institutional investors may also invest equity in urban rail projects indirectly via private equity funds or specialized investment vehicles. An example of such a vehicle is Brazilian investment company Invepar, which is owned by pension funds of two of the largest banks and the national oil company of Brazil. Invepar has investments in three urban mobility projects, including two metro systems and one light rail project. In some markets, such as Mexico, institutional investors are able to invest equity in infrastructure projects through the public capital markets via specially designed securities that are issued by specialized investment vehicles.

### **Commercial Banks**

Traditionally, most infrastructure projects have been financed via loans. Commercial banks are the primary source of long-term financing for infrastructure projects due to their ability to tailor disbursements to match construction schedules and their ample understanding of project risks. However, recent regulatory changes have reduced the ability of commercial banks to provide long-term financing and encouraged public agencies and project developers to consider issuing bonds to finance their infrastructure projects. This source of financing also includes banks that, although government owned, operate commercially and provide loans at market rates.



### Capital Markets (Institutional Investors)

Private partners and project companies undertaking urban rail PPPs may issue bonds in the capital markets,<sup>6</sup> the proceeds of which are used to finance a single-asset infrastructure project with limited recourse. Project finance bonds may be either public issues or private placements, which are not quoted and are sold to a limited number of investors. The buyers of bonds are typically institutional investors, such as insurance companies and pension funds, which require long-term, fixed-rate returns and matching long-term liabilities.

Although selling bonds to finance infrastructure is not a new idea, it is not widely used for new transport projects. There have been multiple bond issuances for transport projects in Latin America, but most of the bonds issued to date have gone to refinance existing debt and to finance expansions of existing PPP projects that already generate stable cash flows (“brownfield projects”). These bonds are often backed entirely by government payments without any exposure to project risk, representing pricier public bonds in disguise. This is the case of the bond financing associated with the sale of government receivables used for the Lima Metro Line 2 project.

The advantage of bonds is that they enable project developers to reach a completely new pool of long-term resources provided by institutional investors. If the creditworthiness of the issuance is sufficient to attract investors, bond financing can have the following additional advantages:

- Bonds are only used for larger projects, as investors want the issue to be sufficiently large so that it has market liquidity and can be included in relevant indexes. For large projects, bank loans may be more limited, so project bonds may be more suitable.
- Bonds could potentially have lower cost than equivalent bank loans, partly due to the wider investor base.
- Bonds can provide longer-term financing than bank loans, which are increasingly only available with shorter maturities.

However, bonds to finance new construction (“greenfield projects”) remain elusive, mostly because the risks associated with construction make them fairly unattractive to nonspecialized institutional investors and because these investors are not set up to assess and price project risks independently. Unlike commercial bank loans, investors in project finance bonds generally do not get as involved in the due diligence process; instead, they rely on the project’s investment bank and a rating agency to carry out the work. Credit-rating agencies such as Standard & Poor’s and Moody’s assign a credit rating to the bond based on an independent review of the risks of the project.

In addition, urban rail projects can be considered riskier than other types of infrastructure and subject to multiple changes and adjustments during implementation. This makes institutional investors' participation more difficult for several reasons: (1) pension funds and insurance companies seek stable cash flows; (2) most investment managers do not have the expertise to assess the risks involved in rail projects; (3) it is difficult to organize multiple passive investors with limited sector experience to make key restructuring decisions when projects go wrong; and (4) unlike loans that can be disbursed over time to match a project construction schedule, bond proceeds are generally drawn once at closing, generating a financial cost for issuers who do not need all the money at once.

Some of these restrictions can be addressed through credit-enhancement mechanisms that bring the credit standing of bond issuances to the level required by institutional investors. This credit enhancement may involve funded products (subordinated debt tranches) or unfunded products (standby letters of credit or guarantees) that provide first-loss protection to bond investors. Also, some MDBs and national agencies may act as bond investors to boost the financing of infrastructure in the capital markets.

When advising the government of São Paulo on the structuring of Lines 6 and 18 PPPs, the World Bank evaluated how a then-new instrument available in the Brazilian capital market (*debênture de infraestrutura*) could be used to attract private capital and reduce the size of up-front government contributions. The resulting financing structure (feasible based on the legal framework at the time) included approximately 20 percent of total financing from the issuance of debentures. However, the proposed structure was not realized given the availability of public financing from the Brazilian Development Bank (BNDES) and the large differential between the cost of BNDES financing and the cost of bond financing in the capital markets at the time.

The application of local bonds in low- and middle-income countries may be limited by the size of capital market for finance in local currency. However, recent experience demonstrates that, in some emerging markets, more long-term finance is available through the domestic bond market than through the local bank market (for example, Uruguay for the financing in 2015 of a social infrastructure PPP). Other emerging markets (such as Chile, Mexico, and, more recently, Peru) are increasingly relying on project bonds as a way to finance infrastructure, catering to both domestic and international investors.

## Financing PPPs in Urban Rail

Projects developed under traditional procurement models (such as design-bid-build, design-build, and design-build-operate-maintain) are financed by the public sector. In order to supplement public financing, project-implementing agencies are increasingly turning to private sources of financing. Private capital mobilization for urban rail projects remains limited relative to project financing in other sectors, and private finance can rarely, if ever, completely replace or eliminate the need for public finance. Even when available, private finance may not be mobilized with the cost and term to maturity required to make projects financially viable.

Although sources of private finance are available outside of PPP project delivery models, project-implementing agencies often pursue PPPs with the objective of mobilizing financing from private sources. In recent urban rail PPP projects in Brazil and Peru, the private sector has contributed between 30 and 50 percent of the total financing required, with the balance provided by the public sector in the form of capital grants. PPPs may also have public partners cofinancing the investments. In China, PPPs in urban rail involve partnerships between the public granting authority and state-owned enterprises. For example, unable to fund the entire project on its own, the city of Wuhu in the central province of Anhui, China, conducted a bidding process for a partner to build and operate two metro lines totaling 46.8 kilometers and to supply part of the Y 14.6 billion required for the project. China Railway Group and China Railway Rolling Stock Corporation (CRRCC), both state-owned enterprises administered by the central government, bid for the project, taking 32.5 and 37.5 percent interests, respectively.

### Public Cofinancing

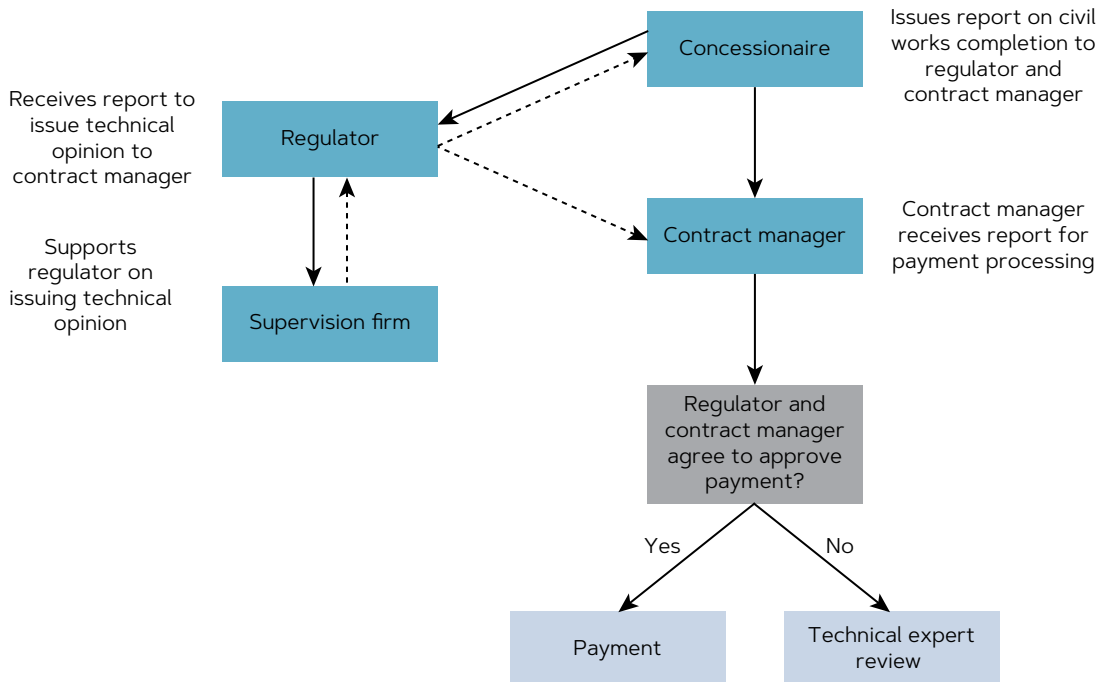
Public cofinancing is intended to support economically justified projects that are not financially viable. Urban rail PPPs often incorporate a public capital grant or cofinancing to offset the private partner's initial capital investment and associated debt repayment obligations. The main objectives of public cofinancing are (1) to catalyze private finance when the size of the capital investment cannot be completely repaid or recovered from project cash flows and (2) to reduce the overall cost of capital for the project, making the project more affordable. Public capital contributions may come from national or subnational government budgets, and portions of these payments can also be financed with loans provided by international and national development banks.

Public cofinancing may come in the form of a grant, often known as viability gap financing (VGF). VGF grants are only disbursed after project investors have

committed equity to the project, thereby putting their capital at risk. Alternatively, VGF disbursements may also track debt disbursements to align the interests of the provider of VGF (the government) with those of lenders who provide due diligence and monitor performance. For example, the Hyderabad Metro PPP in India uses VGF. This project was awarded in 2010 to the bidder that requested the lowest VGF support, equivalent to 12.35 percent of the total project cost. Additionally, the metro in the city of Pune, India, is also being developed with the expectation of incorporating VGF in the financing structure.

Public cofinancing may also come in the form of periodic payments made to the private partner as repayment for a portion of the capital expenditure required to construct infrastructure or provide equipment. The payments are usually tied to the attainment of project implementation milestones (contractor reaches a scheduled delivery stage or completes a specific construction deliverable). This form of public cofinancing was used to finance the Lima Metro Line 2 PPP (see figure 10.2).

**FIGURE 10.2. Public Capital Contribution Payments to Concessionaire: Lima, Peru Metro Line 2**



Determining the appropriate level of capital grant and defining appropriate construction milestones are a challenge for project planners. A larger-than-needed or badly designed capital grant can reduce risk transfer to the detriment of value for money incentives when private partners do not have sufficient capital at risk in the project. Conversely, insufficient capital grants can result in a potentially unstable private concessionaire and correspondingly large risk premiums (Mandri-Perrott and Menzies 2010). In the Lima Metro Line 2 PPP, where private bidders were given the option to determine which work milestones would be financed by public cofinancing and which would be compensated through deferred payments under the RPI-CAO structure, rating agencies identified a potential way for the private partner to reduce its risk by allocating the most difficult works (mainly related to tunneling) to cofinancing (cash reimbursements) (Standard & Poor's Ratings Services 2015). It is also important for governments engaged in the preparation of urban rail projects to factor in the legal and financial viability of mobilizing up-front public capital contributions (see box 10.6).

Another issue to consider is the taxation applicable to payments made to private partners under public cofinancing schemes. South Africa's Gautrain Rapid Rail Link incorporates a substantial capital grant by Gauteng Province.

#### **BOX 10.6.**

### **Removing Barriers to Public Cofinancing of Public-Private Partnership Projects: Metro Lines 6 and 18, São Paulo, Brazil**

When the government of São Paulo was preparing the public-private partnerships (PPPs) for Metro Lines 6 and 18, the existing regulation in Brazil (Article 7 of the PPP Law of 2004) prohibited the public sector from making any financial contribution to a PPP project prior to the commencement of operations. This legal restriction, also present in the PPP laws of Colombia and other countries, resulted in the need to (1) mobilize greater amounts of private capital up-front, diminishing the return on equity of the project, or (2) raise additional commercial debt to fund construction works. Both options increased

financing costs and, therefore, demanded a higher availability payment (*contraprestação*) during operations or higher tariffs to make the project financially viable. The mismatch between the time when investments took place and the time when they could be remunerated was reflected in a higher required rate of return of the project, elevating the cost-of-service provision. Recognizing that this approach was financially inefficient, before tendering of the São Paulo projects, the legal framework was modified, allowing the public partner in a PPP to make contributions during and after construction.

Prior to a special legislative act, Gauteng's capital grants would have constituted taxable income for the concessionaire, representing additional cost that would have been charged back to Gauteng Province in the form of higher bid prices (Mandri-Perrott and Menzies 2010).

Public provision of specific infrastructure or rolling stock can help to reduce up-front costs to private partners. However, it is important for private partners to have an incentive to perform and maintain the assets adequately. For example, in the PPP for the development and operation of the suburban rail system in Rio de Janeiro, the public sector procured and financed the trains in exchange for the private concessionaire's investment in station upgrades, railway rehabilitation, and improved equipment. In this case, the city government, following World Bank procurement rules, was able to obtain significant savings in the acquisition of rolling stock.

### **Private Financing**

Urban rail projects under PPP schemes have been financed from private sources using project and corporate finance. As is the case with other infrastructure sectors, most urban rail PPPs are financed through project finance. Urban rail PPPs require substantial up-front private investments that exceed the capacity of developers' own balance sheets. Project developers and sponsors prefer the off-balance sheet and nonrecourse nature of project finance (see table 10.3). However, these attractive characteristics also make project financing challenging to structure and it may be necessary to complement it by corporate finance.

#### *Project Finance*

Project finance structures generally involve a special-purpose vehicle—an independent legal entity established for the purpose of undertaking the project. The vehicle raises debt financing from lenders and debt or equity from project sponsors. As special-purpose vehicles are legally separated from project sponsors, lenders are said to have limited or no recourse to sponsors regarding their debt investments. Limited recourse, typically employed in financing, is where recourse either is limited to a fixed monetary amount or is subject to certain performance criteria (for example, cost and time overruns during construction and revenue or cash shortfalls during operations when developers commit further capital toward debt service). For project financings, the loan structures rely primarily on project cash flows for repayment, with the project's assets, rights, and interests held as secondary security or collateral.

A structure in which the government or procuring agency owns part and even the majority of shares in the special-purpose vehicle implementing the project can be regarded as a form of private finance as long as "the private sector is

**TABLE 10.3. Advantages and Disadvantages of Project Finance for Urban Rail Public-Private Partnerships**

ADVANTAGES	DISADVANTAGES
<ul style="list-style-type: none"> <li>• Off-balance sheet</li> <li>• Separates project credit profile from developers' credit profile—the project company is insulated from developer default. Similarly, developers are insulated from project liabilities</li> <li>• Can achieve high leverage ratios</li> <li>• Can create greater tax shields because of greater leverage, which can reduce the overall cost of capital</li> <li>• Reduces managerial discretion over free cash flows because of lender-imposed constraints</li> <li>• Provides additional mechanisms for spreading risk through syndication and securitization</li> <li>• Can improve project quality through additional lender due diligence</li> <li>• Can achieve much greater transparency for the grantor with regard to project company operations and financial performance through lender reporting and control requirements; this can be very important when assessing performance-related payments and when setting or adjusting fare levels</li> </ul>	<ul style="list-style-type: none"> <li>• Greater transaction costs than corporate finance</li> <li>• Only available for larger projects (&gt; US\$100 million, rarely a problem for urban rail initiatives)</li> <li>• Requires additional due diligence and associated time when structuring</li> <li>• Possible change in bid prices when final price is dependent on prevailing credit market conditions (that is, interest rates), as final financing terms may not be set until after preferred bidder selection</li> <li>• Lengthy time between bid award and financial close or project commencement given the complexities of project finance structures and documentation requirements (typically on the order of 12 months, but may be much longer if the project structure is not bankable); this timetable can conflict with grantor or political project schedules</li> </ul>

significantly involved as an equity investor (with a significant portion of the equity shares) in the project company. Therefore, the private partner assumes the project risks, participates significantly in the management of the company, and/or the infrastructure operations and the debt financing is at risk of performance" (ADB et al. 2016, 40). This structure was used in PPPs for the development and operation of light rail systems in Tenerife and Zaragoza in Spain.

### *Corporate Finance*

When urban rail projects are financed by private companies (sponsors), these companies may choose to raise financing for project development on their own credit (see table 10.4). In contrast to project finance, lending for corporate finance projects derives security for debt repayment from the sponsors' balance sheets or other nonproject security. Naturally, sponsors often try to minimize the use of this form of financing to avoid burdening their own balance sheet and to have the capacity to invest in more projects beyond what they could afford on a corporate basis.

**TABLE 10.4. Advantages and Disadvantages of Corporate Finance for Urban Rail Public-Private Partnerships**

ADVANTAGES	DISADVANTAGES
<ul style="list-style-type: none"> <li>• Lower transaction costs because credit risk assessment is based on sponsor credit rather than complex project credit risk</li> <li>• Simpler, easier to obtain, and faster to structure than project finance</li> <li>• Requires smaller amounts of due diligence and associated time because sponsors' balance sheets provide additional security</li> <li>• Depending on sponsor's credit rating, may offer lower margins on debt</li> <li>• Offers greater flexibility to accommodate changes (such as renegotiations)</li> </ul>	<ul style="list-style-type: none"> <li>• Places sponsors' assets and balance sheet at risk</li> <li>• Lower debt-to-equity ratios</li> <li>• Typically, available only for smaller investments</li> <li>• Does not isolate project from sponsor credit profiles and vice versa</li> <li>• May limit public control over refinancing activities and prevent public sharing of refinancing gains</li> <li>• May realize fewer benefits related to project transparency for public authorities than project finance structures</li> </ul>

The relative merits of either structure depend on the size and risk profile of the project in question. Larger, greenfield urban rail investments almost always take on some form of project finance in order to limit the liability of developers and raise sufficient capital. Nevertheless, smaller urban rail investments such as minor extensions or refurbishments may draw on corporate finance, depending on their size and scope. For example, the provision and maintenance of rolling stock may be financed using a contractor's or supplier's balance sheet.

### Bankability

In PPP projects, especially those in low- and middle-income countries, governments have to pay special attention to bankability. Bankability is defined as the ability of a project to be accepted by lenders as an investment or the ability of the project to raise long-term finance on account of the project's creditworthiness, given the expected sufficiency and reliability of future cash flows (ADB et al. 2016).

Project-implementing agencies should plan project funding and financing requirements early to ensure that their project is bankable, while at the same time keeping the right level of incentives for the private partner to perform. Finalizing a project's financial structure usually occurs during later stages of planning and procurement—after many key decisions have already been made. Revisiting public approval processes and contractual arrangements along the way can result in substantial delays and lost



confidence when amending earlier decisions. Therefore, it is imperative for early decision making to take into account such requirements and their impact on a project's future financial and commercial structure. "Road shows" and other events designed to test market interest can help planners to get a sense of the market's perception of proposed risk allocations and other project features.

When considering corporate or municipal financings, the bankability of a project is determined by the borrower's balance sheet. Bankability becomes more complex in project finance structures where the capacity of the borrower to service debt depends on the effectiveness of contractual arrangements and creditworthiness of third parties and where repayment ultimately depends on the ability of the project sponsors to complete the project and to put it into service for the benefit of paying users.

The term "bankability" summarizes investor-lender sentiments and their willingness to commit debt or equity capital toward a project. Equity investors look at their expected return, which is driven by their ability to mobilize as much debt as possible. Lenders look at the balance between sponsor equity and debt financing (gearing). Although project financing aims to maximize gearing (debt is typically cheaper than equity), equity requirements should nevertheless be substantial enough to ensure that the sponsor's commitment makes it too costly to withdraw when the project runs into problems. The maximum gearing that is accepted by banks is conditioned by the uncertainty associated with the project cash flows, such that projects with riskier cash flows due to economic, credit, or legal risks demand more equity.

From the point of view of lenders, bankability is determined by the ability of the project to meet debt service payments after fulfilling O&M obligations, which depend on the size and volatility of revenues and costs. This ability is measured through the debt service coverage ratio, defined in broad terms as the ratio of project revenues net of operating expenses over debt service (principal and interest) owed in a given period. Projects that can demonstrate a sufficient debt service coverage ratio can access debt at a relatively lower cost.<sup>7</sup> Having a lower quantum of debt will generally result in an acceptable debt service coverage ratio.

Bankability goes beyond financial analysis in the consideration of four broad criteria: (1) creditworthiness, (2) legal viability, (3) economic viability, and (4) technical feasibility. Lenders and investors evaluate each of these criteria in order to assess a project's bankability and determine their level of interest in the project. Table 10.5 includes a list of the key questions that financiers might ask to improve their understanding of these four criteria.

Project-implementing agencies need to put themselves in the shoes of private financiers and answer these questions in a credible way. The inability to answer or an uncertain response to any of these questions will raise concerns over the project's bankability and the project financiers will demand credit support and enhancement. Such credit support and enhancements can be provided through the project documents (PPP agreement) or by third parties, including development finance institutions and MDBs (see the next section).

**TABLE 10.5. Factors Influencing Project Bankability**

PROJECT ASPECTS	QUESTIONS FOR DETERMINING BANKABILITY
Creditworthiness	<ul style="list-style-type: none"> <li>• Do project developers have adequate capacity and incentives to deliver sustainable long-term operational performance? Do they derive significant value from ancillary activities outside of the concession company (for example, local property development and turnkey construction contracts)?</li> <li>• Can the grantor meet its financial obligations to the project?</li> <li>• How certain are project revenues? Who bears ridership and farebox risk, and how realistic are ridership forecasts?</li> <li>• Are project cash flows sufficient to support envisaged levels of debt?</li> <li>• Does the project benefit from any grantor or sovereign guarantees; does the project benefit from guarantees or insurance on its debt (for example, partial risk or credit guarantees and political risk insurance)?</li> <li>• Is there sufficient equity cushion to protect lenders if the concession's value decreases? Do project developers have sufficient "skin in the game" (that is, value at risk)?</li> <li>• In the event of termination, what mechanisms guarantee debt repayment?</li> <li>• Do the project's financial ratios meet lender expectations (for example, principal and interest cover ratios, debt service cover ratio, loan life ratio, and debt-equity ratio)?</li> </ul>
Legal viability	<ul style="list-style-type: none"> <li>• Does the grantor have the authority to grant the concession or PPP?</li> <li>• Will the project require any additional legislation (for example, a PPP law)?</li> <li>• How strong are the project's contractual arrangements with input suppliers (such as rolling stock suppliers)?</li> <li>• What legal protections or channels for recourse do investors have in the project's jurisdiction (for example, access to international standard arbitration)?</li> <li>• Are legal decisions enforced in the project's jurisdiction (rule of law)?</li> <li>• How strong are property rights in the project's jurisdiction? Is there potential for regulatory "clawback" if ridership numbers exceed estimates and revenues are well above forecast?</li> </ul>

*(table continues next page)*

**TABLE 10.5. Factors Influencing Project Bankability (Continued)**

PROJECT ASPECTS	QUESTIONS FOR DETERMINING BANKABILITY
Economic viability	<ul style="list-style-type: none"> <li>• Is there a market for the project's services? Does urban rail offer sufficient value to customers?</li> <li>• Are there threats from competing services (for example, buses) or technological obsolescence (for example, ticketing systems)?</li> <li>• Is the system's route aligned with target markets or population centers?</li> <li>• Does regulation protect against the threat of new market entrants? How stable is that regulatory environment?</li> <li>• Are project inputs (for example, electricity) available at reasonable prices? How stable are input supplies? Will new urban rail services require dedicated input suppliers (for example, a dedicated power plant)?</li> <li>• How stable is the project's macroeconomic environment? How would changes in inflation, foreign exchange, and interest rates affect project cash flows? How will such risks be mitigated in the contract? Have any standby credit facilities been arranged to deal with potential lags between financial shocks and tariff adjustments?</li> </ul>
Technical feasibility	<ul style="list-style-type: none"> <li>• Does the project use proven technology?</li> <li>• Are construction costs reasonable and realistic?</li> <li>• Is the construction and commissioning timetable realistic?</li> <li>• Does the project rely extensively on proprietary technology?</li> <li>• What standards govern the construction of civil works, rolling stock, signaling, and communication systems? Are local standards available, adequate, or appropriate?</li> <li>• How flexible is the systems design? Can simple alterations to rolling stock configurations increase system capacity? Are stations and platforms designed for additional growth?</li> <li>• Is the proposed technological solution appropriate for local conditions and the availability or scarcity of skilled labor?</li> </ul>

### Credit Support and Enhancement Instruments

Project-implementing agencies around the world have used credit support and enhancement instruments to leverage limited government resources and to tap into new public or private financing sources. Even when projects are funded via public finance, governments or urban rail project-implementing agencies may use credit enhancement instruments to access new financing sources or lower the cost and increase the tenor of financing, relative to the conditions they would be able to obtain should they try to access the market on their own.

Credit support and enhancement instruments can be provided through certain provisions included inside project contracts (PPP or loan agreements) or

provided by third parties that are not signatories to the contract, but have a development finance mandate to support the project.

### **Inside the Contract**

Various derisking techniques can be embedded in the PPP payment mechanism or elsewhere in the contract under specific commitments to facilitate access to long-term financing or to decrease the overall cost of capital. These inside-contract enhancements that improve project bankability can include certainty of payment, step-in rights, termination compensation, and foreign exchange risk guarantee.

#### *Certainty of Payment*

Certainty of payment clauses improve the bankability of urban rail projects by providing lenders greater assurance that the public sector will honor their debt repayments or payments to the private partner. Certainty of payment can be included in project documents in several ways:

- Limits to the percentage deductions that can be applied to availability or service payments (that is, 80 percent fixed and 20 percent subject to deductions), thereby increasing cash flow certainty
- Fixed deferred government payments that are unconditional and irrevocable to remunerate capital investments undertaken by private parties. Examples of this include the high-speed rail PPPs in France and Spain and the RPI-CAO structure used to finance the Lima Metro Line 2 PPP (see box 10.3).
- Guaranteed funds to provide security for government payment obligations under the PPP contract
- The contractual commitment to establish escrow accounts and trustee structures that allocate and reserve government resources (such as fare collection) to protect the cash flows available to fulfill PPP payment obligations
- Minimum revenue guarantee to protect the project company from significant declines in ridership below the base case. This is equivalent to the floor of the demand bands that have been used to share ridership risk in the PPPs for the Canada Line in Vancouver and Metro Line 4 in São Paulo (see chapter 7).

#### *Step-In Rights*

The lenders and the grantor may enter into direct agreements with the project participants that specify step-in rights, notice requirements, cure periods, and other issues intended to maintain the continuity of the project if the project

company defaults. A project may not require separate agreements when provisions can be included in the relevant project document or when some other solution is available.

### *Termination Compensation*

Termination compensation refers to contract mechanisms that guarantee all or a certain percentage of the outstanding debt in case of early termination, including termination by default of the private partner. This is sometimes referred to as “debt underpinning” (Farquharson et al. 2011).

### *Foreign Exchange Risk Guarantee*

Most relevant in the context of cross-border financing (debt in foreign currency), guarantees against the risk of foreign exchange fluctuations may be required. These contractual guarantees may take several forms, including (1) tariff revisions linked to foreign currency exchange movements in user-pays PPPs; (2) government compensation payments to cover private losses caused by devaluations beyond a predefined exchange rate threshold; (3) direct government guarantees to protect lenders; and (4) the partial or total denomination of payments in foreign currency (ADB et al. 2016). An example of this last form of guarantee is the dollar-denominated payments in the Lima Metro Line 2 project PPP.

## **Outside the Contract**

Governments and project developers may also opt for instruments “outside of the contract”—such as direct and explicit guarantees to lenders, partial payment guarantees, or public loans—that not only provide additional means of financing, but also increase the project’s credit rating. These outside-contract credit enhancement instruments can be provided by governments, development finance institutions, or export credit agencies as credit support or third-party guarantees.

### *Development Finance Institutions*

Multilateral and bilateral development finance institutions (DFIs) are specialized development banks or subsidiaries set up to support private sector development in low- and middle-income countries. Multilateral DFIs are private sector arms of international financial institutions, such as the IFC of the World Bank Group and the Inter-American Investment Corporation of the Inter-American Development Bank Group. Bilateral DFIs are either independent institutions—such as COFIDES (the Spanish Development Finance Institution) or the Netherlands Development Finance Company—or part of larger bilateral

development banks—such as the German Investment and Development Company of the German Development Bank (OECD 2017).

DFIs can be an important partner in the development of urban rail projects in low- and middle-income countries. They can help mobilize commercial financiers in support of complex projects in new sectors. DFI financing is provided to private enterprises under commercial terms and at market rates; it is not intended to replace commercial banks' willing to finance a project, but rather is intended to crowd in commercial financiers that are new to the country or sector and that can benefit from the implicit credit protection in hard currency-denominated cross-border financings.

DFIs use the A/B loan structure provided by the IFC to crowd in private investment. In this loan structure, the IFC retains a portion of the loan for its own account (the A loan) and sells participations in the remaining portion (the B loan) to commercial lenders (participants). The project borrower signs a single loan agreement with the IFC, and the IFC signs a participation agreement with the participants and is the sole contractual lender (lender of record) for the borrower. While the IFC is the lender of record, the participants' involvement is known to the borrower and all transactions are transparent. The A/B loan structure allows participants to benefit from the IFC's status as a multilateral development institution. All payments, including principal, interest, and fees gain the advantages of the IFC's preferred creditor status. The IFC commits to the participants to allocate payments pro rata between the A and B loans. As a result, the IFC cannot be paid in full until all participants are paid in full (IFC 2017).

DFIs can also provide support to PPP financing by means of credit enhancement products, such as guarantees. The IFC offers a partial credit guarantee that serves to improve the credit of bonds and loans issued by private borrowers. For example, under a partial credit guarantee, the IFC could make an irrevocable commitment to pay principal, interest, or both on debt issued by a private project company up to a predetermined amount. This commitment on the part of an AAA-rated institution allows beneficiaries to gain access to cheaper and longer-term financing.

### *Export Credit Agencies*

Export credit agencies (ECAs) promote and facilitate foreign investment and export of goods and services of their particular nation's companies. They can provide financing and guarantees for the benefit of private companies involved in a project as part of a private finance PPP or provide export financing for the benefit of a supplier of a project delivered via traditional public procurement.

In urban rail projects, ECAs affiliated with different country governments have supported the financing of imported rolling stock and associated signaling and communication systems that originate in their countries. Although some ECAs can provide project financing through banks, most provide financial support directly to a public buyer via guarantees to the buyer's bankers (that is, a form or option of public financing). ECA financing can take the form of loan guarantees or direct lending, while in the more limited context of private finance under project finance PPP schemes, they may provide political risk insurance to facilitate the private equity investment, mitigate risk for lenders to the special-purpose vehicle, or provide working capital guarantees.

Most ECAs from OECD member countries abide by the Arrangement on Officially Supported Export Credits, which sets upper limits on the amount of assistance that foreign governments can offer in support of their exports. In 2014, the OECD issued new export credit rules for railway development (OECD 2013). The rules lengthen repayment periods for contracts involving an overall value of more than 10 million in special drawing rights (US\$15.3 million) and provide for repayment up to 12 years for transactions in high-income OECD countries and up to 14 years for transactions in all other countries. In low- and middle-income countries, ECA-backed financing can generally offer better terms than commercial financing.

ECA financing may be particularly useful when local credit markets are underdeveloped or when sovereign risks reduce the attractiveness of private finance. When used as part of project finance structures, ECA financing can lower the interest cost and extend the term of the financing to a level that otherwise would not be available to project sponsors. In this sense, a project requiring private capital in the form of the provision of equipment and rolling stock can achieve a more efficient financing structure.

Various projects in low- and middle-income countries have used ECA financing. In 2011, the Santo Domingo public transit authority used financing from four ECAs to finance the purchase of electromechanical equipment and rolling stock (originating in Belgium, France, Germany, and Spain) for Line 2 of the city's metro. In 2014, the Metro de Santiago in Chile (a publicly owned company) obtained a US\$800 million commercial loan and ECA-insured financing for equipment (including rolling stock) and systems for new (Lines 6 and 3) and existing lines. ECA financing has also been used for projects developed as PPPs, such as the Lima Metro, which included an ECA-covered 20-year financing facility of US\$800 million provided by SACE, an Italian ECA. In this case, the ECA covered lenders against the risk associated with the securitization of government payment certificates.

### *Credit Support*

Urban rail PPP projects have been financed via government loans provided through credit assistance programs. Lending public money to private partners at concessionary interest rates can help to overcome disadvantages resulting from the private sector's higher cost of capital. However, public soft loans cannot compensate for fundamental flaws in project risk allocation; a concession company may still be unable to service debt even at lower "soft" interest rates. For example, Kuala Lumpur's STAR and PUTRA concessions both incorporated government "soft" loans (Mandri-Perrott and Menzies 2010). Nevertheless, ridership risk was fully transferred to the concessionaires; actual ridership was below projections, and both companies ended up needing public bailouts (Phang 2007).

In addition to direct credit assistance, public financing can be provided through national development banks. BNDES has provided financing for the development of metro projects executed as PPPs in Brazil, including new lines for the Salvador and São Paulo metros. In the original financing structure for Line 6 of the São Paulo Metro, BNDES committed not only to finance the state of São Paulo's public capital contribution, but also the private consortium that was awarded the project. Using government loans for both the public and private financing reduced the potential for the increased market discipline that is often brought about by commercial lenders.

Box 10.7 describes an instrument used in the United States to support private finance schemes. The government provides financing and raises the credit rating of the commercial debt by providing funded or unfunded instruments with a lower-priority claim to the cash flows generated by the project. This support is a form of credit assistance as well as a form of credit enhancement (see the next section on third-party guarantees).

### *Third-Party Guarantees*

Multilateral institutions also offer guarantee products that have been used to support the financing of urban rail projects in low- and middle-income countries. These guarantees have backed national and subnational financings and can also be used to mitigate the risks and enhance the credit of private or public financings.

One example of a third-party guarantee for publicly financed projects is the Non-Honoring of Sovereign Financial Obligations (NHSFO) guarantee provided by the Multilateral Investment Guarantee Agency (MIGA). NHSFOs have been used for financing metro projects in Panama and Turkey, allowing these projects to mobilize commercial financing from international banks with better conditions than otherwise would have been possible (see box 10.8).

In addition to NHSFO coverage, MIGA can also provide insurance against political risks, including breach of contract obligations, for the benefit of investors.



**BOX 10.7.****TIFIA Credit Assistance Program in the United States**

The Transportation Infrastructure Finance and Innovation Act (TIFIA) program of the U.S. Department of Transportation provides public credit assistance for qualified transport projects, including urban rail. The TIFIA credit program is aimed at filling market gaps and leveraging substantial private co-investment by providing supplemental and subordinate capital (U.S. Department of Transportation 2017). TIFIA was created because state and local governments that sought to finance large-scale transportation projects with user revenues often had problems obtaining financing at reasonable rates due to the uncertainties associated with these revenue streams.

Credit assistance can come in the form of loans, loan guarantees, and standby lines of credit. It is available to subnational governments, state agencies, and private partners under public-private partnership (PPP) arrangements. Loans offer flexible repayment with a maximum term of 35 years from substantial completion, including a grace period of five years. Loan guarantees provide full faith-and-credit guarantees by the

U.S. federal government for a borrower's repayments to a nonfederal lender. Finally, standby lines of credit are contingent federal loans to supplement project revenues, if needed, during the first 10 years of project operations. The TIFIA credit facility is subordinate to cash flows during repayment, but it has a lien on par with senior creditors in the event of bankruptcy.

TIFIA support has been used to finance the Dulles Corridor Metrorail and the Purple Line projects in the Washington, DC, metropolitan area. In the case of the Purple Line, the Department of Transportation made a loan of US\$874.6 million to Purple Line Transit Partners, the private partner in the design-build-finance-operate-transfer arrangement under which the project is being developed. In the case of the Dulles corridor, the Department of Transportation made a US\$403 million loan to Fairfax County, a US\$195 million loan to Loudoun County, and a US\$1.2 billion loan to the Washington Metropolitan Area Transit Authority (WMATA), all public entities.

Source: U.S. Department of Transportation 2017.

**BOX 10.8.****Multilateral Investment Guarantee Agency's NHSFO Guarantees for Urban Rail Projects**

In Turkey, the Multilateral Investment Guarantee Agency's (MIGA) Non-Honoring of Sovereign Financial Obligation (NHSFO) coverage is supporting the expansion of Istanbul's Metro system, which will reduce traffic and congestion,

provide better access to jobs, and improve the quality of life in the metropolitan area containing 18 percent of Turkey's population. In December 2010, MIGA issued an NHSFO insuring the municipality of Istanbul's guarantee of a

*(box continues next page)*

**BOX 10.8.****Multilateral Investment Guarantee Agency's NHSFO Guarantees for Urban Rail Projects** *(Continued)*

US\$19.5 million loan by WestLB of Germany to Istanbul Electricity Tram and Tunnel in the Otogar-Bağcılar-Ikitelli-Olimpic Village Metro project. This project involves the extension of light rail from the main bus terminal to residential areas.

WestLB later approached MIGA to seek additional coverage for a much larger loan. In this case, WestLB AG, the London branch, was the lead agent for a consortium of lenders in the Kadıköy-Kartal-Kaynarca Metro extension. This project involves the first underground metro system on the Asian side of Istanbul. It will eventually connect with the European side of the city. The first phase of the project is 22 kilometers of urban rail line from Kadıköy to Kartal and includes the

construction of 16 metro stations. The second phase will extend the metro line by 4.5 kilometers from Kartal to Kaynarca and construct a parking and maintenance area.

Again, the loan was provided to the Istanbul Metropolitan Municipality with MIGA's NHSFO covering US\$409.2 million from the risk of a default by the municipality on its obligation to pay principal and interest due to WestLB and the lenders. The project demonstrates how MIGA can cover subsovereign credit risk without requiring a Ministry of Finance guarantee. The MIGA coverage allows the Istanbul Metropolitan Municipality to cover the financing gap from phase I that resulted from the withdrawal of a key lender and the additional financing needed for phase II.

The World Bank and other MDBs offer partial guarantees that support private or public financing. World Bank payment guarantees can backstop government payment obligations under urban rail PPPs, improving the creditworthiness of the project and allowing it to access private finance. The World Bank can also guarantee part of the debt obligations issued by a government entity or state-owned enterprise in connection with the financing of an urban rail project.

Project-implementing agencies and governments should explore in advance the availability of these instruments and ensure that they can be secured in time to be offered to potential lenders and investors. MDBs and DFIs providing these types of credit-enhancement mechanisms need to be called early to ensure that all due diligence and structuring can be done prior to the solicitation of bids.

**Conclusions and Recommendations**

In sum, a variety of instruments can be used to finance large, capital-intensive urban rail projects. In fact, many projects employ a combination of different public and private financing instruments to minimize the cost of capital committed to the project (see box 10.9).

**BOX 10.9.****Leveraging Multiple Financing Instruments: Metro Line 2, Lima, Peru**

Under the financing plan for Lima Metro Line 2, the government will finance the works to be executed and rolling stock to be purchased during the first phase of the project, while the concessionaire will finance the second phase, thereby reducing overall financing costs. The financing of the project will ultimately involve bonds, multilateral development bank (MDB) and bilateral loans, development finance institution (DFI) loans, and commercial loans in both local and foreign currency and sourced in the banking and capital markets.

**Government Financing**

The government of Peru resorted to multiple sources for its direct financing of the project:

- *Own resources.* The Peruvian government financed some of the project components, notably utility network relocations, from its own budget.
- *MDB loans.* The World Bank, Inter-American Development Bank, and Andean Development Corporation provided loans of US\$750 million to finance the government's up-front capital contribution.
- *Bilateral loans.* In December 2016, the government announced additional loans with the German Development Bank and the French Development Agency of US\$200 million and US\$126 million, respectively, to finance its up-front capital contribution.

**Concessionaire Financing**

The concessionaire's financing plan involved more than US\$2.5 billion in term financing backed by the Peruvian government's deferred

payment obligations and provided by different sources:

- *Bonds issued in the international capital markets.* In June 2015, the concessionaire successfully placed a US\$1.15 billion bond backed by government-backed securities: RPI-CAOs (*retribución por inversiones-certificado de avances de obras*, described in box 10.3). The bond reaches final maturity in 2034 and has a yield of 5.875 percent.
- *DFI loans.* The private sector arm of the Inter-American Development Bank (now IDB Invest) provided a commercial loan of US\$450 million to the concessionaire (Metro de Lima Linea 2 S.A).
- *Export credit agency (ECA)-supported loans provided by commercial banks.* In October 2015, the concessionaire obtained US\$800 million in RPI-CAO financing guaranteed by SACE, an Italian ECA, from the following banks: Cassa Depositi e Prestiti, KfW-Ipex, Société Générale, Banco Santander, and Instituto de Crédito Oficial. SACE support, made possible by the presence of Italian companies in the concessionaire, contributed to the diversification of financing sources.
- *Revolving value added tax facility from local commercial banks.* In 2016, the concessionaire also obtained a US\$28 million revolving value added tax facility to finance the refund of the value added tax incurred as a result of the project.
- *Commercial loans.* Although a commercial short-term revolving loan for working capital was considered part of the concessionaire's financing package, this facility was never closed.

No matter what combination of financing instruments is used, it is important to consider the importance of underlying funding structures and to keep in mind the following recommendations.

***Focus on establishing a strong funding structure for the project and for the entire urban transport system.*** Given the low capacity of urban rail projects to recover capital expenditures from user tariffs, the first step in any financing plan should be to enlarge and diversify the sources of funding that can be used to obtain financing. Solid financing structures require strong funding schemes that incorporate reliable revenue sources and that provide sufficient security for lenders and investors. Funding arrangements and sources between different levels of government (national versus local) must be clear and free from the risk of political interference. No matter the project delivery method, the ability to mobilize financing for one or more individual projects will never solve the underfunding problem that most urban transport systems face and that threatens their long-term sustainability.

***Incorporate alternative sources of funding in project design.*** Advertising, commercial space leasing, and revenues from property development can complement farebox revenues. Structuring projects to take advantage of land value capture may require (1) the inclusion of property development mandates as part of the mission of newly created metro companies and (2) the passage of legal reforms that enable new charges that can be directed toward these costly projects.

***Use public cofinancing in a way that can effectively lower the cost of capital without reducing performance incentives.*** Although public authorities are increasingly resorting to PPPs to develop urban rail projects, not all projects delivered this way will be able to obtain a majority of their financing from the private sector. Most urban rail projects require substantial public funding because their large implementation costs cannot be covered entirely from private sources. Attempts at implementing purely private urban rail concessions have a poor track record, and the public sector has had to bail out unsuccessful projects (Mandri-Perrott and Menzies 2010).

Project financings (under PPP structures) still require sizable public financial contributions up-front (that is, grant financing or “pure cofinancing”). Providing public cofinancing up-front reduces the overall cost of capital and results in more manageable amounts of private investment. In highly sophisticated markets, the most common financial structure of PPPs is when the majority of financing comes directly from the government in the form of grants or derisked payments. In other countries, the unwritten rule is to have at least 30 percent of public financing in the mix.

**Prepare projects to ensure financing eligibility from main sources of international development finance.** In general, the financing of urban rail projects in low- and middle-income countries has required the participation of multiple MDBs and bilateral sources. Governments and implementing agencies contemplating financial support from these institutions need to plan early to ensure that the projects are developed following the procurement, fiduciary, environmental, and social management requirements of these institutions.

**Consider various financing instruments and deploy them where they make the most sense.** Given the multiplicity of components and sources of financing of urban rail projects, it is important to define early a financing structure that combines different sources and types of financing in the most cost-efficient way. For instance, when projects are developed under an equip-operate-transfer PPP in which the private capital obligation is in the form of investment in rolling stock and equipment (see chapter 8), the project can eliminate expensive project finance exposed to construction risk and focus on ECA-backed financing associated with the supply of trains and equipment. In general, pure project finance may not be feasible, so other options involving blended public and private finance need to be considered.

## Notes

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1. This global average farebox recovery ratio is slightly lower than the average for CoMET and Nova metros, which overrepresent systems in high-income countries.
2. In Brazil, publicly operated metros produce nonfare commercial revenues equivalent to approximately 5 percent of fare revenues. This is much lower than the 15 percent reported by some privately operated metros.
3. For example, the Bogotá Metro Company was created with the specific mandate to exploit development-based LVC opportunities.
4. A private entity is defined as a legal entity that is (1) carrying out or established for business purposes and (2) financially and managerially autonomous from national or local government. Some public entities that are organized with financial and managerial autonomy are counted as private entities. Other examples include registered commercial banks, insurance companies, sovereign wealth funds, and institutional investors investing primarily on a commercial basis (World Bank 2017).
5. These major MDBs are the African Development Bank, Asian Development Bank, Andean Development Corporation–Development Bank of Latin America, EBRD, European Investment Bank, Inter-American Development Bank, Islamic Development Bank, and World Bank.
6. If the sponsor issues the bond, the financing is considered corporate financing. If the project company issues the bond, it is considered project financing.

7. For specific insights and information about debt ratios and bankability, see the annex on “Project Finance” of *The EPEC PPP Guide* (<http://www.eib.org/epec/g2g/annex/1-project-finance/>) or “Key Issues in Developing Project Financed Transactions” (<http://ppp.worldbank.org/public-private-partnership/financing/issues-in-project-financed-transactions>).

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# 11

## PREPARING FOR CONSTRUCTION

Sofía Guerrero Gámez, Joanna Moody, and  
Ramon Munoz-Raskin

Preparing for construction during planning and design of an urban rail project is critical to managing the project's delivery schedule, costs, risks, and socioeconomic impacts. Many of these considerations arise because construction takes place in densely populated urban areas where interactions with the community are magnified. No matter the vertical alignment or method used, construction in these urban environments can interfere with existing utility infrastructure, including water, electricity, and waste; can cause ground movements that threaten the structural integrity of nearby buildings; and can constrain the movement of goods and people around the construction site. For these reasons, urban rail projects have to be planned (see chapters 3 and 4) and designed (see chapters 5 and 6) carefully, keeping in mind all of the negative impacts of construction (see chapters 14 and 15). It is important to create the appropriate institutional environment to manage project development through construction and to monitor asset management and operations (see chapter 12). Construction activities have to be carried out in a way that ensures credible project delivery and supports the long-term operations of the system (see chapter 13).

The nature and scale of construction impacts will depend on project design, particularly horizontal alignment (or right-of-way) and vertical alignment (whether the rail is at-grade, elevated, or underground).

*Photo:* Crossrail Tunnel Boring Machine cutterhead being installed at Westbourne Park, 2012. *Source:* © Crossrail, Ltd. Reproduced with permission; further permission required for reuse.

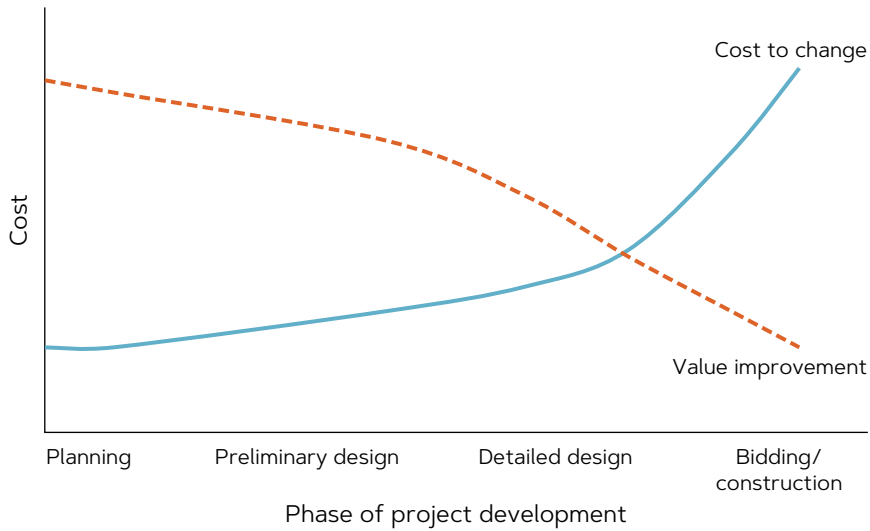
For many urban rail systems, lines may have segments with different vertical alignments—such as underground segments in dense downtown areas and elevated or at-grade segments in more suburban areas and airport connections. Different segments require different construction methods and sequencing of works. In addition, urban rail construction almost always necessitates the management of multiple contracts for civil works, rolling stock, and mechanical, electrical, and other systems. All of these features are interdependent and have to be designed and implemented to work together (see chapter 5). Careful interface and project management is essential from planning through construction (see chapter 4).

This chapter presents project decision makers with a brief overview of the many prerequisite studies needed to understand the impact of urban rail construction on the urban environment and to make the best decisions regarding different construction methods. Many of the studies discussed in this chapter build off of preliminary studies conducted during alternative analysis (chapter 3) and project design (chapter 5), with sufficient additional detail to support construction activities. This chapter highlights the importance of active and informed management and stakeholder engagement by the project-implementing agency throughout the sequence of construction works, even after the project has been bid. Ensuring the safety and security of construction personnel and city inhabitants is paramount at all times. The final sections discuss the special considerations necessary and construction methods available for segments at-grade, elevated, and underground.

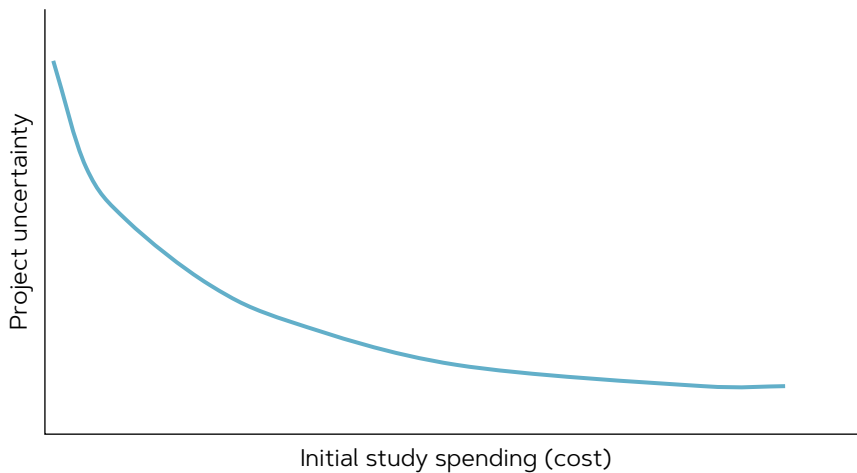
### **Prerequisite Studies**

Many decisions made in the early steps of project development will affect the project's constructability, construction schedule and cost, and construction methods. Therefore, it is important for the project-implementing agency to invest time and money in high-quality preliminary studies of local conditions to inform planning and design of the project in preparation for bidding and construction. As the project progresses, it becomes much more difficult to change its design or implementation, and the value of any improvements begins to depreciate (see figure 11.1). Obstacles identified during construction and any resulting changes in design will have a higher cost and greater impact on project schedule than if they had been identified and mitigated prior to implementation. The more detailed the studies, the better project implementation can be planned and designed from the beginning. Practical experience shows a higher risk of unexpected delays or cost overruns in the absence of such studies.

**FIGURE 11.1. Cost of Design Changes Curve**



**FIGURE 11.2. Relationship between Risk and Resources Spent on Preliminary Project Studies**



Each urban rail project is unique and involves a high level of risk. As the quality of studies increases, risk and uncertainty in the project design and construction methodology decline (see figure 11.2).

All of the studies discussed in this section are necessary for any urban rail project, but in some cases, a higher level of detail may be warranted depending on the vertical alignment and construction method selected for the project.

These case-specific considerations are discussed later in this chapter in the sections on at-grade, elevated, and underground urban rail construction.

### **Geotechnical Site Investigation**

Site investigation determines the engineering properties of soil and rock and how they will interact with planned construction. Site investigation establishes parameters for foundation, substructure, and infrastructure design and assesses the potential geotechnical, geoenvironmental, geological, and hydrological risk to humans, property, and the environment (RSA Geotechnics n.d.). The design and scope for each investigation will depend on site-specific circumstances—such as the anticipated geology, previous use of the site, and level of seismic risk—and proposed design and construction method. In particular, a higher level of detail is needed when investigating sites where soil conditions are unstable or where segments will be constructed underground.

It is usual for the geotechnical site investigation to be carried out as a phased exercise, such as the following:

1. Desktop study and reconnaissance survey
2. Field investigation, sampling, and analysis
3. (Interpretive) report
4. Design of remediation strategy, if necessary
5. Validation and monitoring of remediation during construction
6. Monitoring of infrastructure and buildings, as needed, for the first 5–10 years of operation

Desktop studies compile and analyze relevant data, including all existing geotechnical information and old aerial photos, which can provide information about infilled areas and channels. They carefully note any obstacles or ground characteristics that will need remediation, such as existing foundations, basements, abandoned mines, and clandestine tanks with potential contaminants. These studies identify preliminary operating areas, develop feasible route engineering plans, assess levels of seismic risk, and design appropriate survey programs prior to field investigations.

These desktop studies inform the number and location of field investigations and sampling from boreholes and trial pits. The density of sampling will depend on the design of the system, with at-grade systems requiring relatively infrequent sampling and underground systems requiring extensive sampling and analysis. Changes in the scope of the site investigation, or even the proposed design and construction works, might be needed in the case of any unexpected findings.

An interpretive report is drafted from the field measurements. This report includes recommendations on foundation design and other geotechnical engineering considerations. From a technical point of view, the geotechnical report should be as accurate as possible since the structural design depends in part on geotechnical conditions. This precision, which increases with the density of field surveys and laboratory tests, is proportional to the cost. Therefore, a balance should be sought between uncertainty and study cost. However, the costs of these up-front studies are often much lower than the costs of uncertainty or of changing the project designs after bidding and construction have started. International experience highlights the importance of investing in geological, geotechnical, and geophysical tests prior to the start of engineering design.

Experienced teams, supervised by external geotechnical experts, should draft the interpretive geotechnical report and design remediation strategies. This report becomes a key contractual document for allocating geotechnical risk during the bidding process (see chapter 7); it helps to define the boundary of risks between the project-implementing agency and the contractor (see chapter 8).

### **Environment, Health, and Safety Review**

An environment, health, and safety (EHS) plan should be completed in conjunction with a social impact assessment (SIA) in order to implement complementary mitigation and management plans. This EHS review should involve the following:

- An inventory of trees potentially affected by the project
- A careful assessment of noise, dust, and vibrational impacts
- An investigation of potential sites for source materials and sites for the disposal or reuse of extracted soils
- An assessment of groundwater and the effects of pumping prior to construction
- An assessment of environmental liabilities due to soil or groundwater contamination (see chapter 15)

### *Remediation of Contaminated Land and Waste Management*

Critical areas of EHS review for urban rail projects are the investigation of sites for the disposal or reuse of extracted soils and the assessment of soil and groundwater contamination. Treatment of contaminated areas can be a lengthy and costly process that has to be completed before construction begins.

Often, urban rail alignments pass through areas near existing or previous gas stations and the soil may be contaminated because of clandestine tanks or oil leaks. Similarly, rail yards are often located on reclaimed garbage dumps and

other land that potentially carries environmental risks. In addition, pumping water potentially contaminated with discharge from the construction site directly into the urban sewage network can create an imbalance in the region's water purification systems. All of these issues can lead to a need for major ground and water treatments that, if not investigated and managed up-front, may affect the critical path of project implementation.

Ground and water contamination may require significant remediation. If this contamination were known up-front, the cost and time of treatment measures could be built into the construction sequence and construction contracts could clearly define the roles and financial responsibilities for remediation. However, if careful environmental, geotechnical, and hydrological studies are not completed, these issues may appear only after construction has begun, causing costly project delays and potential contract disputes. Therefore, paying attention to initial alignments and EHS reviews is crucial in sequencing the construction works to save time and money.

### *Safety*

Any potential or perceived safety risks should be mitigated proactively. The safety of passersby and construction workers should be carefully considered throughout design and construction of the system. Worksites should be fenced off and detours marked so that pedestrians cannot wander into the construction zone or areas with vehicular traffic. In addition, the sequencing of construction activities, proper design and support of temporary works, and training and staffing of workers should all be planned to ensure the safety of workers. Laborers at the site should be aware of any risks associated with their own tasks, should be equipped with proper personal protection gear, and should know how to act and work safely in the construction zone. A health and safety management and inspection system needs to be in place to monitor and correct any safety issues for both workers and residents during construction (see chapter 15).

### **Social Impact Assessment**

For any major project, particularly in densely populated urban environments, construction will cause significant impacts on surrounding communities. Parties along the right-of-way, around station areas, and adjacent to other construction sites may be disadvantaged by several factors, including

- Noise, vibrations, and dust;
- Difficult access to properties and businesses (and related loss of revenue);
- Disrupted traffic patterns; and



- The barrier effect—where the infrastructure cuts one side of the community off from the other.

The influx of workers to project sites can also put pressure on local housing markets and cause conflicts with the local community. Furthermore, some social impacts, including noise, vibrations, and the barrier effect, can persist beyond construction and through operations. These social impacts should be identified, anticipated, and mitigated during the planning and design of the project (see chapter 14).

The project-implementing agency should complete a corridor-level and station-level inventory of existing businesses and buildings along the alignment. This inventory should document the location of buildings and structures, their type (that is, permanent versus semipermanent versus temporary; high-rise versus low-rise), footprint, construction materials, and existing conditions. Although a smaller-scale inventory to this effect may be completed during preliminary project design to plan for social impacts such as relocations or economic displacement (see chapter 14), a more detailed study will need to be completed along with final design in order to prepare for construction. From this inventory, it is possible to determine the risk of damage to each building, based on its unique depth of foundation, age, and building materials. Special attention should be paid to buildings of historical or cultural significance (see chapter 14). Such an inventory is a useful project management tool, since it helps to allocate limited resources to mitigate settlement of high-risk or high-importance structures along the alignment and can offer protection against potential claims of damages. The time that it takes to inventory local businesses, buildings, and archeological and paleontological heritage of all sites should be budgeted into the sequence of construction works.

Involvement and liaison with the community are key during planning and construction. In addition to setting up a grievance redress mechanism, disruptions should be communicated in a timely manner, and mitigation measures should consider feedback received from local residents. Although the implementation of urban rail projects has social impacts, community engagement in project development can be an opportunity to create community buy-in. Many initiatives, such as name or design competitions, public workshops, and school visits can help to connect the community to the project. Furthermore, key services provided to the community, such as local health centers and schools near the worksites, may require special treatment so that they can keep their doors open during construction. City supply networks such as gas, water, sewage, and electricity should also be maintained with as little disruption as possible.

## Roles of the Project-Implementing Agency

No matter the final design, construction method, or procurement arrangement for the urban rail project, the project-implementing agency has to play an active role in planning for construction and overseeing implementation of the project's civil works. Although some of the risks, roles, and responsibilities may shift to a private sector partner under alternative procurement arrangements such as public-private partnerships (PPPs), the project-implementing agency will, in almost all cases, have key supervisory authority and responsibility as the owner of the project. Staff from the project-implementing agency will have to manage contracts with the construction entity as well as relationships with other external stakeholders, including municipal public works agencies, utility owners, project sponsors, and community groups and individuals affected by project implementation. The management of different parties can be one of the most challenging aspects of urban rail construction. It is the responsibility of the project-implementing agency to ensure clear and timely communication and execution of jobs and to manage stakeholders' expectations. The project-implementing agency has to sequence its own tasks (such as preconstruction planning, prerequisite studies, and enabling works) with those of the contractor or private partner and all other stakeholders to ensure adherence to the project schedule (and budget).

### Land Acquisition and Sequence of Works

Project-implementing agencies are often responsible for acquiring the land necessary for project implementation—both the temporary land needed for construction as well as any permanent land needed for rail right-of-way, shafts, stations, rail yards, and maintenance facilities. It is important to consider options in the design of the project (particularly its horizontal and vertical alignments) to minimize the need to acquire land as well as to consider the availability and cost to acquire nonpublic lands. Land acquisition is a complex process that, if poorly managed, can affect the project cost and schedule. A qualified team of legal and project staff, including social and environmental impact experts, is responsible for acquiring land prior to the start of any civil works (see chapter 4). Construction contractors have to know the dates and conditions in which sites will become available, because this information is linked directly to the sequence of project works. Delays cost contractors time and money and are a significant source of change order and overage claims. Therefore, land acquisition is a key responsibility of the project-implementing agency that should be managed as part of the full sequence of construction works.

For many project-implementing agencies, land acquisition may be constrained by the existing legislative and regulatory framework. In many countries,

individual property rights and lack of authority on the part of the project-implementing agency to expropriate land can limit the horizontal alignment to existing public rights-of-way (often along main roads). The costs and implications of this kind of legislation for design and construction should be assessed as part of project planning. Any city planning to build a new urban rail system should carry out a legal analysis and modify any legislative barriers to appropriate land acquisition.

### **Stakeholder Management and Community Engagement**

It is important to sustain communication and collaboration with the many stakeholders affected by construction of the urban rail project, particularly local residents whose daily lives may be disrupted by construction activities. This community engagement begins with project initialization and continues throughout planning, design, construction, and operations. For the entire length of the alignment, the project-implementing agency and the contractor have to coordinate and communicate with municipal works departments for the diversion of utilities and with municipal streets departments and transit authorities for the provision of temporary and long-term complementary works such as sidewalks, bike lanes, and roads to access stations. The project-implementing agency also has to work with law enforcement, transportation service providers, and citizens for traffic management. For each segment of urban rail construction, liaising with the community is important to identify impacts on local business owners and citizens and to design mitigation measures to minimize disruptions during construction. These mitigation measures might include temporary walkways with clear signage communicating how to get around construction areas and how to access adjacent shops and services (see chapter 14). Community engagement also plays an important role in maintaining the safety of the construction site since many accidents and even fatalities happen when pedestrians, drivers, or others interact with construction activities.

#### *Utilities Diversion*

Urban utilities and supply networks—including water, sanitation, gas, power, telephone and fiber-optic wiring, and traffic lights—are multiple, dense, and, on many occasions, major. As a result, construction of any urban rail system is likely to interfere with these utility networks.

During early planning and design of the project, it is important to assess the existing layout of utilities along the project alignment.<sup>1</sup> Studies early in project planning should focus on the location of the main utility supply networks and important junctions, which may be extremely difficult or costly to deviate and can affect the construction and alignment of infrastructure. As the project

moves into design, more detailed, site-specific investigation will be needed. To complete this assessment of existing utilities, the project-implementing agency should contact proprietary service organizations and municipal public works departments to provide utility maps and network information. This official information should be complemented with on-site inspections and even a topographic survey, if necessary. The project-implementing agency then identifies which utilities should be protected or relocated and how. Even when utilities are far enough below the surface to avoid damage from construction, they may need to be diverted so that their maintenance will not affect the safe and efficient operations of the train system once construction is completed.

Although existing utilities are being diverted or protected, additional power and water supplies, as well as drainage systems, may be installed to support the new rail system. Both above- and below-ground space may be needed to house new electrical substations, storm ponds, and sewage shafts or to integrate new supply networks with existing utilities. Utility owners are involved in providing any new utilities needed for the rail system and in designing the necessary diversions and protection measures to minimize the risk to existing utilities from ground movement and surface settlement.

While up-front and active communication and early investigation are important, there are always variations between the inventory and the actual position of utilities. Many urban areas in low- and middle-income countries have incomplete records of utilities, which were developed before the implementation of consistent and centralized network planning. Even with careful mapping of utility location, it is often recommended that the project-implementing agency (in collaboration with utility owners) oversee an investigation of existing utility supply infrastructure using trial pits. The number and associated cost of these trial pits will depend on the level of detail of existing paper records of utility locations, vertical alignment, and structural design of the system, and number of culturally and environmentally sensitive areas identified within the construction zone by the social and environmental impact assessments.

Even after these trial pits are completed, it is common to encounter unforeseen utilities once construction begins. Accordingly, it is important for construction contracts and negotiations with utility owners to clarify the roles and responsibilities in case of unforeseen utility deviation or geotechnical risk (see also chapter 7). If the utility inventory is completed prior to bidding the project, the project-implementing agency can specify roles and allocate risks in project contracts, mitigating delays and allowing for prompt responses to uncertainties. If the utility inventory is not completed prior to bidding, all of the utilities risk and uncertainty can be passed to the contractor, but this often comes at a high price. The project-implementing agency has to balance the time and resources

needed to compile a complete inventory of utilities with the risk premiums that might be built into a contract if the studies need to be completed by the contractor or private partner.

### *Traffic Management*

Construction of a rail system within an urban area will disrupt daily travel patterns of pedestrians, public transport, and private transport. Project planning and design should consider different alternatives with a view to minimizing the overall impact on traffic throughout the construction and operation periods. During construction, especially for at-grade and elevated alignments, station areas, sidewalks, surface public transport routes, and roads may be closed or detoured around the worksite. Although some travel connections may be restored after construction, traffic may be diverted permanently along the alignment of at-grade and elevated systems and in station locations. In addition to the temporary or permanent closure of roads, construction vehicles can add heavy traffic to congested and often narrow urban streets. It is often necessary to regularly transport materials from storage areas outside of the dense urban core to worksites and to return excavated soil and other materials to disposal locations. These logistics and their impact on traffic have to be considered. In some cases, construction traffic may be confined to certain routes (based on infrastructure capacity) or restricted to certain off-peak hours (that is, to reduce noise pollution at night or to avoid commuting and school hours during the day).

It is essential to perform a rigorous planning of the occupation of public roads and the impact of rail construction on road traffic conditions before releasing any area for construction work. This traffic management study should, where possible, keep open or enable alternative routes. Any diversions of traffic will cause considerable confusion for pedestrians and drivers as they rearrange their itineraries; to minimize the effects of the diversion or reorganization, it is necessary to conduct communication campaigns and disseminate appropriate information to urban residents and taxi and bus drivers in advance of disruptions. Compliance with scheduled deadlines for the detour is essential. If necessary, bus service and other public and private transport services in the area should be improved to meet residents' transportation needs. Of all community impacts, traffic diversion and travel time delays garner the most complaints from urban residents during construction. Therefore, traffic management planning is a critical part of preconstruction efforts that can connect implementation with the project's SIA (see chapter 14).

The impact of construction activities on traffic needs to be managed from a system's perspective. Multiple infrastructure projects in the same urban area can have cumulative impacts on traffic and can, at times, mean delays in finalizing a

traffic management plan for a given corridor. The project-implementing agency may need to liaise with other projects to perform a cumulative impact assessment when considering traffic management plans for the implementation of urban rail. Traffic management planning and implementation during construction are often assigned to the contractor or private partner. However, the project-implementing agency and local authorities continue to play an oversight role in approving these plans, evaluating their cumulative impact with other infrastructure projects in the region, and ensuring their dissemination to all relevant stakeholders.

### **Building Technical Capacity within the Project-Implementing Agency**

For many project-implementing agencies in low- and middle-income countries, an urban rail project is often the first of its kind in the locality. Therefore, local technical capacity in different underground construction methods and the necessary sequencing of construction works may be limited. It is important for a project-implementing agency to review its construction management and other technical capacity carefully and to complement this capacity with external experts well in advance of awarding any contracts or beginning the construction of civil works (see chapter 4). For example, Quito, Ecuador, designed its first urban rail line as an underground system but had no previous experience with underground construction. Recognizing this knowledge gap early in project development (well in advance of construction), Metro de Quito was able to hire a company to assist with value engineering of the project design (see chapter 6) and to manage bidding and construction.

The need to conduct prerequisite studies and to consider the role of the project-implementing agency in managing construction applies to any form of urban rail construction; other considerations are specific to the vertical alignment and construction method employed for the project. The following three sections provide an overview of construction methods for at-grade, elevated, and underground urban rail systems, respectively, and discuss critical considerations specific to these vertical alignments.

### **At-Grade Urban Rail Construction**

Many of the first urban rail systems were constructed at-grade—on surface level, interacting with most urban activities (including pedestrian and street traffic). An at-grade urban rail system (with dedicated right-of-way) generally consists of an exclusive platform with very limited pedestrian and vehicle crossings. At-grade systems are the simplest to construct because they forgo the

need for additional elevated structures or tunneling, but as the value of land in dense urban centers increases, they have become costlier. For many reasons—such as increasing value of urban land, high political costs associated with competition for constrained road space, and the barrier effect—at-grade rail is now most commonly developed for suburban, regional, and commuter rail corridors rather than for metro systems in downtown areas.

### **Special Considerations for At-Grade Systems**

The operational efficiency of at-grade urban rail systems depends on the exclusivity of their right-of-way, which can create a physical barrier between neighborhoods on either side of the tracks. This barrier disrupts existing traffic patterns and requires protection of right-of-way.

#### *Barrier Effect*

At-grade urban rail systems on a dedicated right-of-way can create a physical barrier that restricts the access of vehicles and pedestrians across the tracks (see image 11.1). This barrier can sever existing social and economic connections

**IMAGE 11.1.** Elevated Intercity High-Speed Rail and At-Grade Urban Rail Lines, Crossed by a Highway Overpass and Pedestrian Flyover: Tokyo, Japan



Source: Tokyo Form via Flickr Commons (CC-BY-ND 2.0).

among neighborhoods and cause delays and discomfort for residents not served by the new rail system. This permanent barrier effect and the impacts of surface-level construction should be investigated carefully when planning the horizontal alignment of the rail line and in SIAs and EHS reviews. These reviews and the identification of mitigation measures entail a high degree of stakeholder engagement and management, especially with local communities adjacent to the planned right-of-way (see chapters 4, 14, and 15).

#### *Permanent Traffic Diversion and Right-of-Way Protection*

Vehicle and pedestrian traffic needs to be redesigned carefully around the new right-of-way for the operational stage of an at-grade system. Temporary barriers used to protect the construction site during implementation should be replaced by permanent fences and other structures to discourage encroachment on the tracks. Protecting the right-of-way is critical to avoiding disruptions and maintaining the safety of the at-grade system during operations. Permanent entrances and exits to the right-of-way and at-grade crossings should be marked carefully and gated with visual signals and audible warnings about approaching trains to prevent humans from interacting with the rolling stock operating on the tracks. The most efficient and safe at-grade urban rail systems limit the number of at-grade crossings and provide infrastructure—such as elevated walkways or tunnels—to facilitate the movement of people from one side of the tracks to the other. Especially for longer-distance commuter rail systems that are most likely to be at-grade, the design should also protect the right-of-way from water encroachment and incorporate adequate drainage and resilience measures to floods and other climate hazards (see chapter 17).

#### **Construction Method for At-Grade Systems**

Preconstruction planning and management of enabling works—including land acquisition, utilities relocation, and traffic management—are critical for the implementation of at-grade urban rail systems. Compared with elevated or underground rail systems, at-grade systems require the most surface land during both construction and lifelong operations. Therefore, the availability and cost of surface land must be considered carefully when determining the horizontal alignment and sequence of construction works for at-grade systems. To reduce the impact of enabling works and construction, these activities should be iterated along segments of the horizontal alignment.

Once the land is procured, the contractor can commence with major land clearing, earthworks, and ground improvements, if necessary. Any existing utilities are either diverted or protected along the entire route, in station areas, and under rail yards and maintenance facilities. The impact of construction traffic



should be considered carefully when managing the movement of people and vehicles around the worksites.

Once preconstruction planning and enabling works are completed for a given section, construction of the at-grade system commences. Construction of an at-grade system involves clearing and leveling the right-of-way, preparing and installing the track infrastructure, and installing the mechanical and electrical systems. Track infrastructure can be built on ballast (usually employed in suburban areas) or on a concrete slab (favored in urban centers) (see chapter 5 for discussion of the trade-offs involved in this and other design decisions). Once construction of the rail track and facilities is complete, the right-of-way is fenced off (when applicable), and new vehicle and pedestrian crossings are constructed to provide controlled and protected access from one side of the tracks to the other.

## **Elevated Urban Rail Construction**

Recognizing the value of at-grade urban land, the growing density of urban activities, and the economic and social disruptions caused by the barrier effect, many cities began to implement elevated rail systems. These elevated systems run on tracks above street level on a viaduct or other elevated structure (usually constructed of steel and concrete). The following sections discuss the special considerations necessary when implementing an elevated segment of an urban rail system as well as the general construction method.

### **Special Considerations for Elevated Systems: Use of Understructure Space**

Similar to at-grade systems, the implementation of elevated urban rail systems creates significant surface-level disruption during construction and requires careful assessment and mitigation of environment, health, safety, and social impacts. In particular, elevated systems can still cause a lasting barrier effect (particularly among tall buildings in dense urban areas). Although some urban infrastructure, such as road and sidewalk connections, can be restored beneath the elevated structure, the elevated alignment can permanently constrain further development of the land.

It is important to consider the use of the space below the elevated structure when designing the system and to incorporate development of the space into the construction contract. This early consideration of understructure space creates efficiencies, can mitigate the social risk associated with the barrier effect that these structures can have on existing urban neighborhoods, and can be politically advantageous when involving community participation. If the use of understructure space is not considered, the infrastructure can rupture the

urban fabric, creating a barrier between social and commercial activities on either side of the tracks similar to at-grade systems.

Although elevated systems can allow for more flexible passage underneath the deck from one side of the rail system to the other, this space is often underused and inhospitable. Urban space is too scarce and valuable to waste; yet, historically, the space below many elevated railways has been problematic. Without careful design to integrate the spaces below the elevated structures with their environment, these spaces can become lonely, poorly lit, and dangerous. Their lack of security and inconvenience can create an intangible, rather than a physical, barrier effect (unless the elevated structures are very high, as they are in some Chinese cities).

An international movement is under way to rehabilitate these underused and degraded public spaces, creating a wealth of international good practice on how to design them to be useful, pleasant, and safe (see box 11.1). Many of these interventions seek to create a public space of environmental quality that enhances and encourages the experience of walking from one side to the next.

No matter whether the function of these spaces is aesthetic, recreational, or commercial, the most successful projects actively seek input from residents of the neighborhood when determining the type of use. Community input can be incorporated via participatory workshops, idea competitions, or other means to give social identity to the project and integrate the space within the social activities of its surroundings. If carefully designed with input from the local community, elevated rail may have fewer long-term impacts on the movement of people and goods throughout the surface of the city than at-grade systems.

### **Construction Method for Elevated Systems**

For elevated systems, land for storage and maintenance facilities is permanently acquired, and access to land along the right-of-way is temporarily granted so that construction can begin. The worksite is cordoned off with enough space to begin the enabling earthworks, diversion and protection of utilities, and construction of temporary works. Along the acquired alignment, the location of utilities is carefully surveyed, but only those utilities that lie in areas where foundations will be poured or where stations will be constructed are necessarily diverted. To reduce the burden of utility diversion, the design of elevated systems should account for the location of utilities when placing the structural supports.

For construction of an elevated system, it is important to design not only the final structure and system, but also the temporary works needed to raise the vertical supports and build the horizontal decks. These temporary construction works

**BOX 11.1.****Use of Space Underneath Elevated Rail Infrastructure: International Experience and Success Factors**

Lessons can be learned from projects across the world that rehabilitate old understructure spaces or design these spaces for new rail and highway systems. In recent years, these understructure spaces have been reimagined as aesthetic parks, recreational public spaces, or commercial centers.

**Aesthetic parks**

One of the most cost-effective means of transforming the traditionally negative image of these spaces is through small aesthetic interventions that make the space favorable to pedestrians and enhance the experience of walking from one side of the structure to the other. These aesthetic interventions often include the installation of lighting (for example, the Phoenix Flowers in Glasgow), landscaping and vegetation (for example, the lavender field at the central station of Mainz, Germany), or local art (for example, Praça XV de Novembro in Rio de Janeiro, Brazil) (Bordas Geli 2016).

In Lima, Peru, municipal decision makers did not consider use of the understructure space up-front in the design and construction of

Metro Line 1. In many neighborhoods, the space beneath the rails became a dumping ground for garbage and was inhospitable for passengers and local residents. Recognizing the need to reinvent these spaces, local artists and community members worked with Metro Line 1 and the Ministry of Culture to identify a low-cost, aesthetic solution that spoke to the society, culture, and history of the city. Through murals of social, cultural, and religious importance, Lima Metro Line 1 created spaces of art that are respected and cared for by local residents. In particular, local members of the Shipibo-Conibo tribe painted geometric murals around the area of the Nicolas Arriola Station where they live (see image B11.1.1) (Alamys 2017).

**Recreational public spaces**

Recognizing that urban space is a scarce and valuable asset, project decision makers can also take advantage of understructure spaces to provide the city with useful recreational equipment that is sheltered from rain. Successful examples of creating recreational space beneath elevated rail lines involved

**IMAGE B11.1. Creating Communal Spaces of Culture, Art, and Safety Underneath the Rail Lines: Lima, Peru Metro Line 1**

Source: Alamys. Reproduced with permission; further permission required for reuse.

(box continues next page)

**BOX 11.1.****Use of Space Underneath Elevated Rail Infrastructure: International Experience and Success Factors** *(Continued)*

community development of skate parks in Cape Town, South Africa, and a public amusement park built with recycled construction materials in Lima, Peru.

**Commercial centers**

A final use of understructure space is the development of commercial projects that generate income and stimulate economic activity in the surrounding area. The area underneath the tracks can house shops or local markets, becoming a point of attraction for passersby. In Caracas, Venezuela, a thriving book and board game market sets up stalls in the space beneath a highway. In dense urban cities in Japan, the development is more permanent, with commercial buildings occupying much of the space below the rail line in some areas (see image B11.1.2).

**IMAGE B11.1.2. Business Thrives Below the Rails of Elevated Trains: Yarakucho Station, Tokyo, Japan**

Source: T. H. Rogers via Flickr Commons (CC-BY-ND 2.0).

will determine the land required during construction of the system and, therefore, the extent of urban area disrupted by project implementation. Temporary works for constructing pillars and decks may be provided by gantries, precast beams, or scaffolding to ground. If scaffolding is used, it is essential to consider the geotechnical conditions required to support the scaffolding. If these conditions are not taken into account, movements of the soil during construction can cause the scaffolding to collapse—the cause of many accidents during the construction of elevated systems. Therefore, the use of scaffolding and other temporary works may require ground improvements prior to construction.

Once temporary works are in place, construction of elevated segments of urban rail starts with the digging and pouring of foundations. After the foundations are laid, vertical pillars are constructed, and the deck is built in segments on these vertical supports (see image 11.2). The depth of the foundation for the pillars and the spacing between them will depend on the characteristics of the soil (determined by geotechnical studies), the location of existing utilities, and the design parameters of the structures. The design should attempt to balance

**IMAGE 11.2. Building the Deck Span across Vertical Supports: Silver Line, Washington, DC**

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substructure and superstructure costs to achieve an optimum balance of life-cycle cost and operational performance (see chapter 6 for more information on design optimization).

Once the supports and elevated deck structure are in place, the rest of the construction proceeds as with at-grade alignments. First, the working platform is prepared. For at-grade systems, the platform can be either ballast or concrete slab; for elevated systems, concrete slab is the standard because ballast could fly off elevated structures and hit people or vehicles traveling below. After the slab is completed, the rails are laid, fixed in place, and then leveled. Along with track construction, mechanical and electrical systems are installed along the alignment. Elevated systems often involve the construction of additional fencing and noise-dampening infrastructure to mitigate the added noise caused by elevated, concrete slab systems.

After completion of the elevated track and systems, the land temporarily cordoned off for construction beneath the track is restored. Vehicle and pedestrian connections severed during construction can then be redesigned and other improvements added underneath the elevated structure.

## Underground Urban Rail Construction

As municipalities recognize the long-term value and scarcity of public space and the disruption of extensive surface construction in densely populated urban centers, underground construction has become the preferred alternative for many urban rail projects, especially metros. Although advances in underground construction methods have lowered the cost of implementation for some underground systems, tunneling requires special considerations beyond those necessary for at-grade or elevated systems. The costs and benefits of underground segments should be weighed before deciding whether or not to adopt an urban rail solution (see chapter 3) and throughout the design process (see chapter 5). For those segments of urban rail designed to be underground, additional studies are undertaken during project planning and design to prepare for bidding and construction of the project. Based on the results of these additional studies and the project budget and implementation schedule, the project-implementing agency then chooses the appropriate construction method to complete the project.

In many cases, the urban rail project may be the first time in history (or in a generation) that a city or country has dealt with large-scale urban tunneling. Therefore, project-implementing agencies should hire external technical advisers or highly qualified staff with enough experience to address the sophisticated complexities of the project (see chapter 4).

### Special Prerequisite Studies for Underground Systems

Construction of underground systems is more complex and risky than construction of above-ground systems. To prepare for underground construction, the usual studies completed for any urban rail system are complemented by more in-depth exploration of the geotechnical and hydrogeological characteristics of the site, settlement of ground during excavation, logistics strategy and sequence of works for excavated materials, and safety of working conditions in confined, underground spaces.

#### *Geotechnical Baseline Report*

Underground projects are at the greatest risk for construction cost overruns and project delays due to unforeseen soil conditions. Accordingly, geotechnical

site investigations for underground projects are completed with the greatest density of boreholes, trial pits, and other sampling. The analysis of these investigations will determine which construction methods are feasible given the geotechnical conditions along the alignment.

A geotechnical baseline report is fundamental both from a technical point of view and from a contractual point of view, since many of the claims and disputes occurring along an underground work are related to the existence of geotechnical conditions different from those initially provided for in the contract. Although a good site investigation gives a reasonable approximation of soil conditions, the reality is not clear until construction begins. The geotechnical baseline report clearly allocates geotechnical risks and defines financial and construction responsibilities for responding to changes in geotechnical conditions. From a contractual point of view, having a good geotechnical report can reduce (but not eliminate) the likelihood of claims and cost deviations for geotechnical reasons (see also chapter 7).

### *Hydrogeological Studies*

Tunnels can alter the existing hydrological conditions of their surroundings by acting as drainage or altering the water table level. Changes to the groundwater system can cause ground settlement that may damage assets with shallow foundations. Hydrogeological studies are needed to document the flow of water and location of aquifers in order to model and assess the potential impacts to the groundwater system due to the proposed underground structure and the resulting effect on assets in the construction zone. These studies can inform site-specific strategies to mitigate any unfavorable effects on the groundwater system due to the proposed tunnel alignment and construction method. If not managed properly, the encroachment of water into underground structures during construction or operation can cause premature failure of assets, requiring more costly maintenance and renewal.

### *Settlement Management Plan*

Excavation and installation of underground urban rail systems inevitably produce ground-borne vibrations and soil movement. These ground movements during construction can cause utilities and buildings to settle and, if not carefully managed, can damage their structural integrity and functionality. Well in advance of excavation, the project-implementing agency carefully documents the location and condition of assets along the route and creates a settlement management plan for those buildings within a conservative zone of influence. The settlement management plan identifies those assets at risk of settlement,

the damage that may be caused to the relevant assets, and whether settlement protection measures will be necessary during construction. This settlement management plan is completed along with the project's preliminary design and is revised or refined to a level of detail to match the final design; in addition, any inventory of buildings in the area affected by construction is updated prior to the start of construction works.

This process has several steps, many of which are completed long before excavation begins (see figure 11.3):

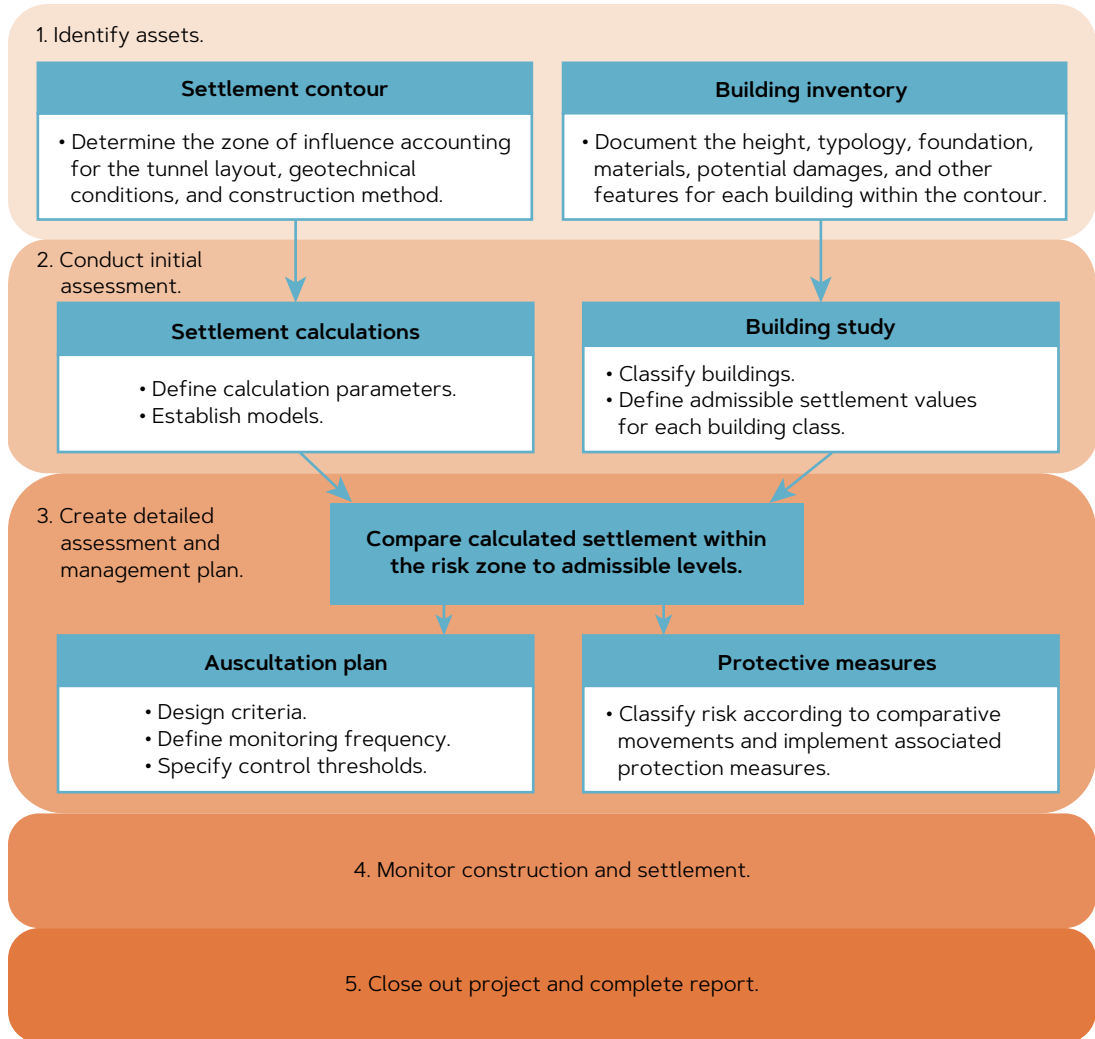
1. *Identify assets.* Calculate the settlement contour of the excavation based on the tunnel layout, geotechnical conditions, and construction method. Inventory the buildings in the settlement contour, including their height, typology, basements, foundation, current condition, and potential damages.
2. *Conduct initial assessment.* Define the parameters and models to be employed in the calculation of settlement. Classify the risk of damage to the identified assets in an initial screening. For those assets that exceed certain agreed tolerances and are deemed at-risk, proceed to the next step.<sup>2</sup>
3. *Create detailed assessment and management plan.* Perform a detailed assessment of each at-risk asset and design monitoring, mitigation, and soil stabilization measures—such as jet grouting, micropiles, grout block or grout piles, and excavation parameter control—to reduce the risk of damage. Decide on the critical settlement parameters that will be monitored for each site, the trigger levels for each parameter, and the actions to be taken in case these levels are triggered for a particular asset. Summarize these trigger levels and related actions in an emergency response plan.
4. *Monitor construction and settlement.* As a good practice, monitor and analyze excavation parameters and settlement parameters jointly. Use the information on settlement as feedback to adjust how the excavation will advance.
5. *Close out project and complete report.* Carefully document project closeout once the observed rate of settlement on installed instrumentation is quite low (for example, less than 2 millimeters per year) and after a minimum period (at least one year) from the end of construction activities.

### *Excavated Material Management Strategy*

Any form of tunneling produces a large volume of excavated material. How this material is transported from the excavation site and how it is processed and disposed of can have significant environmental impacts and mitigation costs. This is of particular concern for urban areas, where streets and traffic can be



**FIGURE 11.3. Steps in Forming a Settlement Risk Analysis and Mitigation Plan for Underground Construction**



greatly disrupted by the addition of construction vehicles and where there is often a shortage of available landfill space. Therefore, any underground construction should be accompanied by a strategy for the transport, decontamination, and reuse (or disposal) of excavated materials. It is important to determine the location and capacity of disposal sites for excavated material and to ensure their availability throughout the work; any increase in the distance to

these sites can have a significant economic and logistical impact on the project. This strategy reinforces the project's overall traffic management plan and environmental study (see chapter 15).

Due to the excess of excavated material resulting from underground works, it is important to consider whether excavated material can be reused in other projects needing infill (such as urban developments, port expansions, or other infrastructure works). Reusing material means less environmental impact and more financial savings. In the case of Crossrail in London and many other projects, this excavated material management strategy is the responsibility of both the project-implementing agency and the contractor (see box 11.2).

### *Worker Safety*

Worker safety is important on all construction projects, but underground construction entails additional hazards that have to be mitigated. Tunnels have to be properly lit, drained, and ventilated to provide visibility, dry working conditions, and breathable air free of dust even in confined spaces. In addition, it is important to consider the effects of staffing on worker safety and to provide appropriate training in safety awareness for all labor. For underground construction, it is very important to conduct a fatigue assessment and to specify the number and length of shifts for each worker. In countries with limited experience with underground construction or lax safety standards, tunnel collapse is the greatest potential safety risk. Oversight of project safety is needed to ensure that tunneling is completed in suitable soil and drainage conditions and with proper support and lining of excavated sections to avoid collapse.

### **Construction Methods for Underground Systems**

There are many construction methods for underground urban rail systems, including the following: (1) cut-and-cover, (2) traditional tunneling methods (such as the Belgian, Madrid, or German methods), (3) sequential excavation methods (New Austrian Tunneling Method), (4) tunnel boring machines (TBMs), and (5) in-situ tunnel construction. Each of these methods has unique advantages and disadvantages, and no one method is superior in all aspects to the others. Choosing the appropriate method or combination of methods depends on many factors that need to be investigated in preconstruction studies and managed throughout project planning, design, and implementation. This section briefly describes each of the above-mentioned construction methods for underground rail systems. The following section presents the trade-offs among these methods and provides guidance on how to choose the most appropriate construction method for a particular project, given local conditions, tunnel design, and institutional capacity of the project-implementing agency.

**BOX 11.2.****Good Practice in Managing Excavated Material: Crossrail, London, United Kingdom**

Crossrail construction generated more than 8 million tons of excavated material. In order to reduce the project's social and environmental impacts, Crossrail adopted innovative approaches to the transport and reuse of this material. In partnership with its individual contractors, Crossrail developed the infrastructure to allow transportation of 80 percent (per ton-kilometer) of the excavated materials away from the construction site by rail or water. This decision alleviated the need for up to 150,000 truck journeys on the streets of London, significantly reducing the impacts on existing streets and traffic throughout construction.

Once out of the city, the material was reused, reducing the need for suitable disposal

sites. Excavation material management plans call for the reuse of 98 percent of the excavated material for nature reserves, recreational facilities, agricultural and industrial land, and other uses throughout London and the surrounding areas (Crossrail 2017). Of these reuse initiatives, the most ambitious is a partnership between Crossrail and the Royal Society for the Protection of Birds for the creation of a wetland nature reserve—Jubilee Marsh—using 3 million tons of Crossrail's excavated material (RSPB Press Office 2017a, 2017b). This reserve is part of Wallasea Island, which will serve as an important flood defense system for London, helping to meet additional climate change resilience goals (see image B11.2.1).

**IMAGE B11.2.1. Jubilee Marsh Nature Reserve on Wallasea Island Created from Crossrail's Excavated Material**

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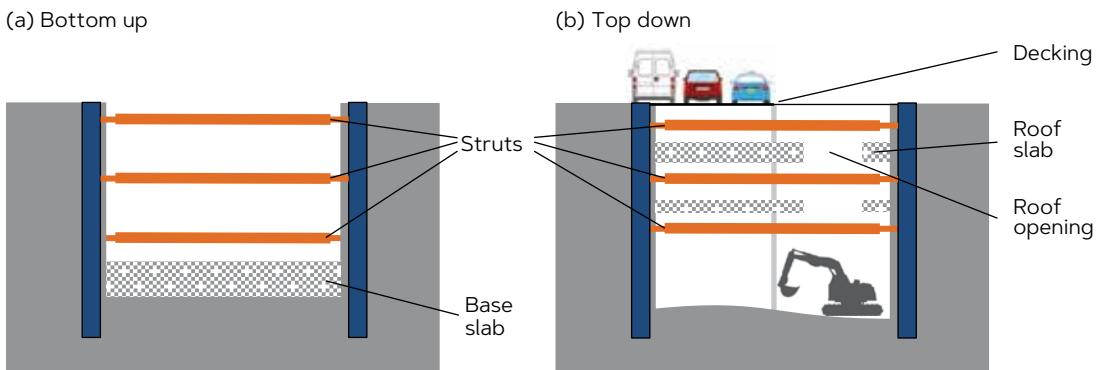
### Cut-and-Cover

Cut-and-cover is a simple method of construction that is most cost effective for shallow tunnels. In cut-and-cover construction, a trench is excavated and roofed over with an overhead support system strong enough to carry the load of what is to be built above the tunnel. There are two basic forms of cut-and-cover: bottom up and top down (illustrated in figure 11.4) (Railsystem.net 2015):

- *Bottom up.* In the bottom-up form, the entire trench is excavated (often requiring temporary props or scaffolding), and only then are the permanent supports and decking installed. The trench is then carefully backfilled, and the surface is reinstated.
- *Top down.* In the top-down form, the permanent structure is built while excavating the trench. Side support walls and capping beams are constructed from surface level by methods such as diaphragm walling or contiguous bored piling. Shallow excavation allows the use of precast beams or in-situ concrete for the roof. The surface is then reinstated except for access openings, allowing early reinstatement of roadways, services, and other surface features. Excavation takes place under the permanent tunnel roof, after which the base slab is constructed.

The major difference between bottom-up and top-down construction is the sequence of works. In bottom-up cut-and-cover construction, excavation is completed all the way to the base first, before the permanent supports and decking are constructed. This fast excavation may be needed to coordinate the timing with that of other tunneling works, but it causes longer surface disruption. In top-down cut-and-cover construction, excavation to the bottom is slower, but the surface level is released earlier since intermediate roof slabs are

**FIGURE 11.4** Illustration of Bottom-Up and Top-Down Cut-and-Cover Construction



put in place as excavation of the lower levels continues. Top-down cut-and-cover construction can further reduce traffic disruption by restoring road traffic on temporary decking over the half of the trench not under construction and then moving it to the half that has just been built.

Whether bottom up or top down, cut-and-cover construction can cause widespread disruption to existing urban activities on the surface of the alignment and can have severe environmental impacts such as construction dust and noise. Trenching is only feasible under existing roadways, parks, or other areas where buildings do not already exist on top of the intended alignment. For deeper tunnels or tunnels in densely settled areas with many large buildings on top of the alignment, the tunnel will have to be excavated without removing the ground above. Any trench will cut through existing utilities below the surface, requiring significant (and often costly) diversion of water, waste, electricity, gas, and other systems. Considering the need for space to relocate utilities over the slab and for connections to stations and other facilities, headroom should be minimized so the trench is as shallow as possible to reduce the volume of excavated material. These disruptions will extend along the entire length of the alignment, although construction can be segmented so that only certain areas are affected at any given time.

In rapidly urbanizing environments, cut-and-cover construction for long segments of tunnel may not be feasible due to the high level of surface disruption and lack of undeveloped land. However, the technique is often used to construct underground urban rail stations. Even in new systems constructed using other tunneling methods, such as Crossrail in London, Lima Metro, Quito Metro, and much of the Madrid Metro system, most of the underground stations are built using cut-and-cover. Cut-and-cover construction generally has two levels, which allows economical arrangements for ticket hall, station platforms, passenger access and emergency egress, ventilation and smoke control, staff rooms, and equipment rooms. Depending on the size of the excavation, cut-and-cover stations can provide greater station space with room for a broader range of facilities, lower cost, shorter construction period, and lower geotechnical risk than traditional excavation methods. If space on the surface is limited or stations are constructed too deep (which can create problems with access and passenger flow), then other excavation techniques are considered for underground station areas.

### *Traditional Tunneling Methods*

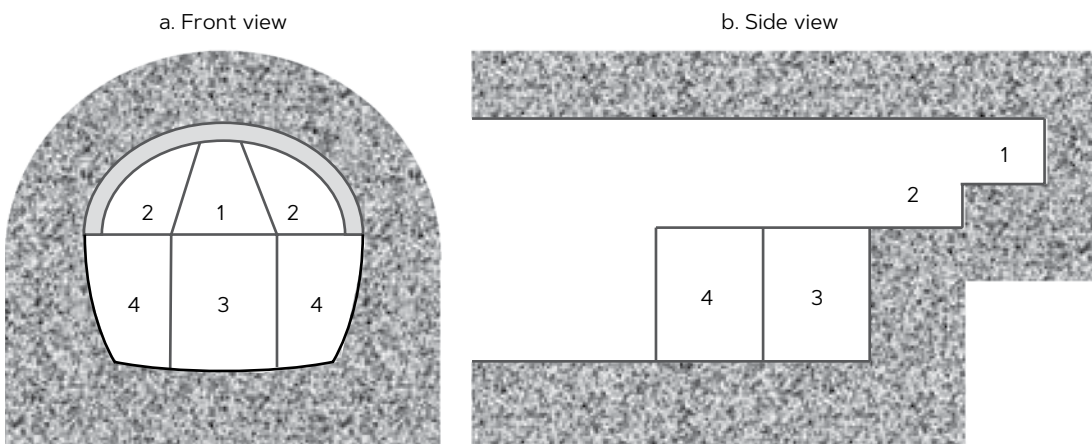
There are many traditional tunneling or excavation methods, including drill and blast, the Belgian method, the Madrid method, and the German method. Any of these can be viable methods for constructing underground segments of an

urban rail system, depending on the type of soil, construction schedule, and many other factors. This section focuses on two of these traditional tunneling methods—the Belgian method (often used for harder soils) and the German method (used for softer soils)—however, much of the implications for project cost and schedule may translate to other traditional tunneling methods not discussed in detail here.

The Belgian method of underground construction sequentially excavates and supports a horseshoe-shaped tunnel using traditional mining techniques and equipment. Generally, construction proceeds in drifts, where smaller cross sections of tunnel are excavated and then supported before the tunnel is widened and the excavation work continues. The Belgian method progresses with the following sequence of operations numbered according to figure 11.5:

1. Excavation begins from the construction of a top heading. The full rise of the arch is supported using steel lattice girders, wood timbers, or other supports.
2. The heading is then extended to each side and supported. This permits construction and lining of the upper part of the arch to stabilize the ground above the tunnel.
3. Once the arch is secured, the center of the tunnel is excavated and the sides are shored up with temporary supports.
4. Finally, the sides of the tunnel are excavated, the shoring is removed, and the tunnel wall masonry is put in place.

**FIGURE 11.5 Belgian Method of Traditional Tunnel Excavation**



*Note:* 1. Excavate the top heading; 2. Extend the heading to each side; 3. Excavate the tunnel center; 4. Excavate the sides of the tunnel.

Permanent supports are designed to enable the ground to support itself. The quick closing of the invert (the bottom portion of the tunnel) to create a load-bearing ring is important (especially for soft soils) and has the advantage of engaging the inherent strength of the ground surrounding the tunnel. Therefore, traditional tunneling techniques often rely on fairly uniform and stable soil conditions. The Belgian method is practical only in moderately firm or hard soils where rock loads are not too heavy; the Madrid method used to construct much of the Madrid Metro system modified the Belgian system for softer soils.

The German method is usually used when the soil along the walls of the excavated tunnel cannot support the load of the vault and the Belgian method is no longer viable. This is most often due to the great span of the vault or the quality of the soil. The German method is used most often to construct underground stations that require large caverns (see image 11.3). It is designed to reduce the open excavation section and to concrete the excavated area as quickly as

**IMAGE 11.3.** Construction of a Station Using the German Method along Metro Line 6: Madrid, Spain



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possible to minimize the time in which the support is loaded and consequently to control soil deformations. First, two galleries are excavated to create the lateral walls. Next, a keyed gallery is excavated and widened, concreting the overhead of the vault, which is well supported by the walls. Finally, the center of the section is excavated. Having three galleries instead of one can require more time and cost than the Belgian method, but it may be more suitable given the soil conditions and size of the excavated vault.

#### *New Austrian Tunneling Method*

The New Austrian Tunneling Method (NATM) is a sequential excavation method where tunnel construction is based on dynamic design informed by measured deformation of the ground. The NATM technique mobilizes the internal resistance tension of the soil to support itself; stability is obtained by redistributing tension. In order to achieve this, the tunnel is built in stages, consisting of excavation and immediate stabilization of walls. Many sequencing patterns are possible for NATM, depending on the soil conditions, final tunnel cross section, and other factors.

Excavation is performed using drill and blast or mechanical shovels, depending on the type of soil at the tunnel face. Immediately after the tunnel face advances, supports are installed to minimize ground loosening and excessive soil deformation. In NATM excavation, the level of support needed is based on the dimensions of the excavated section and the local ground characteristics, conserving the inherent strength of the surrounding soil as a main component of tunnel support. At minimum, support is also provided by sprayed concrete in combination with fiber or welded-wire fabric reinforcement, but in areas with abnormal movement, forepoles, rock bolts, and girders may be used to provide additional support. Once these supports are installed, concrete lining is cast in place over a waterproofing membrane.

Potential deformations of the excavation have to be monitored and modeled carefully. NATM requires the installation of sophisticated measurement instrumentation in lining, ground, and boreholes. In the event of observed movements, the advance of the excavation is slowed, the support design is increased, or other parameters are changed in response. This monitoring makes the method very flexible, even if teams encounter unexpected changes in the ground or rock conditions (such as crevices or pit water) not captured in the geotechnical baseline report or other prerequisite studies.

Due to its sequential nature, NATM is slow (advancing only about 2.5 to 3.0 meters per day), but it can be varied to address more efficiently the specific ground conditions being encountered along the segment. This sequential excavation technique provides flexibility in the alignment and may reduce



geotechnical risk. Determining the minimum support measures required based on monitoring measurements avoids economic waste that comes from needless overdesign of supports. Apart from the monitoring sensors and tension modeling software, the equipment required for implementing NATM is standard excavation machinery and, therefore, can be readily procured. Consequently, up-front equipment costs can be lower for this method than for TBMs, which can require long procurement and assembly periods. This construction method may work best for shorter underground segments as long as enough access points facilitate the delivery of materials and disposal of excavated material.

### *Tunnel Boring Machine*

A TBM is a machine used to excavate and build tunnels with a circular cross section. The use of a TBM can industrialize the process of excavation, reducing risk, time, and labor. However, the machines are sophisticated and require significant skill from the project-implementing agency in the management of construction sequence and from the construction contractor in the use of specialized teams for machine operations and logistics. The advantages and disadvantages of TBM construction should be considered carefully given the specific design of the project and local conditions.

TBM construction begins with the design and procurement of the actual machine. TBMs are designed with a fixed excavation diameter based on the internal diameter of the tunnel and the thickness of the concrete segments and other lining needed to support the tunnel walls (according to the geotechnical conditions and depth of the tunnel, among other characteristics). Therefore, TBMs often are designed and procured specifically for a given urban rail project. The production of these custom machines is expensive—on the order of €9 million for a 7-meter diameter (single-track) tunnel or €13 million for a 9-meter diameter (double-track) tunnel—and can require around one year to design and procure. The sequence of construction works and contracting arrangements between the project-implementing agency and the construction contractor should account for the time to procure and deploy the machine.

While the machine is being procured, a launching shaft is excavated so that the assembled machine can be placed in position at the start of the tunnel (see image 11.4). This assembly can take up to three months, during which time ancillary facilities such as power and water supply (which is substantial), storage and distribution of concrete segments, transport of excavated materials, and recycling of water used in construction are planned and constructed (see image 11.5). Based on the availability of land, the machine can be assembled at the launch

**IMAGE 11.4.** Tunnel Boring Machine Victoria Being Lowered into the Launch Shaft

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point or off-site. Once assembled, moving the machines is difficult and costly, so significant logistical planning is needed to acquire the land for entry and exit and to manage road closures and transport of the large machines to the launch shaft.

Once launched, the TBM excavates the tunnel and moves excavated soil on conveyor belts to the launch point or other retrieval shafts. Precast concrete segments are fed into the tail of the machine and erected to support excavated areas as the machine advances. The operation of a TBM is resource intensive, requiring a large support network of manpower to supply the machine with tunnel segments, power, and water and to clear away excavated material. Once the machine begins excavation, stopping it is costly, so careful preplanning of construction sequences is necessary.

The typology of the TBM varies depending on the characteristics of the soil being excavated and the corresponding level of support of the tunnel face needed (see table 11.1).

**IMAGE 11.5.** One of Crossrail’s Tunnel Boring Machines, with Back-End Supply of Power, Water, and Concrete Segments



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**TABLE 11.1.** Typology of TBMs Based on Soil Conditions and Corresponding Levels of Tunnel Face Support

FACE SUPPORT	SOIL CONDITIONS	TYPE OF TBM	TUNNEL LINING
None	Hard rock	Open type	Auxiliary equipment (anchors, shotcrete, steel girders)
Nonpressurized	Hard rock or stable soils with little water	Simple, single-shield	Precast concrete segments
		Double-shield	
Pressurized (active)	Soft soils, even with high water pressure and large amounts of groundwater	Slurry machine	Precast concrete segments
	Soft, fairly cohesive soils	EPB machine	

Note: EPB = earth pressure balance; TBM = tunnel boring machine.

For hard rock, TBMs use nonpressurized shields with disc cutters mounted on the head to create compressive stress fractures in the rock and to chip it away from the tunnel face. The excavated rock is then transferred through openings in the cutter head to a conveyor belt for removal from the tunnel. The choice of single- or double-shield TBM depends on the type of rock and the excavation speed required. Double-shield TBMs are normally used in unstable rock or where a high rate of advancement is required since the machines can simultaneously excavate and install concrete segments to line the tunnel behind the face. Single-shield TBMs, which are less expensive, are more suitable for hard rock and have to alternate between excavation and installation of concrete segments (Spencer et al. 2009).

In many urban environments, soft soils and the presence of key assets on the surface of the tunnel alignment necessitate the use of TBMs with positive or active face control to maintain the soil pressure during excavation. These TBMs maintain pressure in the machine chamber to balance the water and soil pressure ahead of the machine. For softer soils, active-face machines offer superior ground control to open-face methods. Two types of active-face machines are in use today: slurry machines using bentonite (sometimes called *hydroshield* or *mixshield*) and earth pressure balance (EPB) machines. Both slurry and EPB machines mix excavated material with additives, which can complicate the management of waste; excavated material is not readily reusable until it is treated to reduce moisture and additives from the soil.

In slurry machines, the excavated soil is mixed with bentonite slurry to create positive face pressure. The soil and slurry mixture is pumped to a plant located outside the tunnel that separates the slurry from the muck and recirculates the slurry to the face of the machine through the feed line. The treatment and recirculation of the slurry should be considered when designing the layout of the construction site since these facilities require significant space. This mixture and resulting pressure can be used for soils of varying hardness as long as the machine does not encounter large, hard rock faces.

For soft, fairly cohesive soils without significant water pressure, an alternative to the slurry TBM is the EPB machine. In EPB machines, soil is admitted into the TBM via the rotation of a screw conveyor arrangement that allows the pressure at the face of the TBM to remain balanced without the use of slurry. The muck is then removed by a conveyor belt.

Behind the face of any shielded or pressurized TBM sits a concrete segment erector, which lines the smooth-cut tunnel face with prefabricated concrete segments. Behind this, inside the finished part of the tunnel, sits the operator control rooms and trailing support system. Support systems can include conveyors or other systems for muck removal, slurry pipelines (if applicable), electricity,

dust removal, and ventilation, as well as mechanisms for transporting precast concrete segments. Careful strategizing of the logistics of material delivery to and from the TBM is essential for efficient and safe use of the machines. Once excavation is complete and the TBM has reached the retrieval shaft, it is disassembled and the parts are transported to a secure location. However, in some cases—as with two of the TBMs in Crossrail—it is safer or cheaper to leave parts of the TBMs in the ground rather than remove them (Dhillon 2014).

### *In-Situ Tunnel*

In areas that are less densely developed but are receiving urban rail infrastructure to support projected growth in urban activity and travel demand, a trench may be excavated and the concrete base, walls, and vault constructed in place (see image 11.6). Then the structure is waterproofed on the outside and the trench is filled, burying the tunnel structure underground. In an urban environment, the layout of an in-situ tunnel needs to run through the city's main streets in such a way as to minimize the impact of construction activities on the surface. More often, this method is used for regional or commuter rail services on the periphery of the city where larger areas of open land are available.

**IMAGE 11.6.** Construction of an In-Situ Tunnel on Line 12 Metro Sur: Madrid, Spain



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## Choosing the Appropriate Construction Method for Underground Segments

There is no single-best construction method for underground segments; each has distinct advantages and disadvantages and requires investment in preconstruction studies as well as active management and sequencing of construction works. The choice of which construction method(s) to adopt should take into account many factors, including, but not limited to, the project and construction budget (including both initial construction and capital costs as well as operation and maintenance costs of the system over the long term), scope, schedule, the technology and resources locally available, and the technical capacity of the project-implementing agency and the available pool of bidders (see table 11.2).

Additional factors that affect the feasibility of underground construction methods include the design of the tunnels (length, diameter, and depth underground) and conditions investigated by preconstruction studies—the (hydro) geological conditions along the alignment, the EHS and social impacts, and the building inventory and settlement management plan. Management considerations include the technical expertise and capacity of the project-implementing agency and any previous experience with underground construction in the host city and country. If technical capacity is lacking, the project-implementing agency should plan to build it in time for the construction of the civil works to commence.

For many urban rail lines with segments along different vertical and horizontal alignments, various construction methods can be combined in a project; however, this complexity entails many contractual and procurement challenges and may not make use of the economy of scale inherent in some of these construction methods (such as TBM) that prove more cost effective when used to construct a larger proportion of the project alignment. Nevertheless, tunnels often are excavated using TBM or other techniques, while box stations and the start of tunnels with a ramp to surface level are constructed using cut-and-cover. In most cases, rail yards are constructed on the service outside the urban core, and tracks from underground or elevated systems in the urban center are transitioned to at-grade to connect to these maintenance and storage yards. Therefore, project decision makers need to have a basic understanding of the implications and major requirements of all of the construction methods available for urban rail projects (even in cases where the final selection of construction method is left to the winning bidder).

**TABLE 11.2. Comparison of Different Construction Methods for Underground Segments**

CONSIDERATION	TBM	TRADITIONAL EXCAVATION METHODS AND NATM	CUT-AND-COVER	IN-SITU TUNNEL
Cost-competitiveness	High initial equipment cost; best for longer tunnels	Lower up-front equipment cost, but slow excavation speed; may be most cost effective for shorter tunnels (or those with diverse soil conditions)	Variable cost, depending on the depth and interference with existing supply networks	Fundamentally used for economy and safety; reduces uncertainties
Speed of excavation	~10–15 meters per day	<i>Belgian method and NATM:</i> ~2–3 meters per day <i>German method:</i> ~0.5 meters per day	Highly variable	~100 meters per month
Temporary land acquisition	Significant land needed for TBM support facilities	Limited to shafts, access, stations, and maintenance or storage areas	Land needed along the entire right-of-way	Land needed along the entire right-of-way
Utilities	Utilities diversion at shafts, access, and stations	Utilities diversion at shafts, access, and stations	Utilities diversion required along the whole length; highest need for detours	Utilities diversion required along the whole length; highest need for detours
Traffic management	Soil transport	Soil transport	Along the whole length (not necessarily at the same time) and soil transport	Exterior soil transport; interior huge traffic movement
Archeology	At shafts and access; at tunnel, less likely as it goes deeper	At shafts and access; at tunnel, less likely as it goes deeper	High risk	High risk
Environment	Soil disposal	Soil disposal	Soil disposal and barrier effect	Strong temporary impact; needs big trenches with huge soil disposal; eliminates ground treatments; better subsidence control
Alignment	Geometric limitation in the TBM radius	Very flexible in vertical and longitudinal alignment; very good for escalators, connections <i>German method:</i> particularly useful for large station vaults	Alignment linked to the surface public space available	More flexible because the construction is in open air; better for connection and special infrastructure

Note: NATM = New Austrian Tunneling Method; TBM = tunnel boring machine.

## Conclusions and Recommendations

The rapid urbanization of metropolitan regions around the world requires the implementation of high-capacity urban transport systems. Such capacity is fundamentally achieved with an exclusive right-of-way, allowing high frequency of large vehicles. This exclusive right-of-way can be constructed on the surface, but the increasingly high economic and social cost of urban land and disruption to existing surface activities have pushed cities to consider alternatives such as elevated or underground rail systems. Most new rail systems in dense urban areas are developed with elevated or underground segments. No matter the vertical alignment and construction method chosen, urban rail construction requires careful preconstruction planning and management of project implementation.

*Dedicating time and money to quality preliminary studies reduces risk during the construction period and provides crucial information for determining the appropriate construction method for the segment.* All urban rail projects benefit from up-front investment in studies to understand the geotechnical characteristics of the site; the EHS implications; the social impacts of the project; the availability of land; the location of utilities; and many other local conditions. Many of these local conditions will dictate the suitability of different construction methods and the sequence of those works. Although the level of detail of these studies will depend on the project design, procurement method, and other factors, investment in prerequisite studies is critical prior to construction. The more detailed the studies, the less risk and uncertainty there are in the project design and construction methodology used.

*Decisions made early in the planning and design processes can have large impacts on the time and cost of construction.* Many of the impacts of urban rail construction depend on decisions made during planning (chapter 4) and design of the project (chapters 5 and 6). Therefore, the construction method and sequence of works needed to implement the project have to be considered carefully as the project is being designed, because making changes after construction begins is much costlier. Many countries implementing their first urban rail line may not have experience with some of the complexities of urban rail construction. It is important that they find external support and build internal capacity for this planning and design prior to the start of construction.

*Communication with all relevant stakeholders during preconstruction planning and actual implementation is critical.* Even the best-managed urban rail construction disrupts urban activities and affects many stakeholders, including construction contractors, municipal councils, utility owners, other



transport system companies, existing business and building owners, and local residents. Urban rail projects are massive, requiring significant teamwork and collaboration. Therefore, it is important to communicate with all of the stakeholders involved and to engage the community in identifying possible impacts and mitigating both the short-term effects of construction and the long-term effects of operation.

**Construction offers an opportunity to build institutional knowledge and labor capacity and to engage communities.** Urban rail construction projects are massive and disruptive of urban activities. Although it is important to identify and mitigate negative impacts of construction, it is also important to think of ways to leverage these projects for value beyond the delivery of new transportation infrastructure for the city and neighborhood residents. Examples of additional value may be the upskilling of labor and retention of new technical expertise or the chance to rethink and redesign disrupted urban spaces—particularly around urban rail stations and beneath elevated alignments—for more livable communities with new commercial, recreational, and cultural areas.

## Notes

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1. Urban utilities and supply networks are often developed according to the layout of the road network. Therefore, reducing the need for land acquisition by planning the urban rail alignment along existing public road right-of-way may require additional time and cost for utilities protection and diversion.
2. Some high-risk buildings may need to be compensated and demolished and jobs or homes resettled. Any ground settlement mitigation plan should account for the social impacts of resettlement.

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12:34  
Arrival  
12:35  
Departure

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# 12

## INSTITUTIONAL SET-UP AND GOVERNANCE OF URBAN RAIL

Georges Darido and Joanna Moody

As urbanization creates metropolitan areas that encompass multiple municipalities, transport needs cross the boundaries of multiple, spatially linked municipal governments. Coordination of these needs requires an institutional approach that is regional in scope. When local travel extends across several municipalities, government authorities need to work together to implement a consistent, coordinated set of transport interventions. In addition, the need for some uniformity in standards and consistency in policies—such as the setting of fares and funding for transportation operations and improvements—calls for institutional coordination at the regional and national levels. Regional and national governments can also take advantage of economies of scale by coordinating and undertaking activities of interest to multiple cities, such as capacity building and research.

In addition to crossing jurisdictional boundaries, trips often involve multiple legs taken on different modes—for example, walking to the nearest bus stop, boarding a local bus, and then transferring to some form of rapid transit. With the involvement of multiple modes, integrated transport planning is critical to ensure seamless transfer among modes, minimize transfers, establish a common fare and payment structure, and provide actual origin-to-destination passenger information. Thus, no single mode can be considered in isolation;

*Photo:* Panama City Metro, 2018. *Source:* Malcolm K. via Flickr Commons (CC-BY-NC 2.0).

instead, each mode has to be examined as part of a “hierarchically integrated transport system” in coordination with other modes of urban transport (see chapter 2).

Institutional weaknesses are the source of many failures in urban transport. The ability of metropolitan areas to undertake comprehensive planning and decision making that is integrated spatially, sectorally, and hierarchically is too often constrained by the highly fragmented governance structures of urban transport (Gwilliam 2002). Typically, several agencies, often at different levels of government, are involved in various aspects of urban transport. At the same time, comprehensive thinking that connects transportation to other key land use and economic development strategies is required (see chapter 3). Given this complexity, institutional coordination and leadership across space and functions are critical to developing an integrated and comprehensive approach to addressing urban transport problems.

Recognizing these problems, a growing body of literature presents successful examples of metropolitan transportation authorities or similar entities that can coordinate multimodal transportation systems across municipal boundaries in conjunction with other aspects of the development agenda of growing urban regions (Gwilliam 2002; Heanue and Salzberg 2011; Kumar and Agarwal 2013). This chapter briefly discusses good practice for institutional structure and governance of a multimodal, integrated transportation system at the metropolitan region level before focusing on how such an authority can set up and empower specific institutions to implement and operate urban rail projects within this broader transportation system.

Within a well-integrated, multimodal transportation system, urban rail can provide high-capacity, high-quality service and also contribute to economic growth and a high quality of life. Urban rail systems are the outcomes of megaprojects, and their success requires robust institutions during implementation and throughout the system’s operational life. This chapter summarizes the functions and characteristics of these institutions and other considerations for decision makers as urban rail is being planned, designed, implemented, and operated.

### **Transportation Governance for the Metropolitan Region**

Urban rail systems do not work in isolation; instead, they provide the greatest benefit to the metropolitan region when integrated (in terms of physical infrastructure, operational planning and service, and fares) into a multimodal transportation system (see chapter 2). Such a multimodal, hierarchically integrated transportation system in a metropolitan region involves a multiplicity of

dimensions—modes of travel and their associated level of service, land use, environment, health, technology, finance and economics, politics, human behavior, and demographics (such as age and gender). All of these dimensions are interconnected and need to be assessed, planned, and managed in a comprehensive and holistic manner. As a result, such systems require coordination among institutions with different authorities and interests. This institutional coordination is key to effective integration of the system that unlocks the most benefits from urban rail and other transportation services.

In most cases, a metropolitan transportation authority or other regional body is needed to coordinate the mobility and land use strategy for the city (Rebelo 1998). Such an authority is responsible for the economic efficiency, regional accessibility, and sustainability of the entire transportation system in the long term through master planning, allocation of financial resources among government jurisdictions, promotion of modal integration, and appropriate encouragement of private sector participation (Rebelo 1998). Such a metropolitan transportation authority is best equipped to decide whether or not to pursue an urban rail solution (see chapter 3) and to create the institutional structures and funding and financial mechanisms needed to carry out such an investment (see the later sections of this chapter).

Box 12.1 outlines the key principles to consider when creating or reforming regional transportation institutions (for other great resources dedicated to metropolitan region transportation institutions, see Gwilliam 2002; Heanue and Salzberg 2011; Kumar and Agarwal 2013).

#### **BOX 12.1.**

### **Principles for Institutional Development and Coordination of Regional Transportation**

No single institutional blueprint for urban transport is appropriate for all countries. Nevertheless, there is enough experience of the difficulties arising from the failure to align policies between jurisdictions and agencies—or to secure collaboration between them—to establish some general principles for reducing governance and institutional impediments to effective transport policy and service integration.

#### **For functional capability and human resource development**

- Municipal or metropolitan transport agencies should establish an administrative structure within which responsibility for all necessary technical functions in urban transport are identified and allocated clearly (see chapter 4).

*(box continues next page)*

**BOX 12.1.****Principles for Institutional Development and Coordination of Regional Transportation** *(Continued)*

- Central governments should develop a training strategy for professional and technical skills in urban transport.
- Scarce professional skills should initially be concentrated and retained by adequate remuneration in either public sector units or private sector consultant organizations.
- Collaboration between authorities should be encouraged both nationally, to share available skills, and internationally, to develop skills and experience.

**For jurisdictional coordination**

- Allocation of responsibility among levels of government should be established clearly by law.
- Intergovernmental transfers should be planned carefully to be consistent with the allocation of responsibility.
- Formal institutional arrangements should be made for collaboration where multiple municipalities exist within a continuous conurbation.
- Central government should encourage coordination at the metropolitan level.
- Obligations statutorily imposed on local authorities should be linked to specific channels of finance (such as direct-line agency funding of reduced-fare or free public transport).

**For functional coordination**

- Detailed planning, of both transport and land use, should be aligned with a strategic

land use and transport plan at the municipal or metropolitan level (see chapter 3).

- Functions should be allocated clearly among agencies, with the public sector at the higher level in metropolitan areas retaining more strategic functions.
- Traffic police should be trained in traffic management and safety administration and should be involved collaboratively in transport and safety policy planning.
- Responsibility for traffic safety should be allocated explicitly, with institutional responsibility at the highest level of the local administration (mayor's office or its equivalent).

**For effective involvement of the private sector**

- Planning and operating responsibility for public transport should be institutionally separated so that operations can be fully commercialized or privatized.
- Technical regulation should be separated from procurement and economic regulation.
- The development of new competitive private suppliers of service should be encouraged through legal recognition of associations and so on.
- A clear legal framework should be established for competition in public transport supply, either in the market or for the market.
- The public sector should develop professional service procurement and contract enforcement skills.



## Institutional Framework for Urban Rail Implementation and Operations

At least three distinct institutional roles are involved in the governance of an urban rail project or system—the authority, the project-implementing or management agency, and the operator (see table 12.1). When public funds are involved, the authority (or project owner, as described in chapter 8) is a public entity or representative of government with the ultimate decision-making responsibility over strategic policy decisions, sector plans and regulations, and funding and administration of contracts. The project-implementing agency is responsible for making technical decisions and for executing contracts for planning, design, construction, and operation and maintenance (O&M) of a line or system with oversight by the authority. The operator, whether a public or a private entity, has direct contact with the project, customers, assets, and the business of service delivery, with oversight by the project-implementing agency and the authority. The operator’s role is central to achieving a successful urban rail system, but it comes into being and exists within a regulatory environment set by the authority and implemented by the relevant agency.

### The Authority

The authority or owner of the urban rail system is a public entity (or more often a collection of public entities at all levels of government) with the following strategic functions:

- Approve the long-range urban transport strategy and policies and decide when and where to develop urban rail projects as part of the urban transport strategy (see chapter 3)

**TABLE 12.1. Three Institutions and Their Primary Roles in the Governance of an Urban Rail System**

INSTITUTION	ROLE
Authority	<ul style="list-style-type: none"> <li>• Urban mobility and land use strategy; long-range planning</li> <li>• Funding and fare policy</li> <li>• Multimodal integration</li> </ul>
Implementing or managing agency	<ul style="list-style-type: none"> <li>• Planning, supervision, and coordination of project implementation</li> <li>• Coordination of project stakeholders</li> </ul>
Operator	<ul style="list-style-type: none"> <li>• Day-to-day operations and maintenance</li> <li>• Service planning</li> </ul>

- Select the procurement strategy and project delivery model (see chapter 8) and delegate responsibilities to the project-implementing agency and operators through contracts for works, goods, or services to plan, design, implement, operate, or maintain the urban rail project or system; in this capacity, bid out tactical or operational functions to private companies, but exercise great care in doing so (see chapter 9)
- Secure funding or financing for the urban rail projects and systems (see chapter 10)
- Ultimately hold the project risks that cannot be transferred to other parties, such as any unknown risks not discovered through studies or investigations (see chapter 7)
- Ensure that the project-implementing agency and operator(s) have sufficient experience, capacity, and resources to carry out the planning, design, construction, operations, and maintenance of a project or system; in particular, implement the policies and regulations to enable the project-implementing agency and operator(s) to carry out their designated functions.

The authority may have a mandate beyond urban rail, such as multiple modes or transport systems, or may represent multiple entities or jurisdictions, such as a metropolitan area with several municipalities. A project involving multiple jurisdictions or levels of government may also have multiple owners and other stakeholders. In such cases, good practice recommends setting up a governing board with representative ownership of all entities and jurisdictions (see the example of the Washington Metropolitan Area Transit Authority described in table 12.5 later in this chapter).

The authority may initially be one or more existing offices of the national, state, or local government with newly hired or “borrowed” specialized staff who are dedicated to the goals of the project or system. As a project advances to construction and operations, good practice suggests creating a special office or department of government dedicated to urban rail. A board of directors should represent all owners and other stakeholders. Board members should have appropriate professional profiles to oversee the project-implementing agency and operators (see the example of Transport for London in table 12.5).

The authority oversees the project-implementing agency and operator(s) and may delegate functions to one or more such entities. The authority requires the support of capable staff, usually relying on the technical and administrative capacity of the project-implementing agency. However, in cases of weak or

nascent institutional structures or privatized management functions, the authority should obtain the direct support of specialized advisers—usually external experts hired as consultants—to ensure project management oversight, safety, security, and other overarching goals. Even when using technical and supervisory consultants to support internal capacity, the decision-making and oversight responsibilities should remain with the authority.

### **The Project-Implementing or Managing Agency**

The project-implementing agency is one or more public entities with technical and administrative responsibility over contracts for planning, design, construction, operations, and maintenance of an urban rail line or system. The project-implementing agency's role typically includes the following functions:

- Carry out the studies, preliminary design, and technical analyses necessary for the authority to decide to develop an urban rail project (see chapter 3)
- Establish the project management plan, technical specifications, level of service, level of quality, safety and security standards, schedules, and budgets for projects and systems (see chapters 4 and 5)
- Supervise contracts for the design, construction, operations, and maintenance of the urban rail project
- Coordinate with all project stakeholders and cofinanciers (if any) to ensure that all legal, technical, and financial requirements are addressed; for example, implement all social and environmental safeguards (see chapters 14 and 15) required by international development institutions
- Manage or conduct the processes for acquiring land, obtaining permits, relocating utilities, and resolving any public obligations to advance the project design or construction (see chapter 11)<sup>1</sup>

The project-implementing agency can be a subsidiary of the authority with a delegated mission, but it needs to be empowered to make technical decisions in the name of the authority. When no project-implementing agency exists, good practice suggests creating a special project implementation unit (PIU) by hiring or borrowing competent staff from all relevant agencies or departments of government for the special purpose of implementing an urban rail project.

When there are multiple independent operators, a special management agency may be needed to regulate these contracts and to ensure a well-integrated and coordinated system. In such cases, this management agency

should be independent from undue political interference and have a stable funding source and governance structure, in addition to the technical and administrative capacities to perform the role of regulator.

### **The Operator**

The operator is one or more entities, public or private, that operate the urban rail assets and deliver services to customers. A public operator may be a subsidiary of a public agency if there is good reason to monopolize operations; otherwise the project-implementing agency may award operations contracts to private operators through open and competitive bidding processes. The operators may exist in an environment of regulated competition for service contracts or may have exclusive rights to operate lines or areas of a system. The authority makes the key decision of how many and what types of operators to have in a system, while the project-implementing agency carries out this decision and related policies through direct oversight of the operator and its performance. The operator's role typically includes the following functions:

- Provide advice during the planning and technical design of an urban rail project to ensure operational efficiency and sustainability
- Perform O&M, including short-term service planning and asset management (see chapter 13)

The final two sections of this chapter focus on the organizational structure and enabling environment of the urban rail operator. The first of these sections presents a spectrum of organizational structures for public and private urban rail operators and discusses some of the key trade-offs with regard to operational efficiency, level of government connectivity and control, and equitable distribution of service. The second provides clear guidance on how to empower an urban rail operator by establishing clear roles and responsibilities, providing a stable and secure source of financing, and creating a governance framework that provides autonomy and accountability. Although some of the discussion in this chapter may be most useful for urban rail developments in cities without existing systems, the recommendations in this final section are applicable to both existing and new urban rail institutions.

### **Success Factors in Setting Up Urban Rail Institutions**

Given the size and complexity of urban rail projects, authorities may see their development as an opportunity to restructure existing institutions with regard

to their roles and responsibilities, funding structures, or governance. Otherwise, existing institutions are the natural choice for project implementation (see chapter 4) and operations (see chapter 13). The decisions become more complex for cities undertaking urban rail projects for the first time. Most of this section is dedicated to these cases; however, any city with existing urban rail institutions can benefit from the key lessons synthesized throughout the chapter.

### **Assessing the Institutional Framework Early and Thoroughly**

The institutional framework surrounding the implementation and operation of urban rail projects can be a critical enabler or constraint in the effective and efficient delivery of infrastructure and service. The decisions regarding who should oversee or manage the implementation (including planning, design, and construction) and the operations (including maintenance) of an urban rail system are not trivial and have to be made early in the project development process to allow institutions to be structured to carry out their assigned functions. These decisions will depend first on whether there is an existing urban rail system within the city and its legacy institutional framework. If no rail system exists, then the institutional structure for an authority, project-implementing agency, and operator must be set up.

The first step in determining the institutional framework is to review the functions of existing institutions by asking: Is there an existing authority or project-implementing agency with responsibility over urban rail? Is there management capacity within these existing government entities to develop and implement a project? Who are the providers of public transport services within the city, and is there a relationship with these government entities? In cities with an existing urban rail system, do current institution(s) need to be restructured to plan, design, build, and operate the project properly?

### **Focus on Project Structuring**

When considering the first urban rail project in a city, forming a PIU early to manage the preparation and implementation of the project is recommended. In some cases, this PIU may itself become the project-implementing agency and even the system operator (as in Quito, Ecuador) or may simply serve in an advisory role when reviewing the existing institutional frameworks and setting up the new entity(s) to implement and operate the urban rail system. If internal technical capacity is not available within the host city, this PIU should seek the input of external expertise (see box 12.2).

As the authority plans the urban rail project, this PIU has to decide early which entity will manage implementation of the new urban rail line through

**BOX 12.2.****Seeking External Expertise Early When Setting Up a New Urban Rail Project—Implementing Agency: Bogotá, Colombia**

As Bogotá considered developing its first urban rail line, the City Council decided to create a new institution—the Metro Company of Bogotá—in 2016 to develop the project. Recognizing the limits of its own expertise in urban rail, the newly elected mayoral administration of Bogotá requested World Bank support to outline the functions and organizational structure of this new

institution. Government officials in Bogotá shared the draft legislation creating the new urban rail governance structure with knowledgeable external experts who provided valuable international experience and lessons learned about institutional mandates, organizational structure, staffing, involvement of private participation, and outsourcing.

construction and, once built, which entity will operate the system. The key decisions at this stage are whether the system will be implemented and operated by a single entity or by two separate entities and how to structure them.

**Transitioning from Project Development to System Operation**

International examples of urban rail entities performing the roles of both a project-implementing agency and operator include São Paulo, Brazil; Santiago, Chile; and Washington, DC. In such cases, experience has shown that the transition from system development to operations can be difficult given the different functions and capacities needed for each role (see box 12.3). Therefore, incentives and governance structures need to be developed along with programmatic improvement initiatives to help project-implementing agencies to transition from construction-focused organizations into customer-facing, service-delivery-focused operators.

Even when separate entities are implementing and operating the project, the transition from project implementation to operations is often difficult. Deciding who will be the future operator early in the process and providing clear channels of communication between them and the project-implementing agency can help to prepare for this transition.

Some project-implementing agencies focus only on developing the project and overlook the importance of operations. The authority needs to ensure that a capable operator will be in place by the time the system opens and that it will have access to the required expertise in the first few years of operation (see box 12.4).

**BOX 12.3.****The Transition from a Construction-Focused Organization to an Operator: Washington, DC, United States**

The Washington Metropolitan Area Transit Authority (WMATA) was founded in 1967 to implement a 103-mile urban rail system in Washington, DC. Construction of the system was phased from 1976 through 2001. Given this long construction period, WMATA's management and financial structures were set up with a focus on project implementation rather than operations. This focus on capital construction is considered a reason for the system's failure to prioritize needed maintenance and renewals. Lack of adequate maintenance resulted in the loss of state of good repair and significant service disruption beyond those seen in other systems of a similar age that more readily adopted a culture focused on long-term operation and maintenance (O&M) (see image B12.3.1). Attempts have been made to shift the organizational culture toward operations, including an institutional restructuring in 2007–08. However, this transition is not fully complete and may be contributing to WMATA's ongoing operational challenges.

**IMAGE B12.3.1. Passengers Stranded as Train Is Held at Station for over an Hour due to Maintenance Delays: Washington, DC**



Source: Karen Rustad Tölva via Flickr Commons (CC-BY 2.0).

Source: Adapted from World Bank and RTSC 2017.

**Embedding Operational Knowledge in the Authority and Agency**

Within the governing authority, a lack of understanding of the complexities of urban rail systems and what makes operations successful can lead to unintended consequences that impair any operator's ability to meet (the often rising) expectations of urban rail service. Embedding technocratic, rail-specific knowledge within the authority—including regulators—will improve the likelihood that the authority and operator will achieve shared ownership and accountability for policy goals. For urban rail systems being implemented and operated by different institutions, bringing operational knowledge into the planning (chapter 4), design (chapter 5), and construction management

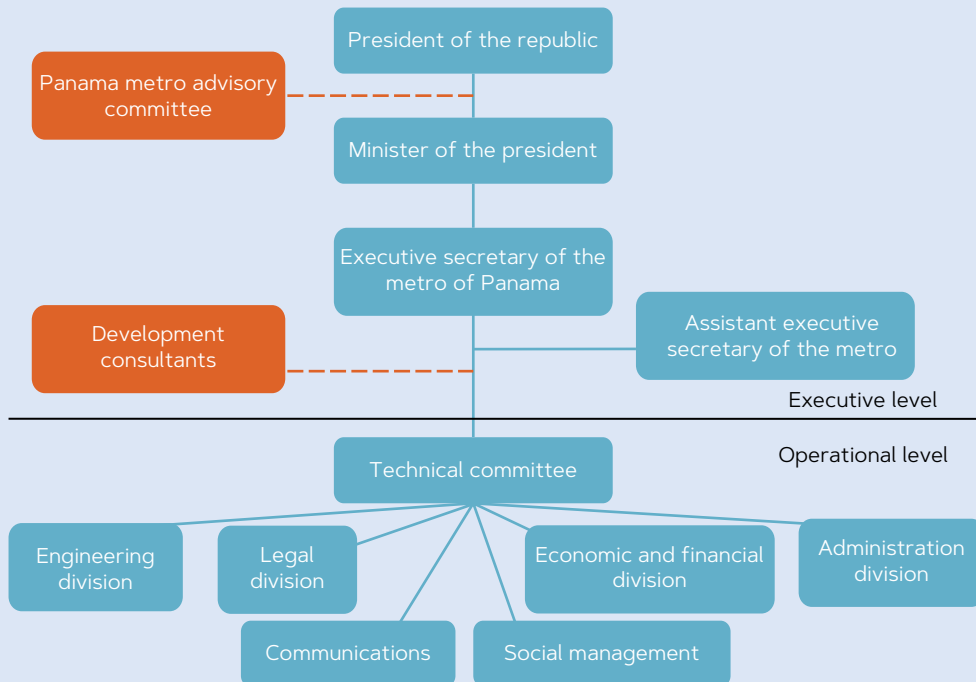
**BOX 12.4.**

**Example of a Public Entity Functioning as Both the Project-Implementing Agency and Operator, with Help from External Experts: The Metro Company of Panama**

The Metro Company of Panama is a public entity created as an urban rail project-implementing agency, which transitioned to functioning as an operator (see figure B12.4.1). Recognizing the need to incorporate operational knowledge into project implementation

prior to the completion of civil works, the Metro Company of Panama entered into a technical assistance agreement with an experienced operator for capacity building and support during the initial stages of operation.

**FIGURE B12.4.1. Organizational Structure of the Design and Construction of Metro Line 1 under the Secretary of the President of the Republic: Panama, 2011**



Source: Adapted from Pulido and Portabales 2014.



(chapter 11) teams of the project-implementing agency is critical for achieving a system that has both operational sustainability and longevity.

### **The Importance of Technical and Political Leadership**

International experience shows that high-level technical and political leadership is critical for urban rail megaprojects to be implemented and operated successfully. This leadership usually takes the form of one or more persons of high credibility and influence within the institution stepping up as “champions” of the project. These champions help to sustain project momentum and offer support throughout the complex processes of project implementation involving multiple public entities, stakeholders, and public opinions. An urban rail project needs both a political champion at higher levels of government and a technical champion.

The authority should always have a political champion who is the credible public face of the urban rail project or system, especially during controversies and debates. The political champion may be a high-level government civil servant or elected official who serves, for example, as the chair of the governing board of the authority or project-implementing agency. The political champion needs to have the support of a strong communications and public relations team.

The project-implementing agency and operator should be led by experienced, full-time technical champions—sometimes referred to as the project director (during project planning or implementation) or general manager (during operations). This champion is an individual with the mandate and credibility to make administrative decisions and overcome technical obstacles to advancing a project or system. This technical champion has to manage multiple contracts and relationships not only with the authority but also with cofinanciers and other government agencies with oversight or regulatory power over the project or system, such as a government accountability office and agencies in charge of environmental, cultural, and social protections.

### **Encouraging Institutional Adaptability**

For cities without an existing urban rail system, the project-implementing agency and operator often have to be established “from scratch,” either as a new institution or as a new functional division within an existing institution. While the introduction of these new institutions provides an opportunity for implementing best practices learned from other urban rail agencies and operators around the world, it can also be extremely disruptive to previously existing institutions. These new institutions may take on some responsibilities for which no other institution was previously responsible, but they are also likely to be given oversight over functions previously handled by existing regional and local government institutions as well as other public transport

operators within the city. For cities with urban rail systems that are being reorganized or expanded, existing institutions are restructured, reformed, or even eliminated to allow responsibilities to shift to the new operator.

For either new or reorganized urban rail institutions, the evolution can be difficult and time consuming. It may take several years before institutions can stabilize and perform a meaningful role (Kumar and Agarwal 2013). The challenge lies not only in establishing these institutions, but also in ensuring that the operator, in particular, has the enabling environment, autonomy, and technical capacity to become a respected and effective organization. It is important to maintain flexibility in approach and adaptability in institutional design to allow for adjustments, while avoiding compromising long-term objectives. The ideal performance of an institution may not result at the time of establishment, so patience is needed for expectations and possibilities to align adequately.

### Spectrum of Organizational Structures for Urban Rail Operators

Urban rail systems throughout the world employ a variety of organizational structures for their operations. Having already discussed the various roles and responsibilities of the authority, project-implementing agency, and operator, this section provides additional detail on the various organizational structures that can be used for the system operator. These organizational structures exist along a spectrum from public sector operators existing as an agency or unit within government to full concession of operations to a private company, with variations such as public corporations and partial privatization in between (see figure 12.1).

This section defines each of the organizational structures along this spectrum, discusses their relative advantages and disadvantages, and provides examples of existing urban rail operators for each structure. These examples illustrate how, anywhere along the spectrum, there can be significant variation in the authority and functions shared among different jurisdictions and agencies of the public sector and any private partners. Recognizing that variations do exist in reality, this discussion highlights some of the major trade-offs of these different organizational structures with regard to accountability to the public need; equitable distribution of service; coordination of operations with long-term,

**FIGURE 12.1. Spectrum of Organizational Structures for Urban Rail Operators**



intermodal urban transport strategy; operational flexibility and efficiency; and rate of innovation.

No single institutional structure works best for all cases. Instead, a prudent consideration of the existing institutional environment and capacities and a review of existing regulation and legislation are needed to decide on the appropriate organizational structure for a city's urban rail operator.

### **Public Operator**

In public ownership models, the planning, financing, implementation, and O&M of the urban rail system are all under the authority of the government, held accountable to the public good. Historically, most urban rail systems have developed under a public ownership model in which operations are carried out by an agency within national-, state-, or city-level government. Examples of public operators at different levels of government still exist among urban rail systems.

For some urban rail systems (usually in smaller countries), the public operator may be part of the national government. Such a model of public operations at the national level has one main advantage: clear accountability. A single general manager (or executive director) has responsibility for all facets of the system and reports only to the highest level of regulatory and policy-making authority (Wilson 1991). For example, Panama City's urban rail was designed and constructed and is now operated by a national governmental unit at the level of secretary under the president (Pulido and Portabales 2014) (see figure B12.4.1). For a large metropolitan area in a federalized country, such a centralized public operator may be set up under the state or other subnational government. One such example is the urban rail operator in São Paulo, Brazil—Companhia do Metropolitano de São Paulo (Metrô São Paulo)—which is a government agency under the state's Secretary of Metropolitan Transportation.

Unlike their more centralized counterparts, public operators under city governments may be more directly accountable to the needs of local users (Kumar and Agarwal 2013). However, public operators at the city level may have jurisdictions limited to municipal boundaries that do not encompass the regional or metropolitan nature of many trips. Among urban rail operators at the city level, examples include the Moscow Metro (operated directly by Moscow's city government) and Tokyo Metropolitan Bureau of Transportation (known as TOEI), one of two metro operators in Tokyo, Japan.

With the rise of metropolitan transport authorities to integrate and develop public transport at a regional level (between the traditional jurisdictions of the municipality and the state), other public operators have been set up under these authorities (see box 12.5). Urban rail operators under the metropolitan transport authority often have the advantage of being able to coordinate among the

**BOX 12.5.****Example of Public Urban Rail Operations under a Metropolitan Transport Authority: Strathclyde Partnership for Transport, Glasgow, Scotland**

Strathclyde Partnership for Transport (SPT), formed in 2006, is the largest of Scotland's seven regional transport partnerships (a form of metropolitan transport authority). SPT's jurisdiction comprises 12 council areas in the west of Scotland: East Ayrshire, East Dunbartonshire, East Renfrewshire, Glasgow City, Inverclyde, North Ayrshire, North Lanarkshire, Renfrewshire, South Ayrshire, South Lanarkshire, West Dunbartonshire, and the Helensburgh and Lomond areas of Argyll and Bute. SPT is responsible for planning and delivering transport solutions for all modes of transport across the region. SPT develops a regional transport strategy and plans investment in infrastructure for public transport as well as streets for private vehicles, cyclists, and pedestrians (SPT 2017). SPT also operates and maintains the Glasgow Subway and provides some subsidized bus service, while

overseeing integrated fare collection and revenue distribution among other providers of bus transport (see image B12.5.1).

The regional partnership forming SPT consists of 20 elected members representing the constituent 12 council areas. Additional members (usually seven to nine) are appointed based on their technical knowledge in areas such as urban planning, rail operations, administration, financing, and law. These members then hire technocratic senior leadership to oversee the administration of SPT's functions.

Other notable examples of urban rail operations set up under a metropolitan transport authority include the London Underground (as a subsidiary of Transport for London), Metro de Madrid, and New York City Transit (under the Metropolitan Transportation Authority).

**IMAGE B12.5.1. Intermodal Transfers at West Street Station: Glasgow Metro, 2011**

Source: Greg Neate (CC-BY 2.0).

boundaries of multiple municipalities and among the different modes of public transport, enabling them to cater to the needs of users who travel throughout a greater metropolitan region. Therefore, if a metropolitan transport authority exists within the host city, it is a natural choice for public operation of the urban rail system.

No matter whether the public operator is set up as part of a national, state, or municipal government or under a metropolitan transport authority, some potential advantages and disadvantages are common to all public operators (see table 12.2). Many of these advantages derive from the fact that operators set up as public agencies clearly operate the system as a public utility, keeping the broader public goals of social inclusion and economic development at the heart of any operations decisions. Many of their disadvantages derive from the potential for an unclear definition of roles and responsibilities in a complex government bureaucracy, a lack of incentives to respond to market needs due to “monopolistic tendencies and bureaucratic ossification” (van de Velde 1999, 147), and the politicization of day-to-day operations.

**TABLE 12.2. Potential Advantages and Disadvantages of Public Urban Rail Operators**

POTENTIAL ADVANTAGES	POTENTIAL DISADVANTAGES
<ul style="list-style-type: none"> <li>• Since all functions are carried out by the public sector, there is less risk of conflict between policy and operations. Even unprofitable routes that have a social value are more likely to be served.</li> <li>• Coordination between different departments or different services can be streamlined because all stakeholders are within the public sector. This is especially true when it comes to coordinating rail service with other forms of public (and private) transportation within the city.</li> <li>• May facilitate a cohesive image for the rail system, which may translate into greater awareness and higher ridership.</li> </ul>	<ul style="list-style-type: none"> <li>• In new systems developed in cities with little or no previous urban rail experience, it may be difficult for a public operator to mobilize the expertise and resources needed without early planning and an adequate budget.</li> <li>• Due to the absence of public transport competition and insufficient interaction between political decision makers and end users, the public operator may pay little attention to the needs of passengers; consequently, users may perceive the operator as being remote and unresponsive.</li> <li>• There may be little or no incentive for management to be concerned with increasing efficiency or productivity because of a lack of commercial objective as long as adequate funding is available (Wilson 1991).</li> <li>• Public operator may see little reason to attempt innovation and actively resist proposals for change.</li> <li>• A low level of managerial autonomy from political interests as well as lengthy and inflexible decision-making processes may contribute to operational inefficiencies in publicly owned urban rail systems (Jain, Cullinane, and Cullinane 2008; Wilson 1991).</li> <li>• Public sector procurement and labor regulations impose constraints.</li> </ul>

Even without changing the basic public ownership model, various initiatives can improve the public operator's function, particularly with respect to efficiency. For example, legislative intervention could provide more autonomy to urban rail management, or changes in top management personnel could initiate greater innovation and responsiveness to users' needs (Wilson 1991). However, in some cases, internal reform within the organization may not be enough, and reorganization may be necessary. The introduction of public corporations could help the operator by establishing a stronger commercial objective and providing some separation between the operator and political interference.

### Public Corporations

Public corporations are "statutory bodies into which the government transfers its authority to operate and govern specified public services, but these corporations adhere to prudent commercial principles" (Jain, Cullinane, and Cullinane 2008, 1240). Public corporations are companies with government at the national, state, or city level maintaining full ownership of company equity (see table 12.3 for examples). In most cases, these corporations are set up under special legislation, offering a mix of the clout that comes with legal and political

**TABLE 12.3. Examples of Urban Rail Operators Set Up as Public Corporations and Their Equity Holders**

URBAN RAIL SYSTEM	OPERATOR	PUBLIC EQUITY HOLDERS
Beijing, China	Beijing Mass Transit Railway Operation Corporation Limited	Wholly owned by the Beijing municipal government
Delhi, India	Delhi Metro Rail Corporation	Joint equity ownership by the national Ministry of Urban Development and the Municipal Corporation of Delhi
Guangzhou	Guangzhou Metro Corporation	Wholly owned by the Guangzhou municipal government
Santiago, Chile	La Empresa de Transporte de Pasajeros Metro S.A.	Wholly owned by the national government: <ul style="list-style-type: none"> <li>• 62.57% by the Corporación de Fomento de la Producción, a subsidiary under the Ministry of Economy, Development, and Tourism</li> <li>• 37.25% by the Chilean Treasury</li> </ul>
Seoul, Korea, Rep. of	Seoul Metro	Wholly owned by the Seoul metropolitan government
Tokyo, Japan	Tokyo Metro Company Limited	Joint equity ownership by the Tokyo metropolitan government and Japan's Ministry of Land, Infrastructure, Transport, and Tourism

backing of the public sector and the flexibility of quicker decision-making typical of a commercial entity. A board of directors consisting of elected officials or political appointees often governs public corporations. This governing board is established to protect the interests of government shareholders and to provide checks and balances against the commercially minded executive management empowered to run the company.

Legal clauses can protect corporatized authorities from some of the political interference more common in publicly owned institutions (Kumar and Agarwal 2013). For example, public corporations may not be as constrained by government procedures or by the limits of government salary scales in hiring professional staff. This may enable organizational decision makers to act more quickly to innovate and respond to changing societal needs. Corporatized urban rail operators have been found to be more efficient than public operators (Jain, Cullinane, and Cullinane 2008).

### **Partial Privatization**

Partial privatization is a unique case of privatizing merely a part of a state-owned or corporatized railway company. In this institutional structure, a publicly owned railway operator sells part of its ownership on the stock market through initial public offerings, usually with the government maintaining control of a majority of shares (Jain, Cullinane, and Cullinane 2008). In this way, the operator is accountable to private sector shareholders and is encouraged to function with a profit motive, but it is still accountable to the strategic vision of the public sector. Partial privatization differs from corporatization in that the partially privatized operator is often less constrained by public procurement and labor laws. The partially privatized operator also can have additional flexibility to pursue private sector and innovative financing and to leverage ancillary sources of revenue. There are very few recorded cases of partial privatization of an urban rail system, with the most often cited example being the Mass Transit Railway Corporation (MTRC) Limited in Hong Kong SAR, China (see box 12.6).

### **Private Operator**

In the past two decades, there has been an increasing interest in private sector participation in the development and operation of urban rail transit systems. The case for private sector participation rests on arguments that the private sector not only provides alternative avenues for financing and developing transport infrastructure projects, it also can promote efficiency in construction, management, operations, and use of technology that may be difficult to match in the public sector (Jain, Cullinane, and Cullinane 2008). Chapters 8 and 9 of this handbook discuss how to consider and structure private participation in the

**BOX 12.6.****Example of a Partially Privatized Urban Rail Operator: MTRC Limited in Hong Kong SAR, China**

In 1975, the government of Hong Kong SAR, China, established the Mass Transit Railway Corporation (MTRC) as a government-owned statutory corporation to build and operate the city's public transport system. One of the most profitable public transport systems in the world, MTRC's operating surplus helped it to launch a successful initial public offering. In 2000, the MTRC was partially privatized and succeeded by the MTRC

Limited, which was listed on the Hong Kong Stock Exchange with the government still the majority stakeholder. In addition to public transport operations of urban rail and bus, MTRC Limited is a major local property developer and landlord. It also invests in railways in different parts of the world and has contracts to operate transit systems in Beijing, Hangzhou, London, Melbourne, Shenzhen, Stockholm, and Sydney.

procurement and delivery of urban rail projects. This section focuses on the potential advantages and disadvantages of involving a private company as an operator (through concession of service provision and sometimes maintenance of infrastructure).

Despite the global trend toward increasing private sector participation in urban rail project development, previous experience of private sector participation in the O&M of urban rail systems is mixed. The balance of advantages and disadvantages of these institutional arrangements depends largely on the details of the contract between the private operator and public sector, but some generalizations are possible (see table 12.4). For example, it is possible that neither the authority nor the private operator is given clear responsibility over a function such as short- and medium-term operational planning and that the function is not addressed; conversely, it is possible that wasteful duplication of efforts may result in conflict if both agencies feel that they have responsibility over a function (Wilson 1991). Accountability within the institutional structure becomes less clear, and it may be harder to coordinate the urban rail lines effectively with the greater public transport system. Therefore, within the public-private contract, roles have to be defined carefully and incentives have to be structured so that the private operator has the room to innovate with operational efficiencies and respond to market forces but is still accountable to the long-term transportation vision for the city and region. Having a private sector operator does not mean that this entity can determine service levels in isolation, even if defined in a contract. A public authority is always present to oversee the



**TABLE 12.4. Potential Advantages and Disadvantages of a Private Urban Rail Operator**

POTENTIAL ADVANTAGES	POTENTIAL DISADVANTAGES
<ul style="list-style-type: none"> <li>• Clear contractual and legal instruments regulate the relation between the authority (government) and the operator, including a service agreement.</li> <li>• Private operator may respond better to market forces and may show improved efficiency due to commercial motivations (Jain, Cullinane, and Cullinane 2008).</li> <li>• Private operator may be better able to leverage opportunities for nonfare revenue, including commercial development and leasing of stations and advertisements.</li> <li>• Private operator may have lower operating costs and more flexibility (not limited by public procurement and labor regulations).</li> </ul>	<ul style="list-style-type: none"> <li>• If the public sector authority does not fulfill its oversight role and produce plans and policies that help to shape the private operator toward the “common good,” a private operator may fail to provide a system that is accessible to all (for example, may fail to deliver services to unprofitable routes or may charge fares that price out certain individuals).</li> <li>• For multiple private operators under separate contracts, it may be difficult to integrate and coordinate their operations with the greater public transport system.</li> <li>• In existing systems, incorporating a private operator for the management of a new line may be inefficient.</li> </ul>

urban rail system as part of a multimodal, hierarchically integrated transport system.

There is the potential for problems in creating complex contracts with private operators and in providing effective oversight and monitoring of these contracts, especially in countries that are still developing their technical and managerial capability. Private participation should never be considered a replacement for internal capacity; the public sector has to understand the details of urban rail project delivery and operations to structure properly a concession contract that produces value for public money. An authority, the project-implementing agency, or an operator cannot efficiently outsource any aspect of urban rail-related works and services that it does not understand (World Bank and RTSC 2017). Therefore, authorities that pursue public-private partnership (PPP) arrangements need to develop and retain the internal competence required to plan, execute, and manage outsourcing arrangements (see box 12.7).

As an alternative to private operators, there are smaller-scale ways to involve the private sector in urban rail operations that are under a public or other institutional structure. Many public operators design contracts with the private sector outsourcing those activities that can be commoditized and easily provided by multiple suppliers or service providers (such as cleaning, call centers, and operational functions where the labor force flexibility of the private sector offers significant cost advantages). These types of contracts, rather than full concession agreements, take advantage of where the private sector can leverage its greatest efficiencies through competition and more nimble labor and procurement practices.

**BOX 12.7.****Example of a Private Urban Rail Operator: ViaQuatro in São Paulo, Brazil**

ViaQuatro is the concessionaire responsible for operating and maintaining Line 4 of Metrô São Paulo. The project encompasses 11 stations and a total extension of 14.3 kilometers of underground track. The operation contract with ViaQuatro was the first public-private partnership (PPP) agreement in the country.

The PPP agreement between the state of São Paulo and the concessionaire took effect in November 2006, allowing ViaQuatro to operate and maintain Metro Line 4 for 30 years. To complement significant public funds contributed by the state of São Paulo, ViaQuatro has invested US\$450 million in systems, equipment, and trains. Over the 30 years of operation, it will invest more than US\$2 billion in the Metro line. ViaQuatro started operations in October 2011. Currently, Line 4 provides safe and efficient mobility to approximately 700,000 passengers per day, and more than 90 percent of users are satisfied with the service.

A key determinant for the success of private sector operators is how they are incentivized through the structure of the PPP arrangement and contractual allocation of certain risks (see chapters 7 and 9). In the case of ViaQuatro, the PPP contract includes:

- *Demand risk sharing.* For the demand risk to be shared between the state and

concessionaire, the public partner agreed (contractually) to reorganize bus routes so as to eliminate competition from other modes. Furthermore, the public partner agreed to guarantee 10–40 percent of the projected demand, ensuring that demand risk is shared according to the observed volume of passengers.

- *Revenue sharing and fare integration.* The concessionaire receives 100 percent of the fare revenue for those passengers who exclusively use Line 4, while it only receives 50 percent of the fare revenue for passengers who use Line 4 and any other line in the system. This provides economic incentives for the concessionaire to provide high-quality service and implement service improvements to increase demand on Line 4.
- *Key performance indicators.* The operation contract set levels of service that the concessionaire is obligated to meet regarding (1) train frequency, (2) average trip times during peak hours, (3) fulfillment of the supply of trains originally programmed, (4) number of accidents, (5) user accidents and number of offenses committed by users, (6) number of complaints or claims from users, (7) nontravel time spent in the station, and (8) user satisfaction levels.

## Empowering the Operator

Whether public, private, or something in between, the operator's role is central to achieving a successful urban rail system. Experience from existing urban rail operators suggests that success depends less on the operator's public or private affiliation and more on the enabling environment in place around the operator and the management of performance (World Bank and RTSC 2017).

No matter the institutional form of the operator, the project cannot succeed without a supportive enabling environment, which the authority is responsible for putting in place. Legal, regulatory, and financial structures set by the authority can either hamper or support an operator's control over its operating environment. In particular, the authority and project-implementing agencies can enable an existing or new operator in three key ways:

1. Establish clear and binding roles, responsibilities, and performance objectives for the operator.
2. Provide financial sustainability through stable, multiyear subsidy arrangements, appropriate fare policy, and the operator's ability to generate and spend nonfare revenue.
3. Create an effective governance framework that provides the autonomy to undertake business-oriented management practices, run by technocratic leaders supported by adequate technical staffing.

In giving the operator greater resources, flexibility, autonomy, or financial independence, the authority may ask for greater accountability for achieving performance targets. Therefore, empowering the operator to manage short-term operations as well as mid-term service planning and asset renewal is better for the authority, the longevity of the urban rail system, and the experience of its riders.

### **Clear Responsibilities and Performance Objectives**

No matter the operator's organizational structure, its roles and responsibilities—and the coordination of these functions with other institutions (particularly the authority)—have to be stipulated through legal (if not contractual) instruments. The operator should be established with clear objectives for service delivery and an understanding of the major risks it is required to manage. Service delivery targets, performance indicators, fares, costs, remunerations, and other details should be specified in some form of service agreement. Furthermore, the operator has to have the legal authority to carry out its assigned functions.

Historically, public operators have lacked this clarity of responsibilities and objectives because they exist as subsidiaries within transportation departments at the national, state, or local level. However, among public operators, roles and relations can be specified through various mechanisms, including shared political consensus and vision or more formal charters and other quasi-contractual documents within a regulatory framework (see box 12.8).

While public operators directly under the national, state, or local government have often lacked clarity regarding their roles and functions, they are traditionally

**BOX 12.8.****Mechanisms for Establishing Clear Responsibilities and Performance Objectives among Operators****Shared political consensus and vision:  
Kuala Lumpur, Malaysia**

In Malaysia, the national government's Vision 2020 policy proposes a target of 40 percent public transport mode share in Kuala Lumpur by 2030 (from a baseline of approximately 21 percent in 2011). The operator in the city has also adopted this target. The shared target encourages both the authority and the operator to make decisions with the aim of achieving this goal and has created a common political consensus (World Bank and RTSC 2017). Although it is better than no alignment of incentives, this type of agreement may be vulnerable to the pressures of political economy and changes in political administration or operator management and lacks a formal enforcement mechanism should incentives become misaligned.

**Compact (or charter): Washington, DC,  
United States**

The Washington Metropolitan Area Transit Authority (WMATA) is a multijurisdictional government agency that operates public transport services in the greater Washington, DC, metropolitan area. WMATA was created by an interstate compact—enabling legislation that set out the purpose and function of the agency, organizational structure and area of jurisdiction, and roles and responsibilities for public transport planning, financing, budgeting, use of revenue and borrowing powers, labor policy, and so forth. This compact was ratified by the legislative bodies of each of its four members: the state of Virginia, the state of Maryland, the U.S. federal government, and the District of Columbia.

more likely to have the backing of high-level functionaries within the government and to comply with policies and regulations passed by the authority. As an alternative organizational structure, corporatized public operators created under special legislation tend to offer the clout of legal and political backing that comes with being in the public sector, but they also can be protected by legal clauses from some of the political interference and confusion of roles that are more common in publicly owned operators. These factors can lend the public corporation the flexibility of quicker decision making typical of a commercial entity.

With private operators, relationships and performance objectives are clearly defined in a contract, which ends up being a much stronger instrument than the quasi-contractual instruments used to regulate the relationships between the government and most public operators. The structure of this contract is often a key determinant of the balance of advantages and disadvantages of having a private operator. Therefore, legal expertise is needed to help to define the roles of the public and private sectors and to

put in place the proper incentives for service quality and efficiency (see chapter 9). Urban rail authorities and their operators can learn from both successes and setbacks in the structuring of these contracts; even for public operators, many of the same incentives and service performance targets defined in PPP contracts could be used to create transparent accountability between the roles of the authority and those of the operator through quasi-contractual agreements.

Appropriate laws that clearly define roles and objectives are necessary, but not sufficient to ensure effective operations, especially in the case of newly established urban rail operators (Kumar and Agarwal 2013). To be effective, urban rail operators also require stable and adequate resources, including secure funding and technocratic, autonomous leadership supported by competent technical professionals.

### **Financial Sustainability**

No urban rail system has demonstrated full financial independence; taken together, initial capital, operating, and asset renewal costs even in the densest cities require some form of subsidy. When initial capital costs are excluded, some urban rail systems can sustainably recover sufficient funds to meet operating costs (that is, the sum of operations, maintenance, and administration costs) as well as some long-term renewal and enhancement costs (World Bank and RTSC 2017). However, half of urban rail systems cannot cover their own annual operating costs, needing some form of subsidy for operation costs and additional funding to support ongoing renewal and enhancement of assets (World Bank and RTSC 2017).

Therefore, the success of an urban rail system is often determined by the extent to which its long-term funding strategy can enable the operator to make investments at the right time such that service quality expectations are met. International experience has challenged the use of debt financing that would derive security for repayment solely from the urban rail system's immediate operating cash flows (World Bank and RTSC 2017). Urban rail cash flows are subject to uncertainty due to changes in political economy and the complexity of urban rail assets. There are only three credible ways to fund an urban rail system's recurring costs (both operating and capital):

- Fares paid by passengers
- Nonfare revenues from commercial activities, advertising, and land development
- Subsidy payments by government on behalf of taxpayers (see chapter 10)

For an operator to carry out its functions successfully, it has to receive money from the public sector and be empowered to collect revenue from operations and commercial functions (see chapter 13).

An urban rail system is a capital investment project that never stops; constant reinvestment to renew and enhance infrastructure is necessary to ensure the service and quality demanded by the public. These capital investment programs span multiple years; a single, annual funding cycle rarely is adequate to fund major programs, particularly when this cycle includes both operating subsidy and capital funding. Any urban rail operator needs stable, multiyear guarantees of subsidy for operations and capital improvement. This stability of funding provides “economies of planning” (World Bank and RTSC 2017). Multiyear funding arrangements allow for smoother and more predictable execution of capital programs and operations by providing certainty over sources of cash and reducing volatility in supply chains for longer-term projects. An annualized funding regime with separate budgets for operations and renewals hinders the operator from developing a whole-life or long-term view of asset management and service provision, as exemplified in Washington, DC (see box 12.9).

### **An Effective Governance Framework with Autonomy**

A governance framework provides the set of processes and decision-making responsibilities that are critical to develop and operate the urban rail system effectively and efficiently. An effective governance framework is required to

#### **BOX 12.9.**

#### **The Negative Consequences of Annualized Funding: Washington, DC, United States**

The experience of the Washington Metropolitan Area Transit Authority (WMATA) highlights the impact of having an operator that is reliant on annualized funding. Despite having one of the highest farebox recovery ratios in the United States, WMATA has no stable, multi-year source of funding. WMATA’s operating subsidy (approximately 27 percent of operating costs) and capital renewal funding are reliant on annual negotiation between four funding jurisdictions: the District of Columbia, Maryland, Virginia, and the U.S. federal government. The necessity of asking for

funding annually leaves the operator vulnerable to wider financial pressures, threatens current levels of service, and makes it difficult to plan major, value-creating infrastructure and service enhancements. As a result, critical long-term measures needed to secure WMATA’s operations and growth by investing in asset renewal and preventive maintenance have not been delivered. This has created multiple safety and operational impacts on customers. WMATA is constantly “catching up” with accrued investment needs rather than delivering new value on its network.

ensure that the operator acts responsibly and transparently in the interests of the authority, while allowing the operator to control critical aspects of its own operating environment (see box 12.10).

Any urban rail governance structure should be accompanied by regular audits. Both internal and independent auditing are means to evaluate the effectiveness of an urban rail operator's internal controls. Maintaining an effective system of internal controls is vital for achieving the urban rail operator's business objectives, obtaining reliable financial reporting on its operations, preventing fraud and misappropriation of its assets, and minimizing its cost

#### BOX 12.10.

### The Impact of Varying Levels of Control over the Operating Environment: London, United Kingdom versus São Paulo, Brazil

London and São Paulo are both effective operators in terms of service performance indicators, despite having very different degrees of control over their own operating environment. London's recent achievements are a story of government-supported success, while São Paulo's story is one of operational excellence in the face of substantial constraints with unintended consequences. London Underground,

as a subsidiary of Transport for London (the metropolitan regional transportation authority), has substantial control over all factors that affect its success, while Metrô São Paulo has control over very little (see table B12.10.1). Although some of these differences are external to an urban rail system and its city, much is subject to the influence and control of its respective authority.

**TABLE B12.10.1. Control over Different Factors in the Urban Rail Operating Environment**

FACTOR	LONDON	SÃO PAULO
Clear objective and allocation of risk	No contract, but consensus	No contract, some consensus
Predictable funding	Yes, with some future uncertainty	Insecure
Control over revenue	Yes, with mayor's support	Only for nonfare revenue
Ability to define or implement corporate strategy	Yes	No
Ability to recruit or reduce staff	Yes	No
Influence over major projects	Yes	Modernization only (subject to financing)
Control over procurement processes	Yes	No

Source: Adapted from World Bank and RTSC 2017.

of capital. An effective governance framework and associated audits achieve benefits for both the authority and the operator (World Bank and RTSC 2017) by means of the following:

- Enabling central government decision makers and funders to hold the authority accountable for planning and rule making
- Enabling the authority to hold the operator accountable through scrutiny of proposals, regulation, and, where applicable, rigorous administration of a contract
- Helping to protect the operator from political decisions that have long-term operational and financial impacts
- Establishing lines of communication between the operator and the authority

#### *Technocratic Leadership*

Effective management depends, to a significant extent, on the operator's autonomy—its capacity to appoint senior staff with a technocratic outlook, set staff terms and conditions, make important decisions without external approval, introduce new business practices, change the service provided, integrate the service with other providers, control costs, and change tariffs (World Bank and RTSC 2017). The authority is instrumental in setting up a leadership model (often a board of directors) with the broad technical expertise necessary to administer, finance, operate, maintain, and expand an urban rail system (such as the case in London, see table 12.5). A dedicated and committed chief executive with the decision-making authority and political drive to innovate is also necessary to guide the urban rail operator to success, in either the public or the private sector.

#### *Appropriate Staffing*

The technocratic leadership of any urban rail operator has to be supported by appropriate levels of technical staffing. Urban rail operations require staff with specialized knowledge of operations, asset management and maintenance, capital programming and infrastructure project management (for network expansions), financing, administration, and others (see figure 12.2).

Giving the operator the autonomy to make staffing decisions is critical, but it may not be enough; finding adequate staff may be difficult because the number of professionals specializing in urban rail passenger transport remains relatively small in most low- and middle-income countries (Kumar and Agarwal 2013). Furthermore, the subject is so complex that the wide range of skills required for comprehensive planning typically results from years of experience. Therefore, it may be necessary to establish programs that provide training and skill



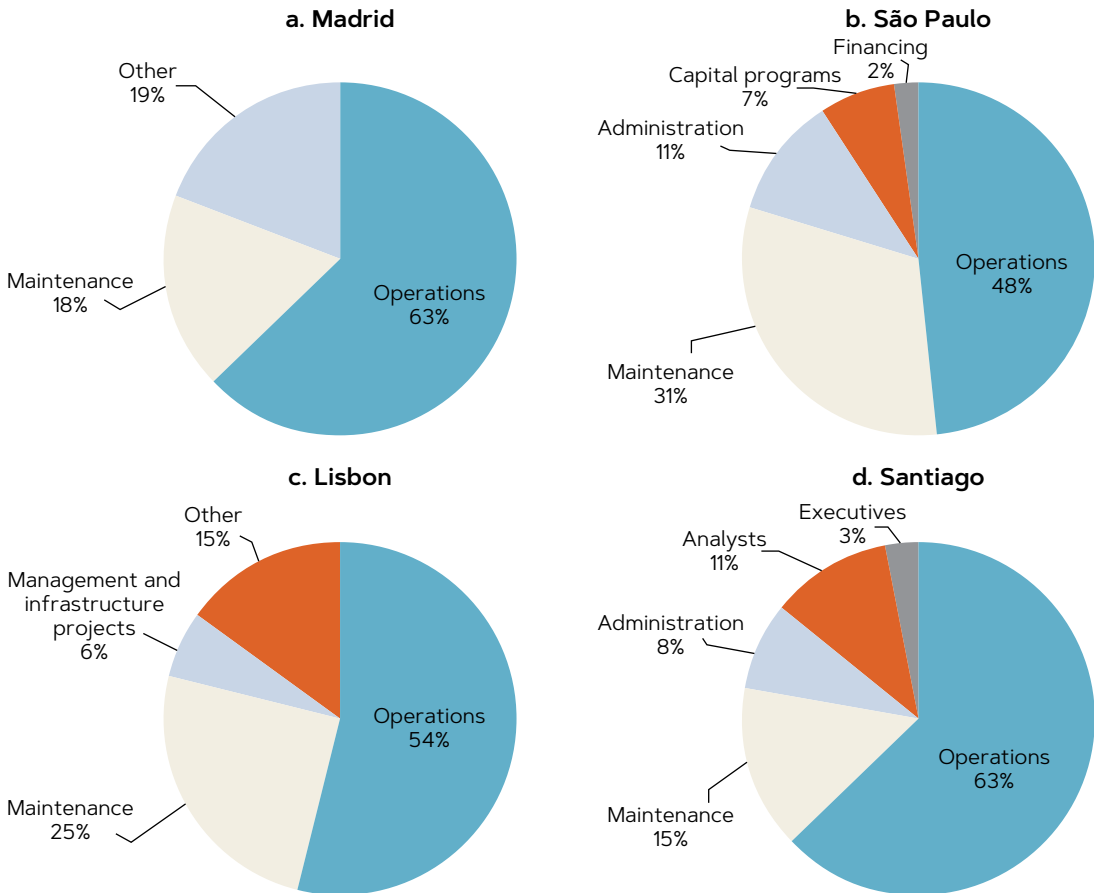
**TABLE 12.5. Implications of Board Composition on the Viability of the Operator: Comparing London, United Kingdom and Washington, DC, United States**

INDICATOR	LONDON	WASHINGTON, DC
Board composition	<p>Transport for London, a regional transportation authority that oversees all modes within the public transport network, is governed by a 15-member board chaired by London’s mayor, who appoints other members on the basis of their technical expertise. Members of the board include experts in finance, property development, accessibility, logistics, labor, and rail or public transport operations:</p> <ul style="list-style-type: none"> <li>• Former managing director of rail operating company</li> <li>• Former chief executive officer of national rail infrastructure authority</li> <li>• Former chair of London’s passenger advocacy group</li> <li>• Former general secretary of a major trade union</li> </ul> <p>Board members are appointed for two four-year terms that coincide with the four-year term of the mayor of London.</p>	<p>The Washington Metropolitan Area Transit Authority is governed by a board of directors with two sitting members (and two alternate members) from each of the four political jurisdictions covered by its service area. All eight members are politically appointed in pairs by</p> <ul style="list-style-type: none"> <li>• The Council of the District of Columbia</li> <li>• The Washington Suburban Transit Commission (Maryland)</li> <li>• The Northern Virginia Transportation Commission</li> <li>• Administrator of General Services (federal government)</li> </ul> <p>Of the two members appointed by the federal government, at least one must be a regular public transport user in the area.</p>
Implications	<ul style="list-style-type: none"> <li>• Technocratic decision making based on experience and technical knowledge</li> <li>• Cross-sectoral views</li> <li>• Long-term holistic outlook on decisions</li> <li>• Decision making based in the urban rail system’s best interest</li> <li>• Board of directors with low turnover</li> </ul>	<ul style="list-style-type: none"> <li>• Little technical or technocratic input, with no qualification for persons with urban rail-related knowledge to sit on the board</li> <li>• Decision making based on political interests, fostering short-termism</li> <li>• Board of political representatives with high turnover</li> </ul>

Source: World Bank and RTSC 2017; TfL, n.d.; WMATA n.d.

enhancement of existing staff, hire from the market, and expose new hires to a wider range of skills than in their academic background. These programs might include the launching of appropriately designed master’s degree-level programs to create a pool of potential workers, knowledge-sharing workshops by external consultants and experts, and apprenticeship and internship programs within the operator to provide hands-on experience (see chapter 4). In addition to human resource development strategies, operators should also be able to invest in systems and facilities that help to maintain and refresh institutional knowledge.

**FIGURE 12.2. Percentage of Staff Dedicated to Different Technical Areas, Including Urban Rail Operations, Fiscal Year 2014**



Source: Adapted from Pulido and Portabales 2014.

### Conclusions and Recommendations

*Establish a transportation authority to coordinate strategic functions, prioritize metropolitan investments, and promote multimodal integration to maximize regional accessibility and the long-term sustainability of the transportation system.* Urban rail systems provide their greatest benefit when they are planned as part of an integrated mobility and land use strategy and fully integrated into a multimodal transportation system

(see chapters 2 and 3). Such a strategic view requires coordination across different levels, jurisdictions, and sectors of government as well as the private sector. A metropolitan transportation authority or other regional body often is created to provide this coordination. Such an authority is responsible for the long-term economic efficiency, regional accessibility, and long-term sustainability of the entire transportation system and should be empowered to undertake master planning, prioritize investments, promote modal integration, and enable appropriate private sector participation. Only after such an institution has decided to adopt an urban rail solution should it consider the governance and institutional structure of the project's implementation and operation.

*Political economy considerations pervade all megaprojects, which often involve multiple levels and sectors of government, complex institutional frameworks, and various stakeholder groups; therefore, urban rail projects need technical and political "champions" to sustain project momentum and support.* Technical and political leadership within a robust institutional framework are key to overcoming implementation and operational challenges. To be implemented and operated successfully, megaprojects often need to have a visible "champion"—one or more persons of high credibility and influence within the institution who can manage complex processes involving multiple agencies and stakeholders. Other success factors for urban rail institutions include the following:

- Assessing the institutional framework early and thoroughly
- Focusing on project structuring and the transition from project development to system management
- Embedding operational knowledge in the authority and its agencies
- Encouraging institutional adaptability

*The authority should define institutional roles for urban rail implementation and management by establishing or delegating to an agency (or agencies) with the appropriate leadership, capacity, and financial sustainability.* The public authority needs to decide early enough what entities will manage implementation of the new urban rail lines through design, construction, and operations. If considering the first urban rail project in a given city, it is recommended to establish a public agency to manage implementation and to consider carefully the options for operations. If the internal technical capacity is not available to make these decisions, the authority should seek the input of external experts.

***Carefully plan for the transition from construction to operations, whether within a single institution or between different entities.*** No matter whether urban rail systems are being implemented and operated by public or private entities, international experience has shown that the transition from construction to revenue service can be difficult. For transitions within the same public entity, incentives and governance structures need to be developed to help management to transition from a construction focus to a customer-facing and service-delivery focus. For transitions between a project-implementing agency and separate or private operators, operational expertise is still needed during the design and construction of the infrastructure to minimize risks and facilitate sustainable operations.

***There is no “best” organizational structure for urban rail operations, so the authority or responsible agency should consider carefully the existing institutional frameworks and relative advantages and disadvantages of each structure.*** Each organizational structure for urban rail operations presents trade-offs among accountability to the public need, equitable distribution of service, coordination of operations with long-term, intermodal urban transport strategy, operational flexibility and efficiency, and rate of innovation. Therefore, careful consideration of the existing institutional environment and capacities and a review of existing regulation and legislation are needed to decide on the most appropriate option along the spectrum from fully public to fully private operations. Public authorities and agencies should consider outsourcing or privatizing essential functions with great care because they need to retain a level of competence and technical capacity to oversee project design, implementation, and long-term operation and maintenance of a system.

***Urban rail operators need to be empowered through clear objectives and contracts under an effective governance framework to perform their functions and to improve assets and services.*** The most successful urban rail operators, whether public or private entities, are supported by stable regulatory frameworks and government policies. Operators need strong external political and legal support, financial capacity, and required manpower and management structure to live up to their mandate and prove themselves able to deliver public value.

No matter the institutional structure of the operator, the authority can help to ensure their success through the following:

- Establishing clear and binding roles, responsibilities, and performance objectives for the operator

- Providing financial sustainability through stable, multiyear funding or subsidy arrangements, an appropriate fare policy that updates annually, and the operator's ability to generate and spend nonfare revenue
- Creating regulatory and governance structures that encourage customer-oriented and sustainable management practices.

## Notes

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1. In exceptional cases, such as vertically integrated PPPs, some of these operational functions may be outsourced to a private concessionaire with the project-implementing agency acting as the administrator of these contracts (see chapter 9). Even if it is possible to outsource some functions, the project-implementing agency needs to have the technical and managerial capacity to manage and negotiate these agreements.

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# 13

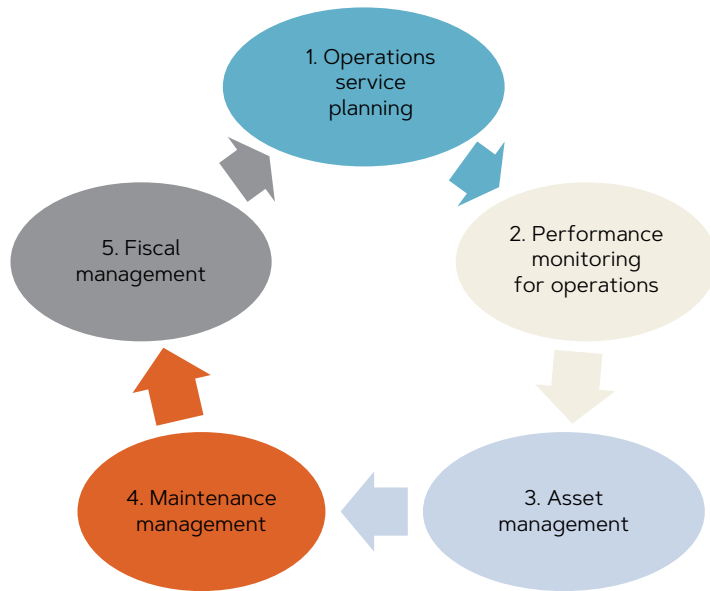
## ENSURING OPERATIONAL AND FINANCIAL SUSTAINABILITY

Georges Darido, Joanna Moody, and Wenyu Jia

The sustainable operation of an urban rail system is complex and requires a different set of tools and capabilities than those needed to deliver the initial system infrastructure. Urban rail systems require the delivery of service on a daily basis concurrent with ongoing capital projects to maintain, renew, and upgrade the system. Furthermore, urban rail systems are operated in coordination with feeder modes and in compliance with fare policy set for the metropolitan region (see chapter 2). The regulation and oversight of such multimodal service and fare integration are the responsibility of government authorities, while operation and maintenance (O&M) planning and management are the responsibility of the rail operator (see chapter 12). This chapter focuses on the O&M responsibilities of the urban rail operator, discussing five key pillars of sustainable urban rail operations (see figure 13.1):

1. Operations service planning
2. Performance monitoring for operations
3. Asset management
4. Maintenance management, and
5. Fiscal management

*Photo:* Track work as part of the Myrtle Viaduct Reconstruction on the M Line, New York City, 2018. *Source:* Marc A. Hermann, Metropolitan Transportation Authority via Flickr Commons (CC BY 2.0).

**FIGURE 13.1. Sustainable Cycle of Urban Rail Operations**

Much of the operating capabilities of the system are dictated by the system design (see chapter 5). Therefore, it is critical to have the input of a “shadow operator” from the earliest steps of project development. Once the infrastructure is delivered, operation of an urban rail system requires a technical and strategic approach to O&M in coordination with financial matters. Financial sustainability balances O&M costs with revenues gained from fares, ancillary businesses, and external subsidies. While chapter 10 of this handbook discusses sources of funding, financing, and revenues for urban rail projects—with a focus on covering and guaranteeing capital expenditures and start-up costs—this chapter considers how these revenue sources and policies should be revised throughout the life of the urban rail system as operating environments change. Much of the information presented in this chapter is applicable to both new (greenfield) and existing (brownfield) urban rail systems, addressing ways to sustain their operations and finances, while providing quality service for all.

### Operations Service Planning

An operating service plan establishes the framework for rail service levels and fleet requirements. Near-term operating plans establish targets to ensure that

the urban rail operator provides adequate service and fleet supply to meet passenger demand. These near-term plans should be complemented by longer-term targets (such as the share of all trips in the metropolitan region made by rail) for milestone years that account for fleet growth and infrastructure improvements to meet and encourage future demand. When undertaking service planning, it is critical to recognize that demand is elastic with respect to the supply of services. Therefore, service plans should meet existing demand and provide a quality of service that fosters ridership growth.

Service delivery is constrained by the system's maximum capacity. This maximum capacity is determined by many factors, including the signaling and infrastructure design of the urban rail system. Automated train control systems can allow trains to operate on short headways and safeguard spacing between consecutive trains on a line (see chapter 5). However, even when signaling is state of the art, other constraints related to track infrastructure, station capacity, and train design can limit maximum capacity. Among infrastructure components, crossovers, junctions, and track geometry directly affect operating speeds and running times. For example, at junctions where multiple lines merge, trains have to slow down to allow safe distance for merging, thereby increasing running times.

Operations planning for an urban rail system takes into account the infrastructure constraints, train control systems, train and rail car capacity, station capacity, hours of service, passenger demand, and equity. The key output of short-term service planning is the schedule of trains, including their frequency and spacing and the coordination of transfers among multiple lines in the network. Short-term operations service planning often takes the following into account:

- *Headways.* Headway is a measure of the distance or time between vehicles operating in a transit system. While the minimum headway is constrained by the design of the infrastructure (see chapter 5), the system should be designed to allow headways that meet the regional accessibility goals of the system (see chapter 2). The urban rail operator sets headways in conjunction with the providers of other transit services in the region to meet the performance standards and level of service dictated by government authorities (see chapter 12). Working within these constraints and with the goal being to provide the best service for its users, each urban rail operator develops its own headway policies by accounting for additional operating factors, such as passenger loads, train composition, dwell times, terminal turnaround, and combined headways at locations where multiple lines share tracks.
- *Running time.* The running time for each train is defined as the total scheduled train time from end to end, inclusive of dwell times at stations and layovers at terminals. Running times vary by time of day and passenger loads.

The layover time is the recovery time for trains and operators to turn around the service. Layover times are affected by terminal designs and operations practices. For example, a front crossover allows quick repositioning of a train for service as it pulls into the assigned terminal platform before finishing the previous trip. A back crossover adds layover time as the train has to move to the crossover before returning to the platform for the next trip. Operating strategies also play a major role in managing the layover time; a dispatching supervisor or an automated system at grade of automation (GoA) 4 can shorten turnaround times and better manage headways.

- *Revenue vehicle requirement.* The revenue vehicle requirement comprises two elements: scheduled revenue trains on a line and gap trains. Gap trains are strategically positioned in the rail network to absorb additional rush hour demand (usually during the morning and afternoon peaks) and, in some cases, to restore service quickly when disruptions occur. The revenue vehicle requirement is expressed both in trains and in rail cars, especially when the urban rail system deploys different types of cars.
- *Operating spare ratio.* Some rail cars are set aside as reserves in the event of unexpected breakdowns of revenue cars, scheduling for special events, emergency maneuvers, or other irregular service patterns. The spare ratio goes from as low as 10 percent for a mostly new fleet to above 20 percent for an older fleet; the rule of thumb is 15 percent.
- *Scheduling and service delivery.* Urban rail operators develop schedules based on the operating plan. Scheduling and staffing of trains is a complex process that stipulates locations and times of train pull-outs and pull-ins, applies efficiency measures, and ensures compliance with labor rules and other regulatory requirements.

When designing service levels and performance targets, regulatory authorities and urban rail operators should consider equitable service levels for all rail corridors and communities. In any urban region, some rail corridors have highly concentrated economic activities, while other corridors serve socially or economically disadvantaged communities in need of rail access (although perhaps at lower demand) (see chapter 2).

### **Special or Occasional Service Planning**

In addition to the regular schedules that deliver high-frequency, high-capacity rail service, some systems may modify service levels and schedules when demand is different from typical weekdays and weekends, such as during holidays or for special events (for example, sporting events and political gatherings). Systems often have different schedules and configurations of cars for these times,

either to match lower demand during holidays or to meet the surge before and after special events. This practice is commonly referred to as “special service” and should be designed to match passenger demand with the expected service supply. Any changes in regular service should be decided in advance so that appropriate internal staffing and other arrangements can be made and so that service levels can be incorporated into passenger information systems and communicated to the public.

### Staffing and Crew Scheduling

Once the rolling stock is allocated to the existing infrastructure, it is necessary to schedule the crew to operate all of the planned service. Staffing by appropriately qualified personnel is an important aspect of service planning that is affected by local labor laws and availability of skills within the local workforce. New advances in signaling and automation technology can allow systems to consider unattended train operations, allowing the crew to be multifunctional, performing both operational and customer-facing duties (see box 13.1). In addition

#### BOX 13.1.

### Use of Multifunctional Staff to Improve Operations: Barcelona and Guangzhou

#### Transport Metropolitans de Barcelona

Transport Metropolitans de Barcelona has developed and introduced an innovative staffing model consisting primarily of multifunctional roles alongside the introduction of increasing GoA into their network (see chapter 5). Automation has reduced the effort required to carry out operational tasks, allowing staff to perform a combination of driving and other customer-facing and station duties. Key benefits of this combination of increased automation and multifunctional staffing include lower staff absenteeism and more reliable service. Downtime due to internal causes has been reduced by 75 percent, since operational issues can be fixed rapidly by various staff, rather than waiting for staff particularly trained in that issue. Absent staff

are replaced more easily owing to the multifunctional training of all staff, which has improved system reliability. Customer and staff satisfaction have also improved.

#### Guangzhou Metro Corporation

In Guangzhou, where most of the network does not have automated operations, training of multifunctional staff to provide a range of tasks required to maintain service has increased labor efficiency. These tasks can include customer service duties and engineering tasks such as being able to diagnose and fix common faults. It also reduces the need for task-specific staff and training and creates a career progression that leads to greater staff retention and skill levels.

to the crew for rolling stock, it is necessary to consider the staffing of station attendants and other customer service functions based on the operation model for stations in the network.

## Performance Monitoring for Operations

Once an operations service plan is established and implemented, it is important to monitor the performance of actual operations against those planned. Measuring and reporting performance are of great importance for urban rail operators, funding partners, oversight institutions, and customers. Performance reporting<sup>1</sup> can assess the level and quality of services delivered, deficiencies in operations and infrastructure, and potential opportunities for improvements in existing operations service plans.

Performance monitoring for operations proceeds along the following three steps, each described in more detail in the following subsections:

1. Establishment of performance indicators and collection of data
2. Determination of reporting frequency
3. Effective synthesis and communication of results

### Establishment of Operations Performance Indicators and Collection of Data

The first step in measuring and reporting operations performance is to determine the indicators to be collected and analyzed.<sup>2</sup> Many performance indicators for urban rail operations have broad applicability, yet the determination of which to use and how to use them for an urban rail system depends on the configuration of infrastructure, stations, and rolling stock. It is advised that each urban rail operator establish a set of performance indicators based on the characteristics of the system and the applications of the data (such as meeting contractual level of service obligations or improving operations service planning and customer relations); the definition of these performance indicators becomes even more crucial when the operator is bound by concession contracts with defined performance thresholds. In projects developed via public-private partnerships (PPPs) or operated and maintained under a service management contract, these operational performance indicators are used to measure the availability of the service under the terms of the agreement. In such contracts, performance indicators may be tied to the payment mechanism so that payment deductions can be applied if the operator fails to meet specified targets (see chapter 9).

Many types of indicators are related to various aspects of system performance and level of service. This section discusses two broad types of operations performance indicators for urban rail systems: line performance indicators and station performance indicators. For systems in which operation is outsourced (either through a PPP agreement or other O&M contract), many other performance indicators may be monitored and enforced through penalties or incentives (see chapter 9). Recognizing that much variation exists and no single set of indicators can fully reflect the complex nature of urban rail system operations, this section introduces measurement concepts for the most widely applied indicators used to assess the movement of trains and passengers through the system.

### *Line Performance Indicators*

Line-based indicators measure the performance of line capacity and operations. Line capacity is defined as the maximum number of trains or passengers that can be carried on a single line. Line performance indicators depict how trains and linear infrastructure support operations and how service supply and quality meet passenger demand. Most urban rail operators track several indicators of line performance since each indicator tells a different story about the quality of operations. The following are some common line performance indicators:

- *Operating speed.* Operating speed is the outcome of rolling stock features and system infrastructure design, such as train control, station spacing, and track topology, and is affected directly by the conditions of infrastructure and rolling stock. Greater spacing between stations, such as on the periphery of commuter rail networks, enables trains to sustain higher speeds. More closely spaced stations, such as those on metro systems in the city center, provide barely enough time for acceleration and deceleration. In any system, curved tracks require lower operating speeds, and tangent tracks achieve higher speeds. Thus, right-of-way or horizontal alignment decisions made during the design step have direct impacts on the operations.
- *Headway.* To balance service supplies with changing passenger demand throughout the day, some urban rail operators differentiate headways within peak, off-peak, weekend, and special event services. Others, especially in commuter or suburban rail systems, apply uniform headways throughout the day. In an operating environment with surges in demand and highly frequent peak services, actual headways often deviate from scheduled headways.
- *Reliability.* Reliability measures on-time performance and is often identified as the main driver of customer satisfaction. Improved reliability has many

positive consequences, including social welfare and financial benefit to the operator, often through increased ridership (Rehnström 1991). Several indicators are used to measure service reliability, the most common being operator oriented and others being passenger oriented (see box 13.2). The management of incidents during O&M planning are very important drivers of reliable operations.

### BOX 13.2.

#### Operator- versus Passenger-Oriented Reliability Measures

Operator-oriented measures of reliability tend to focus on the vulnerability of the network to disruption and the operating performance of the network compared with some agreed level of service. Traditional operator-oriented metrics include measures of service availability (for example, number of train cancellations), average punctuality or regularity (for example, percentage of trains arriving on time), network vulnerability (for example, number of incidents by cause), and total and average delay (in time units) across all trains in the network. All medium and large urban rail systems in the CoMET<sup>a</sup> and Nova<sup>b</sup> benchmarking groups track and report most, if not all, of these operator-oriented measures (Barron et al. 2013). These measures can be calculated easily using operations data from signaling and train control systems. They are useful for making decisions about how and where to invest in order to enhance reliability of train service. However, these aggregate measures of network performance take into account only the operator or supply perspective and sometimes fail to reflect the user experience. Therefore, some urban rail systems are incorporating demand-side data from automated fare collection

systems to develop passenger-oriented measures that describe the degree of variability and uncertainty in travel or wait times.

Some of the most common passenger-oriented measures of reliability include the travel time index (which measures how much longer travel times are during peak compared with off-peak hours) and the planning time and buffer time indexes (which measure the total time and extra time, respectively, that travelers should allow to ensure on-demand arrival) (Lomax et al. 2003). For tap-in/tap-out systems with full journey information, it is possible to compare actual travel time between stations for each trip with how long that trip is scheduled to take to get a measure of travel time reliability across all potential origin-destination pairs on the network. Such an indicator is used by the Washington Metropolitan Area Transit Authority (WMATA) in Washington, DC (Duggan 2016). For tap-in systems with less accurate origin-destination information, it is possible to calculate the percentage of passengers who waited less time than the scheduled headway to get a metric of wait time reliability, as is done in Boston on the Massachusetts Bay Transportation Authority rail system (MBTA 2016).

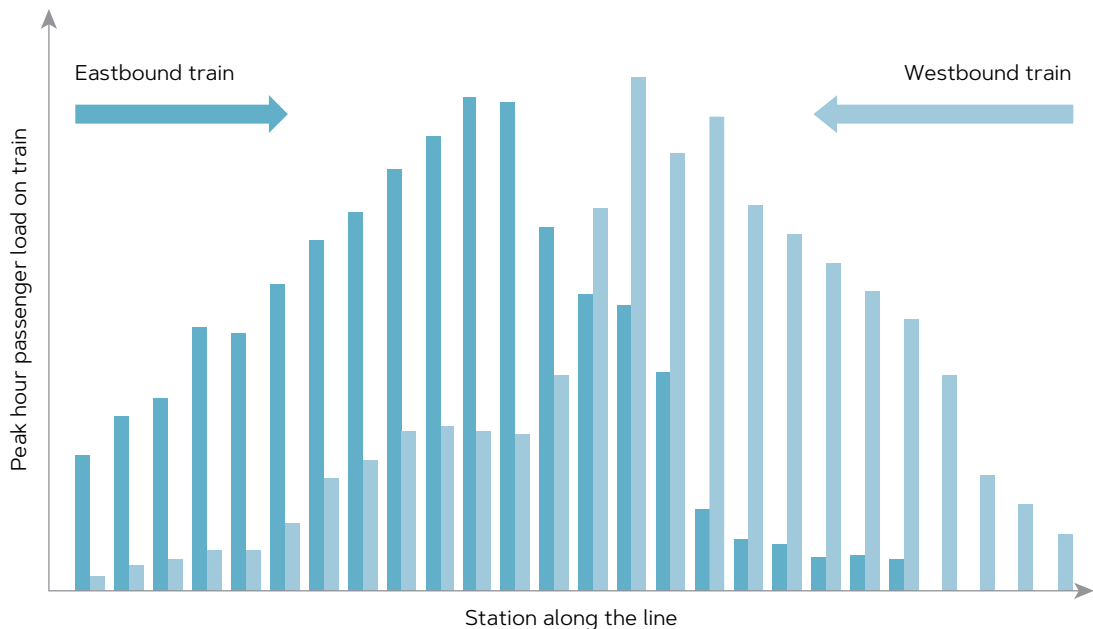
a. CoMET: the metros in Beijing; Berlin; Guangzhou; Hong Kong SAR, China; London; Madrid; Mexico City; Moscow; New York; Paris; Santiago; São Paulo; Shanghai; and Taipei.

b. Nova: the metros in Bangkok, Barcelona, Brussels, Buenos Aires, Delhi, Lisbon, Milan, Montréal, Naples, Newcastle, Rio de Janeiro, Singapore, Sydney, and Toronto.



- Maximum load volume.* Maximum load volume measures passenger congestion on a train. Understanding the location, timing, and level of maximum load volume helps urban rail operators to develop operations and investment strategies to relieve congestion and expand line capacity. Increasing train length is one quick way to reduce maximum load volume, as long as there are reserve cars and the length remains within the constraints of station platform length and the power and traction capabilities of the system. A productive urban rail line is expected to carry comparable volumes of maximum load in both directions, which maximizes capacity use and produces higher efficiency and revenues (see figure 13.2). In reality, however, the unbalanced distribution of jobs and housing along an urban rail corridor often results in a maximum load volume in the commuter direction and a light load in the reverse direction.
- Rail car occupancy.* Rail car occupancy measures passenger congestion in a rail car. There are multiple ways of deriving rail car occupancy, including passengers per square foot or meter (London), passengers per car (Washington, DC), optimal passenger capacity (New York City), number of people standing per square foot, or number of passengers per seat (Jia and Chow 2015).

**FIGURE 13.2. Example of Maximum Load Volume Measurement and Reporting**



Source: Adapted from Antos, Jia, and Parker 2017 based on Washington Metropolitan Area Transit Authority data.

- *Dwell time.* Dwell time measures the time at a station platform between when a train stops to drop off passengers and when it begins moving again after picking up new passengers. Dwell time is determined by platform and train configurations, volume of alighting and boarding passengers, and distribution of passengers along the platform. The planned average dwell time does not always reflect real dwell times at different stations throughout the line or system. It is the real dwell time that conditions the operating speed and travel time experience of the customer. Excessive or inconsistent dwell times delay train operations, cause poor headway adherence, and reduce efficiency and reliability. Monitoring dwell time performance allows urban rail operators to improve or modify schedules and take remedial actions.

Accurate and timely data and data technology influence the selection of performance indicators. Each indicator is calculated using different inputs, not all of which may be available for a given urban rail system. For most urban rail systems, headway and dwell time data can be captured easily from any rail operations control and data center. However, maximum load volume requires an interface to download and translate faregate origin-destination data into line-based estimates and is thus only an applicable indicator for urban rail operators with the data-gathering sensors and technology to maintain passenger origin-destination data. If automatic origin-destination data collection mechanisms are not in place, urban rail agencies can perform less frequent, manual counts of the number of passengers alighting, boarding, and riding at maximum load stations. The manual counts demand labor resources and long-term commitment to make the data comparable and trackable over time, so substituting reliable, automated data generation with manual methods is discouraged in cases other than contingencies.

### *Station Performance Indicators*

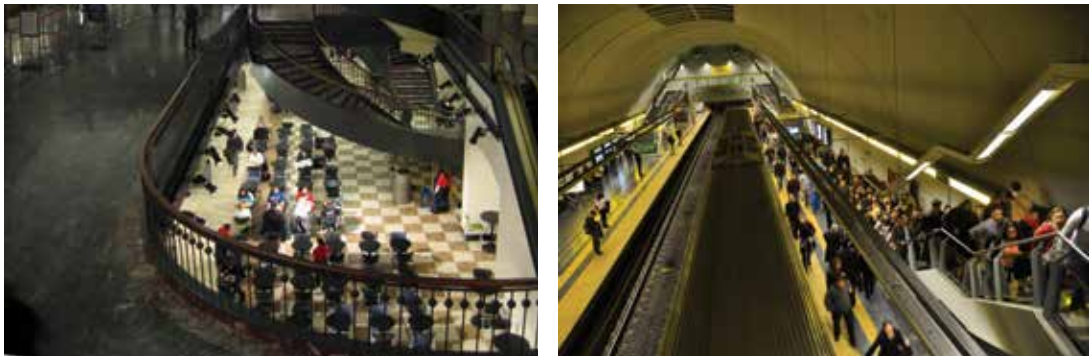
Stations are where passengers enter and exit the urban rail system and make transfers between lines. Station capacity and design determine the maximum horizontal and vertical passenger movements through an array of circulation facilities. A typical urban rail station starts with vertical access (escalators, stairs, and elevators) on the street; one or more mezzanines hosting fare vendors, faregates, and station kiosks; and additional vertical facilities connecting mezzanines and platforms. At transfer stations, vertical facilities are provided at multiple locations to connect lower and upper platforms. Urban rail stations are complex systems to measure due to their compact size and the fact that passenger movements and circulation facilities interact with each other; a bottleneck at one location has ripple effects on other circulation facilities (Antos, Jia,

and Parker 2017). Due to high variances in station designs, urban rail operators have to select station performance measures carefully for faregates, vertical access (namely, elevators, escalators, and stairs), and platforms that are applicable to their system (TCRP 2013).

- *Faregates.* The type, capacity, number, and location of faregates determine how quickly entering or exiting passengers can be cleared from the mezzanine onto the platforms or within the station. Clearing exiting traffic that all arrive together on a train is more important than clearing entering traffic, as space immediately inside faregates is often constrained and queues can spill quickly over connecting circulations all the way to the platforms. In comparison, entering traffic is often less of a concern, as arrivals to the station are more diffuse over time and faregates can help to regulate inflows. Faregate measures include clearance time (seconds per passenger) and volume-to-capacity (V/C) ratio (number of passengers passing through divided by the theoretical maximum number of passengers that can be accommodated at capacity for a given time). When developing such measures, data should be based on 15- to 30-minute intervals in the peak hour.
- *Elevators, escalators, and stairs.* All urban rail stations are built in a vertical layout, from street level to either underground or aerial platforms, requiring elevators, escalators, and stairs to move passengers across multiple levels (see images 13.1). Elevators, in particular, facilitate the movement of people—especially for riders with constrained mobility—and often are preferred by passengers in deeper stations.

Due to space constraints, vertical circulation facilities are placed along high-traffic pathways, where passengers moving in different directions mix with

**IMAGE 13.1.** Levels and Vertical Access in Front-End Space before Faregates at Union Station, Washington, DC, United States (left) and by a Platform in Buenos Aires, Argentina (right)



Source: Carlos Felipe Pardo (CC BY 2.0).

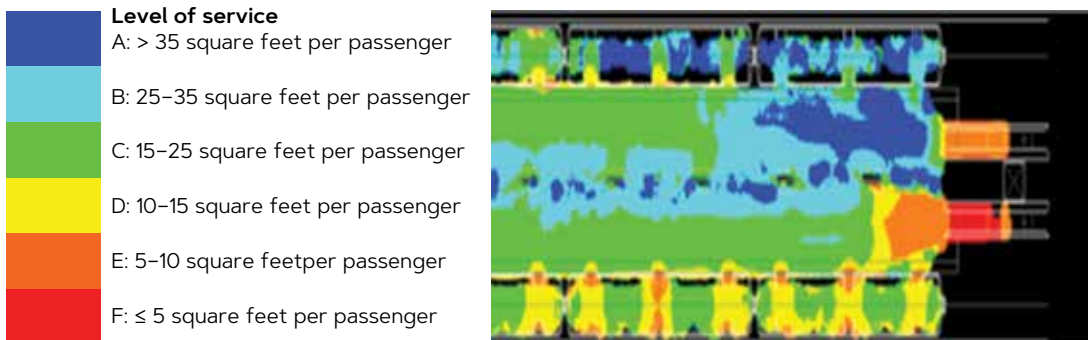
each other and with waiting passengers on the platform. The lack of capacity to clear queues on escalators and stairs, before the next train arrives one or two minutes later, poses grave safety risks. There are two ways to measure vertical circulation performance: V/C ratio and queue clearance time. Similar to how the V/C ratio is calculated for fargates, urban rail operators can collect passenger traffic data inside a station during the height of the peak and measure this information against the practical operating capacity. Queue clearance time estimates how long it takes a passenger to move through the small queue zone at the boarding area of escalators and stairs and assesses whether or not the clearance is less than the train headway. In the case of center platform station designs, safe clearance time should be less than the combined headways in both directions.

- *Platforms.* Platforms are the most dynamic circulation area inside the station, with a constant presence of passengers waiting for trains and moving along narrow passageways. Such mixes of passenger flows are blocked by platform structures—escalators, stairs, pylons, panels, seats, and trash bins. Unsafe situations can arise when passenger volume surges or when sudden blockages occur. Up-front station design should account for and mitigate these situations. Platform performance can be expressed by passenger density (square feet or meters per person), which calculates the accessible space around a person using the highway level of service concept (see figure 13.3). All areas used by structures should be excluded from the level of service calculation.

### Determination of Reporting Frequency

Once relevant line and station performance indicators are established and data collection methods are in place, it is important to determine the frequency at

**FIGURE 13.3. Platform Passenger Density: WMATA Union Station, Washington, DC, United States**



Source: WMATA Department of Planning and Joint Development 2011.

Note: Areas in orange or red (level of service E and F) point to serious crowding, which occurs at train doors and approaches to escalators and stairs. WMATA = Washington Metropolitan Area Transit Authority.

which operational performance indicators will be analyzed and reported. Even when data are readily available on a real-time basis, it can take substantial staff time to analyze and synthesize meaningful trends. Therefore, it is important to weigh the resources required to measure and report operational and other performance data against the usability of up-to-date information. Many urban rail operators differentiate reporting schedules, with some performance measures released monthly and others that require more analytical processing released on a regular, yet less frequent, basis.

It is important to account for the institutional capacity of the urban rail operator when determining the frequency of reporting. To establish an effective and continual reporting system, priority is given to acquiring skills and knowledge required for performance reporting. Operator staff have to be able to understand complex operations, interactions between infrastructure and operations, data mining, and strategic communication. Additionally, within the operator, data ownership is often split among different functions and units, including information technology, the rail operations control center, and the maintenance department. The ability to coordinate and collaborate within an agency is another important consideration when collecting data and scheduling reporting.

### **Effective Synthesis and Communication of Results**

Last, but perhaps most important, urban rail operators need to describe succinctly the results of their operations performance monitoring for a diverse audience, including funding partners, politicians, businesses, customers, and local communities. Reporting day-to-day operations performance in simple, easy-to-understand indicators and trends informs the urban rail operator and the public about the quality and level of services delivered, the match between service and demand, and, ultimately, how well the operator meets customers' expectations. It also assists in the evaluation of operational changes, improves the agency's accountability and transparency, and helps to identify weaknesses in the system design and market. Detailed technical reports should be produced to inform internal operations service planning, but technical results should also be synthesized and visualized to highlight important trends for less technical external stakeholders.

### **Asset Management**

Compared with other modes of public transport, urban rail systems necessitate the highest level of investment for the highest potential capacity. Once in place,

this investment requires disciplined maintenance and management every year with a long-term commitment to preserve assets and to deliver safe and reliable services for years to come. Asset management needs to be proactive and should be planned and implemented as soon as the system is built; waiting until the system reaches technological obsolescence or assets reach the end of their useful life is often too late, since assets usually deteriorate before reaching that point and become more expensive to rebuild or replace. Aging and underinvested assets threaten service reliability and safety by increasing the probability of rail car breakdowns during revenue service, malfunctioning train controls and signals, and failed communications, equipment, and facilities.

### **Asset Management Needs and Process**

For urban rail systems in many high-income as well as low- and middle-income countries, asset management is a new way of doing business, and its definition means different things to different agencies. The U.S. Federal Transit Administration defines asset management as “the strategic and systematic practice of procuring, operating, inspecting, maintaining, rehabilitating, and replacing transit capital assets to manage their performance, risks, and costs over their life cycles, for the purpose of providing safe, cost-effective, and reliable public transportation” (TAM News 2016, 1).

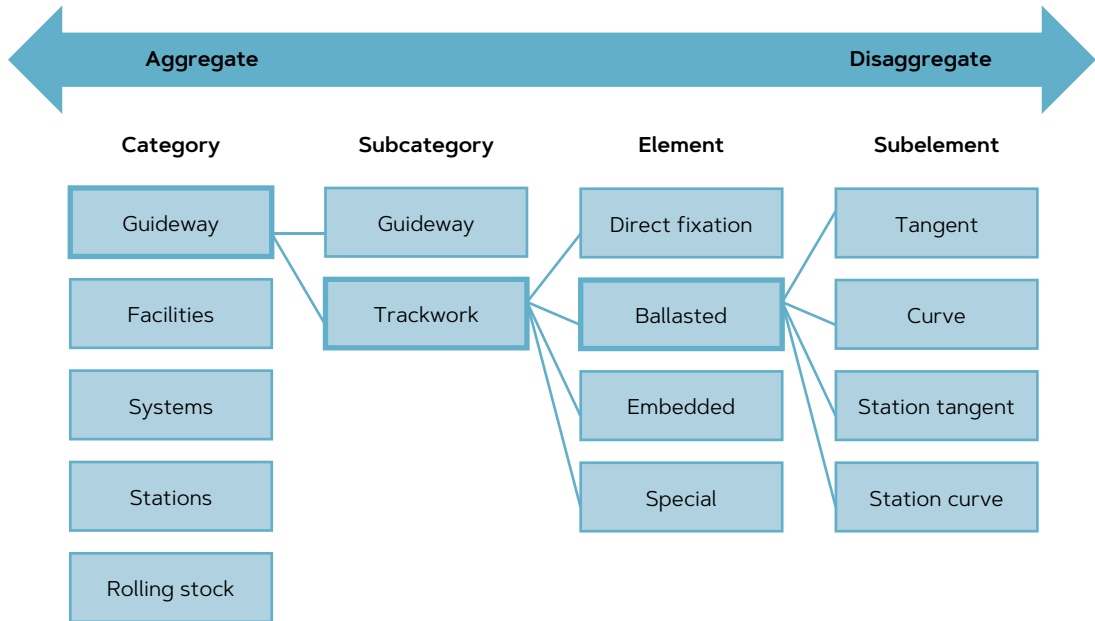
Asset management is a holistic process that goes beyond regular maintenance. Each urban rail system should identify and formulate an asset management process that is compatible with its assets, capital funding mechanism, and decision-making processes.

### **Asset Inventory**

The asset inventory is the foundation of asset management. For urban rail systems, developing an inventory means accounting for all rail assets or asset groups. Defining proper hierarchical asset groupings should be one of the first efforts of inventory development (see figure 13.4). Asset groupings within the hierarchy should be defined comprehensively to cover and classify all assets and to avoid any double counting; therefore, categories within the hierarchy should be mutually exclusive.

Once the asset hierarchy is established, the urban rail agency has to define the data attributes to be recorded for each asset. The most important attributes are age, useful life, quantity, location, past rehabilitation(s), dates of most recent and next scheduled inspections, physically inspected condition, mileage (rolling stock) or area size (facility) or length (track), and replacement and rehabilitation costs. Such features are inputs to prioritizing asset needs and developing asset improvement projects.

**FIGURE 13.4.** Example of a Four-Level Asset Hierarchy System for Urban Rail

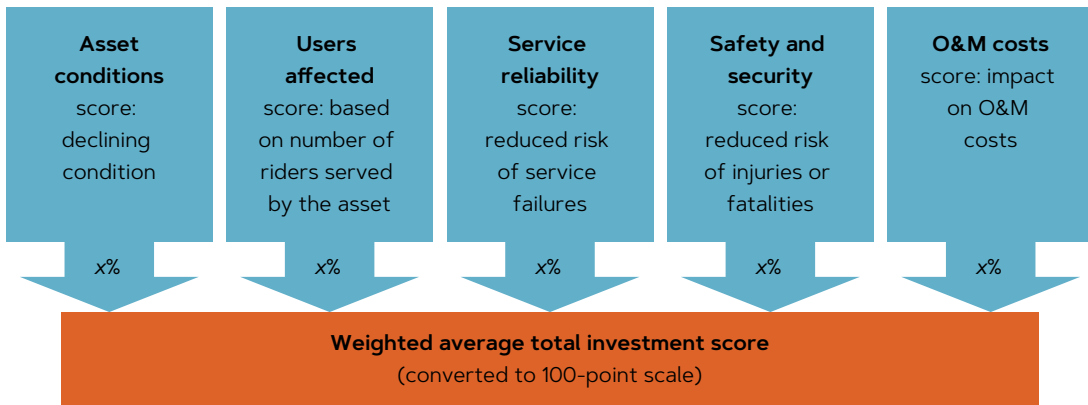


Source: Adapted from CH2M Hill 2013.

Ideally, the inventory is hosted in a secure database that is accessible to authorized asset owners for updating and monitoring. However, such a central database is nearly infeasible for all assets. In practice, each major asset has its own data software that is designed to contain a very detailed history of an asset and its maintenance record. It is recommended that a designated entity within the operator be the lead for developing and updating the asset inventory.

### Asset Needs Prioritization

Urban rail systems require significant capital maintenance funding for the upkeep of asset conditions. In cases where resources are limited, these funds should be allocated to those assets with the greatest need for repair, rehabilitation, or replacement. Even new urban rail systems may find that a portion of assets deteriorate or become obsolete faster than expected due to wear and tear from high use, environmental conditions such as humidity and water leakage, or technological advancement. For example, water leakage in underground tunnels can shorten the useful life of insulators from 10 years to less than 4 years (WMATA 2017). Therefore, on completing the asset inventory, it is imperative for the agency to prioritize asset needs. The prioritization identifies assets in urgent need of capital

**FIGURE 13.5. Prioritization of Assets Using Multiple Criteria**

Source: Adapted from CH2M Hill 2013.

Note: O&M = operation and maintenance.

intervention, forecasts short-term deterioration and changes in condition, and estimates annual funding requirements for the next 1–5 years.

Prioritization should be based on asset conditions, as well as other criteria that align with the strategic goals of the urban rail operator, such as the impact on ridership, safety, or service quality. Prioritization criteria need to be measurable with reliable data generated from the urban rail system. The operator then develops weightings for each criterion, builds consensus on those weights among other relevant system stakeholders, and comes up with an overall score that ranks assets based on their needs and the benefit of mitigated deterioration (see figure 13.5). Although prioritization of assets is needed for the short term, this prioritization needs to be complemented with a long-term fiscal management strategy that provides the resources to maintain all assets in a state of good repair.

## Maintenance Management

Asset management establishes an agency-wide business process to build asset data, track and monitor asset conditions, and program and fund asset renewal and reinvestment at a strategic level. Distinct from asset management, maintenance management executes capital actions at a ground level on a daily basis with the objective of preserving a state of good repair for infrastructure, rolling stock, and associated systems related to service provision.

### Types of Maintenance Approaches

This section highlights three types of maintenance approaches: reactive (repair based), preventive, and predictive. Table 13.1 defines each of these approaches



**TABLE 13.1. Progression of Maintenance Approaches**

PURPOSE	APPROACH	ADVANTAGES	DISADVANTAGES
Reactive (repair based)	Corrective maintenance: operate asset until failure; fix only when broken	<ul style="list-style-type: none"> <li>• Low short-term maintenance costs</li> <li>• Longer intervals between maintenance checks</li> <li>• May be suitable for some short-lived electrical and mechanical equipment (for example, light bulbs)</li> </ul>	<ul style="list-style-type: none"> <li>• Can be inefficient</li> <li>• Unexpected breakdowns: more frequent train or service-critical asset failures with potentially greater service impacts, such as delays</li> <li>• Unplanned maintenance</li> <li>• Higher total life-cycle costs</li> <li>• Stress and wear on other components</li> </ul>
Preventive	Rule-based (fixed-plan) maintenance: interval-based diagnostic and inspections and usage-based maintenance and renewal based on time or distance	<ul style="list-style-type: none"> <li>• Lower total life-cycle costs</li> <li>• Improved efficiency and effectiveness of maintenance activity</li> <li>• Higher levels of fleet use and availability</li> </ul>	<ul style="list-style-type: none"> <li>• Higher short-term maintenance cost</li> <li>• Increased labor resources</li> <li>• More frequent maintenance checks</li> <li>• Tends to be single-output-focused (targets a specific improvement or efficiency)</li> </ul>
Predictive (proactive)	Condition-based maintenance: real-time diagnostic monitoring of assets	<ul style="list-style-type: none"> <li>• Targets multiple outcomes and balances objectives; likely to be most efficient from a whole network perspective</li> <li>• Improved rolling stock and other service-critical asset reliability and availability; less service disruption</li> <li>• Optimizes maintenance schedules</li> <li>• Avoids unnecessary maintenance due to extended condition-based maintenance frequencies</li> <li>• Increases long-term cost-effectiveness</li> <li>• Tailors maintenance interventions to specific requirements just before they are needed</li> </ul>	<ul style="list-style-type: none"> <li>• Requires rigorous data collection, including additional cost for monitoring sensors and equipment</li> <li>• Requires dedication of staff as well as advanced training and skill level</li> <li>• Dependent on deployment of more sophisticated technological platforms</li> <li>• Difficult to overcome organizational inertia; requires strong leadership to challenge current practice</li> </ul>

Source: Adapted from Parasram et al. 2012.

and lists their advantages and disadvantages. For any urban rail system (with the exception of some short-lived equipment), more sophisticated preventive or predictive maintenance is necessary to avoid service disruption or deterioration from asset failure. Preventive maintenance constitutes the core of maintenance, including scheduled progressive inspection and servicing to meet regulatory and inspection requirements. No matter how well an agency executes preventive maintenance, unexpected breakdowns happen to old and new assets. Predictive maintenance troubleshoots and proactively mitigates such breakdowns.

The type of maintenance approach employed by the urban rail system should match the technical and managerial capabilities and resources of the system's operator and may be different for different types of assets (for example, rolling stock versus lighting equipment in stations). To date, the most common maintenance approach among advanced urban rail systems is preventive maintenance based on asset component life-cycle assumptions (see box 13.3).

In summary, sound maintenance approaches improve service reliability, reduce O&M costs, and boost the trust of government authorities, communities, and other stakeholders in the operator and its services. Although sound practices are used in urban rail systems around the world, barriers still exist to the development of effective maintenance approaches. Lack of funding, poor incentives and management, inflexibility of standards, risk-averse leadership, lack of asset data, unreliable technology, and lack of appropriate staffing and facilities impose challenges for effective maintenance management. Therefore, no matter the maintenance approach employed, strong recognition from all

**BOX 13.3.****Life-Cycle Maintenance Management**

Life-cycle maintenance management is the most commonly applied preventive, rule-based maintenance approach among current urban rail systems. Life-cycle maintenance management enables urban rail systems to target routine inspections and maintenance to those assets nearing an expected point of failure. Life-cycle maintenance requires urban rail systems to make useful-life assumptions

for each type of asset in the asset inventory and to specify the frequency of rehabilitations needed for each asset (see table B13.3.1). With life-cycle considerations incorporated into maintenance, urban rail systems are in a stronger financial position to manage operation and maintenance (O&M) costs and to maintain service quality by avoiding breakdowns and disruptions.

*(box continues next page)*

**BOX 13.3.****Life-Cycle Maintenance Management** (Continued)**TABLE B13.3.1.** Example of Major Useful-Life Assumptions for Selected Urban Rail Assets

ASSET CATEGORY	ASSET SUBCATEGORY	ASSET ELEMENT	USEFUL LIFE (YEARS)	NUMBER OF REHABILITATIONS
Guideway	Track structure <sup>a</sup>		80	0
	Ballasted rail	Tangent	40	0
		Curve	25	0
	Embedded grade crossings		12–20	0
	Wood ties		28–32	0
Facilities	Rail car maintenance shops		60	5
	Rail storage yard		50	1
	Work equipment		20	0
Systems <sup>b</sup>	Underground utilities	Lighting	20	0
		Pumps	30	0
		Fan plants	25	0
	Communications	Radio	15	0
		Cable (nodes)	20 (10)	0 (0)
		Phone	10	0
	Security and surveillance		5–10	0
	Train control	Metro cab signals	25	0
		Wayside signals and train stops	40	0
		Roadway crossings	25	0
		Interlocking	40	0
	Fare collection	On-vehicle fareboxes	10	0
		In-station	10–15	0
		Universal fare card system	15	0
	Electrification	Right-of-way traction power	Contact rail	40
Overhead catenary			40	0
Substations			25–30	0
Stations	Stations <sup>a</sup>		60	5
	Station parking	Garage	20	1
		Lot	10	0
Revenue vehicles	Suburban rail	Locomotives	30	1
		Coaches	50	1
		Electric multiple units (EMUs)	35–30	1
	Metro rail cars		25	3

Source: Data from RTA 2016.

a. At-grade, elevated, or underground.

b. Other systems, such as passenger information and communication systems, have short useful lives or require continuous upgrade since they quickly become obsolete.

stakeholders that maintenance is important and deserves dedicated resources is critical for the sustainable operation of the system.

Maintenance roles and responsibilities associated with system operation need to be defined from the beginning of the project. There is a wide range of maintenance arrangements in between complete internalization and centralization using the operator's own personnel and total outsourcing to specialized companies with payments for availability, quality, and other performance indicators. If adequately structured, vertically integrated PPPs—in which a private company is given the responsibility for delivery and integration of all project components and for O&M of the system over a long period—may offer incentives for life-cycle maintenance management. To capitalize on the potential advantage offered by a PPP, granting authorities have to develop maintenance protocols or requirements and establish associated performance indicators in the contract. These performance indicators should be monitored adequately and incorporated as part of the payment mechanism (see chapters 9 and 10). In addition, PPP agreements need to establish clear conditions in which the assets (and associated data on their condition and previous maintenance) should revert to government possession at the end of the contract.

In current practice, intermediate arrangements in which basic maintenance (per kilometer or per unit of time) is carried out by the operator's own staff, and more advanced, long-term asset reviews and capital maintenance are carried out by specialized companies (sometimes even the original construction contractor of the system) have proven most efficient (World Bank 2017).

### **Staffing and Facilities**

To ensure effective maintenance approaches, urban rail operators need to build maintenance capacity up-front and to strengthen this capability over time. Due to the complexity of rail asset components and the intricate interplay among these components, maintenance crews are required to possess seasoned, hands-on practice as well as engineering expertise in electrics, mechanics, structure, and other areas. For developing cities undertaking an urban rail project for the first time, setting up technical training and apprenticeship programs from project inception can help to provide a local labor force with the skills necessary to operate and maintain the urban rail system on the start of revenue service (see chapter 4).

In addition to capable and appropriate staffing of maintenance crews, urban rail systems require adequate facilities in which to conduct regular maintenance. Rail yards, strategically located within the network, function as much more than office space and storage yards for fleet. Inside rail yards, crews conduct critical maintenance work such as rail car cleaning and washing, routine maintenance

**IMAGE 13.2.** Locomotive under Repair at a Commuter Rail Maintenance Facility: MBTA, Boston, Massachusetts, United States

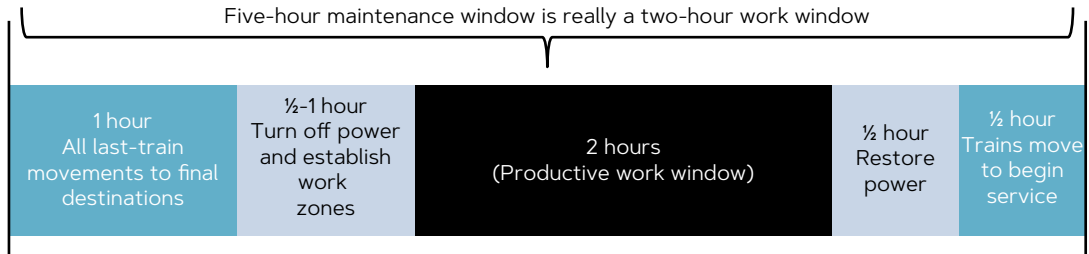


Source: Wikimedia Commons (CC BY-SA 3.0).

and minor repairs, and heavy repairs and overhauls (see image 13.2). Each rail yard should be equipped with or have flexible access to specialized maintenance equipment as well as mission-critical structures, hardware, and software to detect deficiencies and make repairs.

### **Dedicated Maintenance Windows**

No matter the maintenance approach adopted, it is imperative to have dedicated windows of time for inspecting and maintaining the system. Despite some notable examples of systems that run late-night or overnight rail service, most urban rail systems have found that having a dedicated overnight maintenance window every day is critical for delivering safe and reliable service. These overnight windows must be long enough to allow time for passenger trains, work trains, and maintenance equipment to move to and from depots and worksites in the system and to stop and restore power to the system (see figure 13.6).

**FIGURE 13.6. Use of a Five-Hour Overnight Maintenance Window**

These overnight maintenance windows are critical for preventive maintenance, enabling workers to find and fix worn or poorly connected parts of track and equipment. These works help to forestall most track fires, bumps, and risks of derailment and are the cornerstone of safe and reliable daily service. For larger capital renewal projects and asset management, systems may need to bring sections of track offline for a weekend or longer.

### Fiscal Management

Fiscal management is the fifth pillar of sustainable urban rail operations. Fiscal management requires balancing two key cash flows: revenues coming into the system and O&M costs spent to run, maintain, and upgrade the system. In other words, financial stability of the system requires adequate management of expenses and income, as happens with most businesses. This financial stability allows urban rail systems to operate and maintain high-quality service and to plan for eventual expansion costs.

Planning for fiscal management is addressed through annual budget development, short-term outlook, and long-term projections:

- *Annual budget.* The operating budget provides detailed service provision specifications, workforce requirements, labor costs, insurance, and departmental breakdowns. The annual capital budget secures funds for capital projects and actions, from maintenance and upkeep of existing assets to development of new projects and expansions.
- *Short-term financial outlook.* The short-term outlook provides financial projections. Many assets and capital actions take multiple years to develop from planning through design to procurement and construction. The short-term outlook allows urban rail operators to estimate labor and

capital project costs over a comparable time frame and to prepare funding requests.

- *Long-term planning projections.* The long-term trend, in the range of 15–20 years, is indispensable because it informs stakeholders of major capital and service initiatives in the pipeline and rallies political and funding support for these initiatives.

Highest priority is given to preparing the annual budget to commit and program funding for operations, service delivery, and priority capital needs (linked to asset and maintenance management) in the upcoming year. Some agencies include the short-term capital outlook in the annual capital budget in recognition of the multiyear nature of capital execution. Capital expenditures are broken into categories or subcategories of assets (see box 13.4). In some cases, agencies provide detailed descriptions of assets.

### Recurring Costs

Recurring costs encompass all costs required to operate, maintain, and renew the infrastructure, rolling stock, and systems once they are built and begin operations. In most countries, accountants draw a fairly clear boundary between capital cost and recurring operating cost. However, the boundary for urban rail systems is often blurred because the interval between periodic maintenance and reinvestment interventions for many large civil works is measured in years and sometimes decades, making them hard to incorporate into an annual

#### **BOX 13.4.**

#### **Example of Capital Improvement Program and Operating Expense Budgets: Chicago Transit Authority, Illinois, United States**

The Chicago Transit Authority provides clear breakdowns of multiyear capital improvements and asset renewals by category (see figure B13.4.1). It has separate cost breakdowns for annual operating expenses, of which labor represents a large majority (see figure B13.4.2). For typical

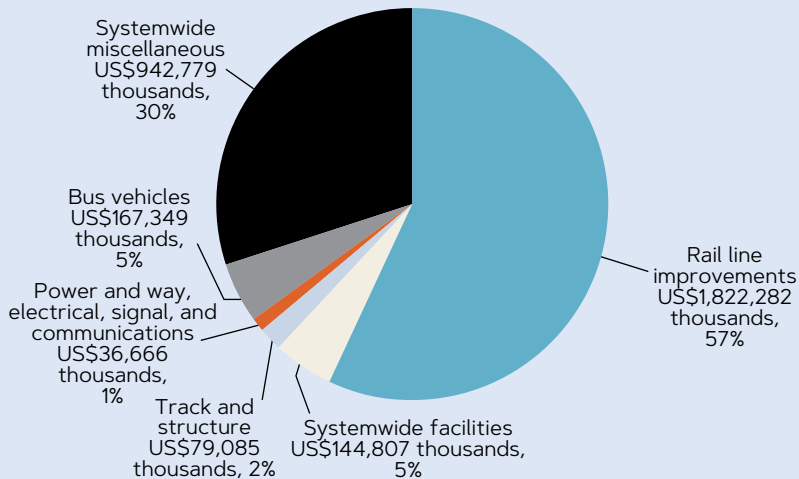
urban rail systems in low- and middle-income countries, the share of labor costs may be a little lower than those shown for Chicago, while the costs of power and fuel and of equipment imported from foreign countries may be higher (see figure 13.4 for an example).

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**BOX 13.4.**

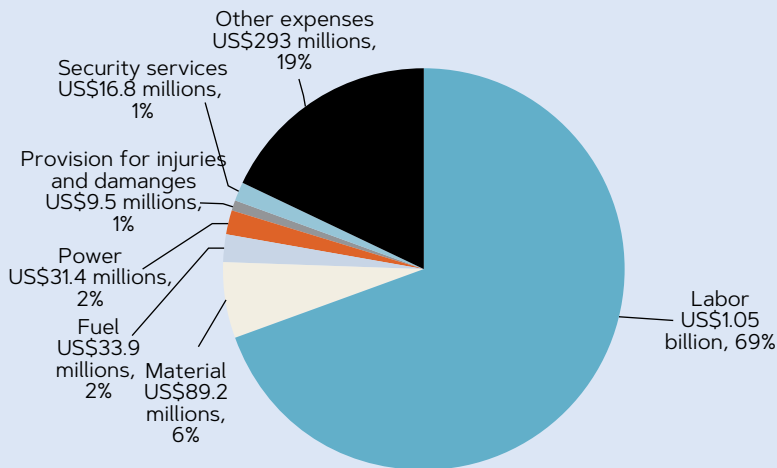
**Example of Capital Improvement Program and Operating Expense Budgets: Chicago Transit Authority, Illinois, United States** (Continued)

**FIGURE B13.4.1. Example of Allocated Expenses for Capital Improvement Program, by Asset Category, 2017–21**



Source: Data from CTA 2016, 56.

**FIGURE B13.4.2. Example of an Operating Expense Budget, 2017**



Source: Data from CTA 2016, 33.



recurring operating budget. Therefore, capital maintenance and asset renewal or replacement are often funded through the capital budget, if at all. Notwithstanding this accounting practice, these items represent significant continuing costs to maintain the system in a state of good repair and have to be considered in all estimates of recurring costs.<sup>3</sup>

For a complete picture of recurring costs, the project-implementing agency should consider incremental accounting sums for periodic maintenance, depreciation, pensions, and other contingent liabilities. It should also consider operating agency expenditures for labor, materials, energy, services, taxes to operate and maintain the trains and infrastructure, supporting business, and information and communications technologies that are critical to service delivery and customer interface.

### *Operating Cost Variability*

Typical operating costs for heavy urban rail projects vary from system to system. At a planning level, preliminary recurring cost estimates are based on operating unit costs most often defined using operating cost per route-kilometer and per passenger carried (see chapter 5). Depending on the unit cost used, there are significant differences between metro and commuter rail systems, even in the same region, due to different levels of service supply and ridership demand (see box 13.5).

#### **BOX 13.5.**

### **O&M Costs for Commuter Rail versus Metro Systems: New York City Metropolitan Region, United States**

The New York City metropolitan region is served by multiple urban rail systems: Metro-North Railroad, Long Island Rail Road, New York/New Jersey Port Authority Trans-Hudson (PATH) commuter rail systems, as well as the New York City Transit metro system. For commuter rail systems such as PATH, individual trains often run longer distances, contributing to lower operating costs per kilometer. However, these same commuter rail systems

often have longer trains with lower ridership per car, contributing to higher operating costs per passenger. For metro systems, the trend is the opposite (see table B13.5.1). Metro systems, such as New York City Transit, often serve shorter distances at high frequencies with higher passenger loads per car. Therefore, metro systems often exhibit higher operating cost per route-kilometer, but lower operating cost per passenger.

*(box continues next page)*

**BOX 13.5.****O&M Costs for Commuter Rail versus Metro Systems: New York City Metropolitan Region, United States** *(Continued)***TABLE B13.5.1. Operating Costs for Metro Systems in New York City, 2014**

Cost (US\$)

SYSTEM	OPERATING COST PER KILOMETER (US\$)	OPERATING COST PER PASSENGER (US\$)
New York City Transit	6.44	1.83
New York/New Jersey Port Authority Trans-Hudson (PATH)	3.21	4.72

Source: FTA 2014.

Note: O&amp;M = operation and maintenance.

*Key Drivers of Operating Costs*

Much of this variation in system operating costs is shaped by differences in factors such as age of the infrastructure, systems, and rolling stock; intensity of use; operating speed; network capacity; and other characteristics (see chapter 5). Research on operational data provided by the urban rail systems belonging to the CoMET and Nova benchmarking groups suggest that, given the design constraints of the system, operating costs are most sensitive to the following:

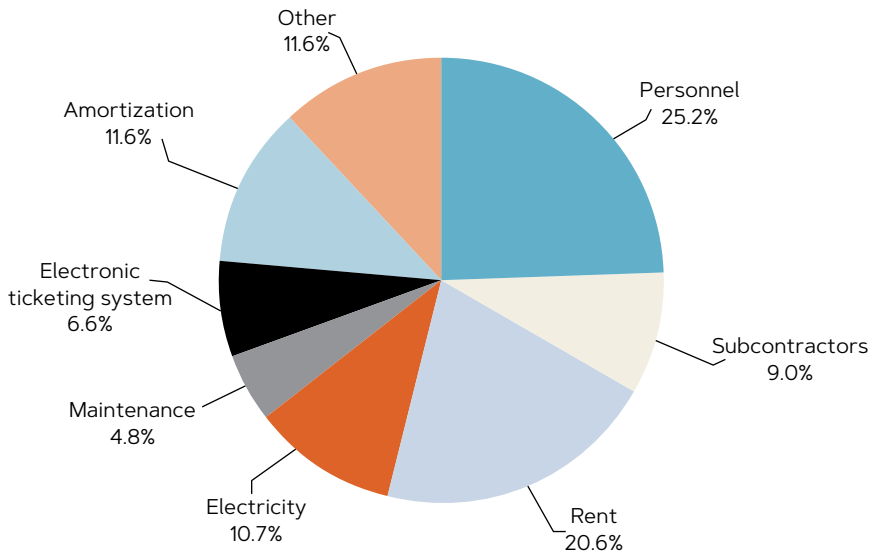
- *Intensity of use.* On average, a 10 percent increase in car-kilometers is associated with a decrease of nearly 7 percent in train service costs per kilometer. Equally, a 10.0 percent increase in passenger journeys is related to an 8.1 percent decrease in train service costs per passenger journey (Brage-Ardao, Graham, and Anderson 2015).
- *Input prices.* On average, a 10 percent increase in staff wages is correlated with an average increase of nearly 5 percent of train service costs. Correspondingly, a 10.0 percent increase in electricity costs is correlated with an average increase of 2.1 percent of train service costs. Accordingly, labor weighs more than electricity when estimating operating costs (Brage-Ardao, Graham, and Anderson 2015).
- *Elasticity of demand.* In cities with mature public transport systems where demand is mostly inelastic with regard to fares, the quantity and quality of services are more important drivers of ridership and fare revenues than fare

prices themselves (World Bank and RTSC 2017). However, for new urban rail projects, early fares may need to be set to attract sufficient ridership to meet demand forecasts.

For most, if not all, urban rail systems, labor is the dominant driver of operating cost. In the United States, labor accounts for approximately 80 percent of the annual operating costs for all heavy rail systems (FTA 2014). A further breakdown indicates that the combined salaries, wages, and fringe benefits for train operators are much lower than the combined personnel costs supporting broad functions of rail service, inclusive of engineering, planning, yard maintenance, information technology, and business administration. This is not surprising, as operating an urban rail system is a large-scale business.

Labor remains a key driver of operating costs for urban rail systems in low- and middle-income countries. However, unlike in the United States—where public transport agencies have broad immunity from taxation on revenue and the cost of electricity and power is relatively low—taxes and utilities may represent additional key drivers of operating costs for urban rail systems in low- and middle-income countries (see figure 13.7).

**FIGURE 13.7. Breakdown of Operating Expenditures for an Urban Rail System in Turkey, 2014**



Source: Data provided by system operator under anonymity agreement.

## Operating Revenues

The financial dynamics of rail projects and services and how these are paid for are influenced by a range of factors, but the most significant is the extent to which revenues associated with a rail project's assets and services cover their full cost (NCRRP 2015). Revenues for urban rail systems can come from user fares, nonfare sources, operating subsidy, or other sources of external funding—for example, dedicated tax revenue or funding from local, regional, state, or national governments (see chapter 10).

### *Fare Revenues*

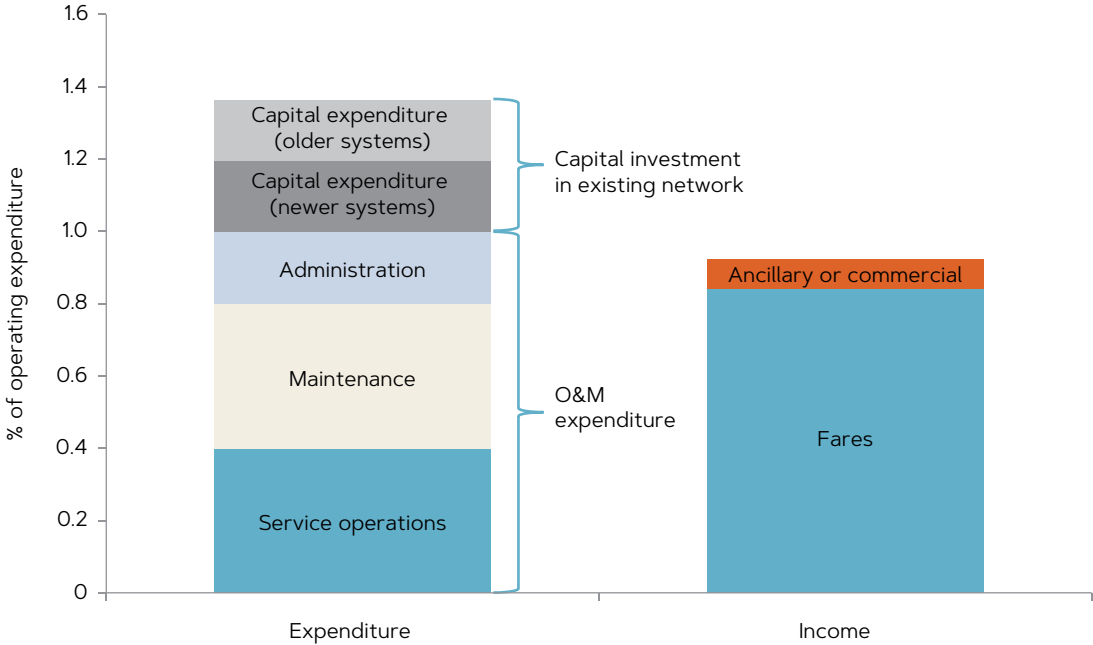
User fares are the primary source of operating revenues generated from investments in urban rail systems. Fare policy has a direct impact on the financial sustainability of the urban rail system and its operator (whether public or private) and the level of external funding (subsidies) required to maintain service, especially in markets with regulated or no competition to provide services. However, fares are most often set as part of a hierarchically integrated transit system (see chapter 2) regulated by a government authority rather than the project-implementing agency or the operator (see chapter 12). Therefore, it is imperative that the operator share its knowledge of operating costs and capital needs with this authority so that fare policies accurately reflect revenue needs.

For most of the world's urban rail systems, farebox revenues are not sufficient to cover full O&M expenditures,<sup>4</sup> let alone initial and recurring capital expenditures (see figure 13.8). In other words, careful fare policy is not enough for an urban rail system to achieve financial stability covering O&M expenditures and recurring capital expenditures. Therefore, other sources of stable revenue are needed, including nonfare revenues from ancillary businesses and external subsidies (see chapter 10).

### *Developing Nonfare Revenues and Ancillary Businesses*

Urban rail systems are increasingly pursuing income from commercial activities. Given that today's urban rail systems comprise about 9,000 stations and 11,000 kilometers of rail line throughout the world, facilities and land owned by these systems represent enormous, relatively untapped commercial and real estate potential for their owners and operators. Recent developments in income-generating commercial activity by urban rail systems have been concentrated in high-income economies, with many of the most lucrative in Asia; however, systems in low- and middle-income countries may also benefit from commercial innovations to increase their nonfare revenues (World Bank 2017). Urban rail system operators and owners can choose from a package of potential commercial activities that produce ancillary revenue, including advertising, leasing of

**FIGURE 13.8. Total Operating Expenditure and Income from CoMET and Nova Metro Benchmarking Groups Showing Farebox Recovery Ratio (data for 1994–2009)**



Source: Adapted from Anderson, Findlay, and Graham 2012.  
Note: O&M = operation and maintenance.

commercial space, sale of naming rights, merchandising, and sale of consulting services and technology (see chapter 10) as well as land value capture and real estate development (see chapter 16).

*External Subsidies*

Urban rail systems require external funding (subsidies) because many groups who accrue benefits from urban rail investment are not those who pay fares—other road users and the community at large (Ardila-Gómez and Ortégón-Sánchez 2016). From a political economy perspective, these subsidies are defensible because public transport tends to have higher benefits than costs; because of its capacity, public transport can carry large volumes of passengers efficiently vis-à-vis other investments that prioritize private car use. Subsidies that keep fare levels low may encourage transfer from private vehicles, alleviating congestion and reducing accidents and other societal or environmental externalities. For CoMET and Nova metros, the average system requires a 9 percent operating cost subsidy to cover the deficit from its commercial income,

and the operating subsidy can account for up to 68 percent of total metro operating revenue (Anderson, Findlay, and Graham 2012). Funding and financing the recurring needs of urban rail systems requires considering a wide set of instruments that go beyond fare income (see chapter 10).

In summary, although fiscal management of O&M costs and revenues is necessary for sustainable urban rail operations, most systems also need to have institutional and financial support that provides consistent external funding and that gives the urban rail operator the autonomy and flexibility to collect revenue and manage expenses.

## Conclusions and Recommendations

### *Decisions made during planning and design affect operational sustainability.*

The operational characteristics and service levels of any urban rail system hinge heavily on the design features and capacities of infrastructure, systems, and rolling stock (see chapter 5). System design needs to take a long-term operations-focused view that maximizes the use of built capacity, provides operational flexibility and efficiency, accommodates future demand growth, and reduces network congestion. For example, the marginal operating cost of transporting a passenger declines as overall ridership increases within typical design limits.

*Performance monitoring and operational benchmarking are essential for improving service and for building trust with government authorities and riders.* It is important for urban rail operators, funding partners, oversight institutions, and customers to monitor the performance of actual operations against those planned. Performance monitoring and reporting can help to assess the level and quality of services delivered, deficiencies in operations and infrastructure, and potential opportunities for improvements to existing operations service plans. Many urban rail systems belong to an international benchmarking group—such as CoMET or Nova—in which they share anonymized performance data, learn from each other, and share best practices.

*Regular maintenance and asset management are essential for ensuring the reliability, safety, and long-term viability of the urban rail system.* As soon as the initial infrastructure is built and operations begin, the operator must turn its attention to asset management and maintenance approaches to ensure that the infrastructure, systems, and rolling stock are sustained in a state of good repair. Once lost, it is very costly and disruptive to try to reestablish a state of good repair. Any maintenance approach requires adequate staff, facilities, and equipment as well as dedicated time windows to provide day-to-day inspections

and upkeep for the delivery of safe and comfortable services. Asset management establishes a strategic process for urban rail systems to inventory, monitor, and fund asset reinvestment needs.

***Responsible and transparent fiscal management allows urban rail systems to program funding for O&M and capital renewal on an annual basis and guarantees the multiyear process of capital implementation.*** Urban rail is a capital investment project that never stops (World Bank and RTSC 2017). Assets age and require renewal and maintenance to ensure that they are in a good state of repair. Reinvestment to renew and enhance urban rail infrastructure is necessary to secure enhanced service. By itemizing O&M and capital expenses into functional categories and sharing the fiscal information with governing authorities and the public, urban rail systems improve their accountability and credibility in managing public funding. This, in turn, helps to secure multiyear, stable subsidies for long-term enhancement of the system.

***Good fiscal management practices have to be supported by fare systems and policies that provide the operating revenue necessary to cover the recurring O&M costs of urban rail systems.*** International experience shows that there is considerable scope for improvement in fare policies (see chapter 2) and nonfare revenues (see chapter 10) to ensure the long-term financial sustainability of urban rail operators. Maximizing revenues is rarely, if ever, the main objective of an urban rail system, with concerns about affordability and equity at the core of fare policy. However, financial sustainability and balance between expenditures and revenues are vital dimensions for ensuring the proper operation of the urban rail system throughout its lifespan. Literature on established urban rail systems suggests that improvement in quality of service, rather than reduction of fares, may be more effective in increasing urban rail ridership and revenues (Brage-Ardao, Graham, and Anderson 2015). It also supports the credibility of a funding strategy that raises fares at least in line with wages to fund service frequency or capacity improvements on the existing network.

## Notes

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1. The monitoring of operations performance is often part of a more comprehensive systemwide program that also measures economic benefits, management performance, and community benefits (TCRP 2003).

2. The CoMET and Nova urban rail benchmarking groups use a system of key performance indicators with approximately 30 top-level indicators, which are designed to measure the overall performance of the operator in six areas: (1) growth, learning, and innovation; (2) financial (sustainability); (3) customer experience; (4) internal processes; (5) safety and security; and (6) the environment (<http://cometandnova.org/benchmarking/>).
3. In the context of urban rail projects, operating costs are the funds necessary to operate and maintain the system on an annual basis. In normal practice, operating costs exclude items such as depreciation and asset rehabilitation and renewal that occur on a longer time scale. Therefore, the data that are available for operating costs are just that: the cash budget of the institutional entity that operates the system and conducts routine, labor-intensive maintenance, excluding recurring capital reinvestments. The data rarely include depreciation and periodic maintenance. Therefore, it is important to scrutinize the components of operating cost data, even across urban rail systems within a single country.
4. Fare evasion and other fraud can present an operational risk to urban rail systems and can affect fare revenues (see chapter 7).

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# 14

## ADDRESSING SOCIAL IMPACTS OF URBAN RAIL PROJECTS

Carlos T. Pérez-Brito

Urban rail systems interact with complex urban environments. When properly implemented, urban rail systems can expand accessibility and foster inclusive development, resulting in a variety of positive and negative social, economic, and environmental impacts. This chapter discusses some of the main social impacts associated with the implementation of urban rail projects, while chapter 15 discusses related environmental, health, and safety impacts.

The chapter begins by defining key social impacts for urban rail projects. Urban rail projects can impose both temporary (during project design and construction) and permanent (persisting through operations) negative impacts on public and private spaces, households, businesses, and entire communities. Urban rail projects can affect households as a result of land acquisition and resettlement and can interrupt and disrupt the economic activities of businesses—formal and informal. Depending on the city, urban rail can have negative impacts on cultural heritage, including damage to paleontological or archeological sites and monuments considered patrimony as well as changes in the aesthetic or architectural landscape in which such cultural sites are located. The chapter also provides several examples of mitigation measures from recent urban rail projects to illustrate possible measures for identifying and mitigating these negative social impacts.

*Photo:* Walking along the rail tracks during flooding, Jakarta, 2013. *Source:* Mulia Sjahrusjiam via Flickr (CC BY-NC-ND 2.0).

It then discusses the frameworks used to evaluate social impacts and their distribution across space, time, and sociodemographic groups. The key building blocks for comprehensive analysis and proactive management of social impacts and their related risks to the project—opposition, project delay, or cost overruns from unanticipated changes in mitigation and design—are environmental and social impact assessments (ESIAs), environmental and social management systems (ESMSs), and environmental and social management plans (ESMPs).

Urban rail corridors often pass through many different municipalities, making administrative coordination of the project difficult. Coordinating and consulting with different levels and ministries of government as well as with large diverse groups of urban citizens pose significant logistical considerations for stakeholder engagement. The benefits of an urban rail project are dispersed and accrue to thousands of people. Due to their dispersion and the time delay between project implementation and the realization of project benefits, persons who benefit from the project are unlikely to mobilize to support the project. Costs or negative impacts fall to a small number of people who have an immediate incentive to mobilize and for whom it is easier to mobilize because they are few in number. Small opposition groups can dominate media coverage and derail even the most carefully prepared project plans. Therefore, stakeholder management and the building of support coalitions are an integral part of addressing the social impacts of urban rail projects.

It is imperative for the project-implementing agency to establish a social team at the outset of project planning. This social team should provide the link between project staff and external stakeholders. The social team should participate in the planning and design processes to inform horizontal and vertical alignment and site research and to incorporate feedback and recommendations from communities in a timely manner. Although it may be impossible to meet the objectives of all stakeholders and to mitigate all negative social impacts, early input from the community and social experts provides an opportunity to make reasonable changes in the project planning and design when they are least costly and can create buy-in and much-needed political support for the project. These issues and the importance of early and sustained communication and stakeholder engagement are discussed in the final section of this chapter.

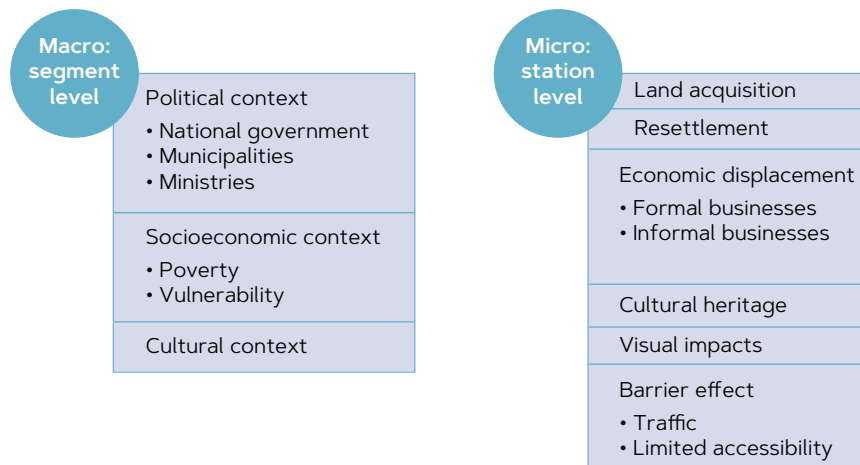
### **Social Impacts of Urban Rail Projects**

Urban rail projects are, by their nature linear, with fairly defined, narrow corridors through urban areas. This linearity creates both advantages and difficulties, particularly in dense urban cities. It creates important challenges when it comes to identifying social impacts, which can take on many forms and change from

one segment or station to another. At the macro level, analysis of corridors and segments and their characteristics is fundamental to understanding the form and spatial structure of the city and its political, topographical, socioeconomic, and cultural context (Pérez-Brito and Acevedo-Daunas 2015). At the micro level, social assessment of stations should include analysis of potential impacts and risks related to land acquisition, resettlement, economic displacement, cultural heritage, visual impacts, traffic, and limited accessibility to transport services for different groups, particularly low-income and other vulnerable populations. Figure 14.1 illustrates this approach, providing some variables to consider at the segment (macro) and station (micro) levels.

Analysis of distributional impacts by sites and segments is needed to identify social impacts and risks, particularly on socioeconomically marginalized urban populations, as early as possible and to minimize their potential negative effects (see box 14.1). For example, social impact assessments (SIAs) are conducted to account for rapidly increasing property values and limited availability of land in downtown areas; extended informal settlements in strategic or vulnerable urban areas; limited recognition of the rights of residential and commercial renters or de facto occupants of urban spaces, such as informal street vendors; urban crime and violence; severe transportation bottlenecks; and interference with complex networks of public and private utilities such as water, energy, and telecommunications; among other social and environmental impacts. SIAs are conducted at the corridor and station level to gain a clear picture of local conditions and to evaluate different planning and design alternatives as part of prefeasibility and feasibility studies.

**FIGURE 14.1. Social Dimensions and Variables at Segment and Station Levels**



**BOX 14.1.****Example of a Corridor Assessment and Social Impact Inventory:  
Quito Metro, Ecuador**

In Quito, Ecuador, the nascent public Quito Metro Company conducted an in-depth social impact assessment (SIA) using public census and household data to analyze different urban scenarios and social dimensions. Such an assessment identifies the different key types of impacts, classifies their distributional effects, and locates where they are happening along the project's area of influence (see table B14.1.1). The spatial distribution of these social impacts was particularly important for Quito, a city that has a strong north-south directionality, with significant expansions of low- and middle-income population on both ends, but particularly to the south (see figure B14.1.1).

In terms of sociodemographics, the assessment was conducted to identify the distributional impacts on populations with different income levels, productive assets,

and types of employment. In terms of spatial distributions, the assessment considered different levels of access to basic services (schools, clinics, hospitals) and distance from specific rail stations. This assessment also accounted for population growth over time, densities, zoning, the concentration of (higher) education and health services in the northern part of the corridor, issues of affordability, and alternative transport options and services available to users. In particular, this analysis allowed the project to identify the segments and stations with the highest concentration of higher education and health facilities and to plan complementary investments—such as improvements to specific access roads, as well as the provision of additional public transport (feeders), parking, and pedestrian walkways—to support higher demand.

**TABLE B14.1. Illustrative Types of Social Impacts and Their Distributional Effects**

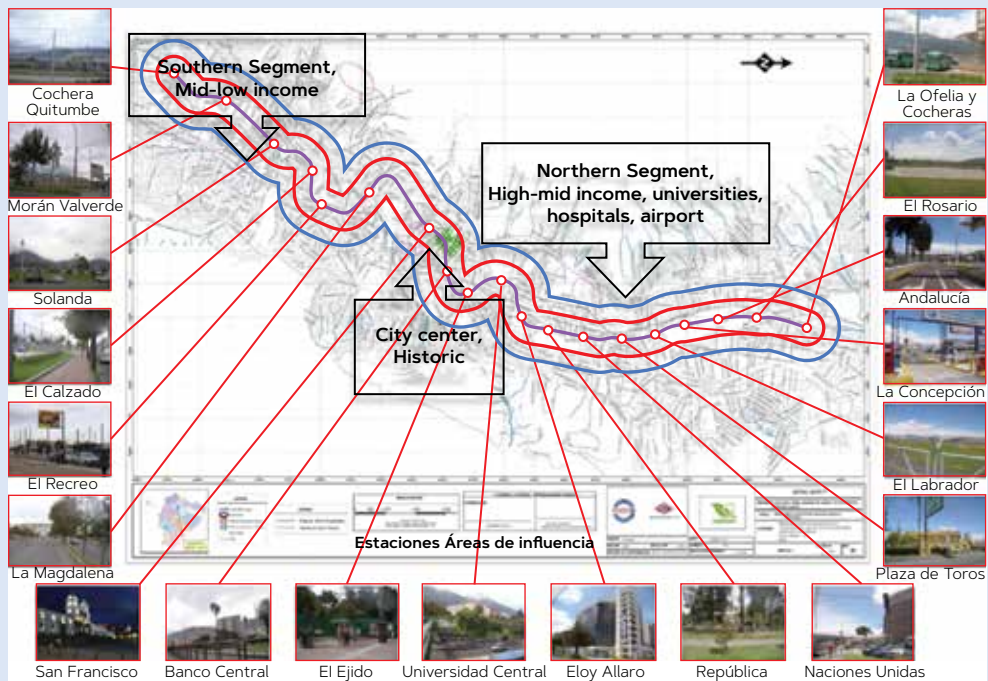
CATEGORY	DESCRIPTION	DISTRIBUTIONAL EFFECTS		
		SPATIAL	TEMPORAL	SOCIODEMOGRAPHIC
Resettlement	Land acquisition, resettlement, relocation, and loss of shelter	Four stations and other metro facilities	Construction phase; in most cases, the impact is permanent	Dense, low-income areas
Economic displacement	Limited access to business—assets with different issues: (a) limited space for parking; (b) no space for loading and unloading; (c) limited access to pedestrian traffic, customers	All stations, construction areas; severe in five stations	During construction; temporal impacts depending on type of construction technique	Mix of formal and informal commerce

*(box continues next page)*

**BOX 14.1.****Example of a Corridor Assessment and Social Impact Inventory:  
Quito Metro, Ecuador** *(Continued)***TABLE B14.11. Illustrative Types of Social Impacts and Their Distributional Effects**  
*(Continued)*

CATEGORY	DESCRIPTION	DISTRIBUTIONAL EFFECTS		
		SPATIAL	TEMPORAL	SOCIODEMOGRAPHIC
Economic displacement	Loss of assets—street vendors, seasonal market—no taking of private land	Near stations and expanded construction areas	Permanent and temporal—begins during construction and continues during operation	Low income, informal commerce
Cultural heritage	Relocation of historic landmarks near stations	Three stations	Temporary and permanent	High-income areas
Visual impacts	Ventilation shafts and tunnels, emergency facility near popular park	Near two stations	Permanent	Middle-income areas
Community engagement	Construction of stations in high-crime areas	Near two stations	During construction phase 1	Low-income areas
Traffic management	Reorganization of routes during construction in key transportation bottlenecks	Southern part of city and downtown	During construction	All
Multimodal integration	Reorganization of bus feeder routes to intermodal stations	Intermodal stations, northern part of city	Permanent	High-income bus operators and low-income bus drivers
Accessibility	Limited access to schools, health clinics, and hospitals by pedestrians and vehicles	Near two stations	Temporary: two cases; permanent: one case	High-income areas
Affordability	Cost of transportation (metro fares compared with previous expenditures on travel)	Communities particularly in southern and northern part of the city	Permanent	Low- and middle-income segments
Environmental and social	Cutting down of trees planted by communities; high opposition by neighbors	Around four stations	Permanent	Middle-income areas

*(box continues next page)*

**BOX 14.1.****Example of a Corridor Assessment and Social Impact Inventory:  
Quito Metro, Ecuador** *(Continued)***FIGURE B14.1.1. Basic Corridor Assessment by Segments and Stations: Quito Metro, Ecuador**

Source: © Metro de Quito. Reproduced with permission; further permission required for reuse.

**Land Acquisition and Resettlement**

Whether urban rail projects are at-grade, elevated, or underground, their construction requires the acquisition of land and the resettlement of current occupants. Underground alignments are often selected because they minimize the long-term social and economic disruption on the surface, but land on the surface is still needed for station areas and temporary staging areas (see chapter 11). Resolving land acquisition and resettlement issues before and during project planning is critical in preparing the project for construction. Ignoring or delaying land acquisition or resettlement issues could translate into significant additional costs. As Calden and Chamley (2010) explain, in the case of megaprojects,



the trick is to spend a good deal of money wisely in the early days of the project, especially when considering real estate acquisition and utility diversions, which pose important risks. In particular, time and resources should be invested up-front to understand the legal frameworks and property rights for real estate acquisition, expropriation, and application of eminent domain in the local context. Putting off getting the land for worksites or buying the buildings that need clearing does not save money; delaying acquisition costs more money in the long run because delayed acquisitions tend to result in delayed construction works (Calden and Chamley 2010).

The de facto occupants of urban spaces pose an important challenge to land acquisition and resettlement for urban rail projects. Considering the socioeconomic conditions of the landowner or tenant and understanding the main characteristics of the property to be acquired—who owns the land, who lives there, and how it is used—can help to identify possible risks associated with its acquisition and to determine appropriate mitigation measures. A property inventory with socioeconomic data on affected populations is extremely valuable for developing alternative layouts for track alignment and for identifying potentially affected properties. Depending on the expropriation or resettlement laws in each country, there are different residential occupation and commercial tenure arrangements for people with and without formal property rights. No matter who is conducting the land acquisition process, those without formal land rights may not be eligible for compensation. For families and individuals with formal property rights, most local laws specify procedures for addressing resettlement based on civil and expropriations laws, under which they are entitled to a range of compensation options.

A useful exercise during project planning is to classify households and business units affected by the implementation of a project into social and economic land use categories (for example, homeowners, tenants or renters, formal businesses, informal street vendors) and to define their corresponding legal status. Mitigation and compensation measures should then be targeted to each unit according to local requirements and practices, negotiations, and community engagement strategies for resolving conflicts (see box 14.2).

Resettlement solutions need to consider property values, limited availability of land in downtown and dense areas, individual's dependency on physical location for accessing public services and job opportunities, and informal residents and street vendors. In low- and middle-income countries, even the smallest urban rail project, by size and financing, can encounter complex resettlement patterns that may involve residents of informal settlements whose rights to occupy the land are not legally recognized. Infrastructure projects in urban areas pose different challenges than traditional rural resettlement. However, resettlement processes in

**BOX 14.2.****Targeted Resettlement and Compensation Planning for Different Household and Business Units: Lima, Peru Metro Line 2**

The Lima Metro Line 2 project defined multiple social units to target compensation benefits and mitigation measures and to allocate the limited resources of the resettlement action plan. The plan defined two social units: (1) household social unit (owner by title or possessor without formal title) and (2) economic social unit (differentiated by income-generating activities and by individuals who conduct formal or informal economic activities). By defining these social units, the project-implementing agency was able to develop specific guidance on compensation measures for displaced households and for businesses. By defining both social units and different types of compensation available through the resettlement plan, the project-implementing agency was able to map and communicate eligibility clearly to project staff and those affected by the project (see table B14.2.1).

The following types of compensation were available through the Lima Metro Line 2 resettlement plan:

- *Transactions.* Recognition of compensation due to the transactions necessary for selling or buying the acquired property and replacement property (new home)
- *Relocation.* Applicable to properties affected in their entirety; applies to homes and businesses that require mandatory temporary or permanent relocation
- *Dwelling reposition.* Secures a new residence of the same as or better characteristics than the current one or contributes to the acquisition of an alternative dwelling
- *Rent.* Designed for those who receive income from renting; keeps income flow for a determined period based on a socioeconomic census that certifies income over the previous six months
- *Economic activity relocation.* Compensation benefit to mitigate the impact of relocating economic activity or maintain income flow; applies to small and vulnerable formal and informal businesses

**TABLE B14.2.1. Resettlement Plan and the Social Units Eligible for Compensation**

SOCIAL UNIT	ELIGIBLE CRITERIA FOR COMPENSATION				
	TRANSACTIONS	DWELLING RELOCATION	DWELLING REPOSITION	RENT	ECONOMIC ACTIVITY RELOCATION
Household social unit	X	X	X		X
Economic social unit	X	X			
Household plus economic social unit	X	X	X	X	X
Economic social unit: lessor (property owner)	X			X	
Economic social unit: lease and sublease holder (renter)	X	X			X

Source: Adapted from Colombia, Ministry of Transport.

Note: X = eligible for compensation; blank = not eligible.

urban contexts are still managed by many project-implementing agencies in the way they have traditionally been handled in rural areas, where people can often be moved far from the project site. This mind-set does not recognize the tremendous impact of removing poor families from high-value areas (both monetary and intrinsic value) and sending them to peripheral and underserved areas. This impact is, sometimes, a very high social and political risk that can severely undermine project implementation (Roquet et al. 2015).

Urban land acquisition and resettlement issues require solutions different than rural projects. These solutions include integrating transport with urban and social issues such as housing and mixed land use (see chapter 16). In this context, the urban rail systems of Hong Kong SAR, China, and Japan illustrate good practice in using zoning readjustment and public-private partnerships to integrate urban planning, mixed land use, and participatory processes to resolve the need to acquire land (Lozano-Gracia et al. 2013). Projects in low- and middle-income countries can learn from these experiences and approach land acquisition and resettlement as opportunities to integrate the urban rail project with long-term goals for urban form and social integration. For example, during the construction of Lima Metro Line 1 in Peru, the resettlement of about 100 families to build an elevated station in a dense area represented a challenge that was turned into an opportunity for community engagement and mixed-income development. In this case, two different groups of residents were resettled in-situ in order to guarantee access to public services and minimize disruption of social-support networks and sources of economic activity.

### **Economic Displacement**

While any permanent displacement of businesses in station areas and along at-grade or elevated rights-of-way is handled during land acquisition and resettlement, another challenge for any urban rail project involves the temporary disruption and displacement of formal businesses and informal commercial activities due to construction. Economic displacement—loss of assets or access to assets that leads to loss of income or livelihood—as a result of construction is one of the most complex and contentious socioeconomic issues linked to urban rail development. In urban areas, such loss can affect formal as well as informal commercial activity. Economic displacement represents an important risk factor for any urban rail project, as (formal) business owners can become an important opposition group if not managed carefully.

#### *Formal Businesses*

To assess the economic displacement of formal businesses, census data should be collected on types and categories of business in the direct and indirect areas of

influence of the project. Depending on the level of detail and availability of such census data, this information should be complemented by on-site investigating of the income streams and economic conditions of business owners and workers in the project area. Such an investigation should try to identify potential income-generating opportunities for local business owners and workers that may be used as alternatives to direct compensation payments. Businesses in the direct area of influence of stations tend to have more negative socioeconomic impacts, depending on their type and reliance on street traffic, because construction fences often curtail pedestrian and vehicle access to businesses adjacent to the site (see image 14.1).

In many cases, individuals affected by economic displacement include formal business owners and shopkeepers, renters, tenants, wage laborers, and informal business owners occupying land they do not own. Depending on the metropolitan region, there are multiple residential occupation and commercial tenure arrangements for people with or without formal property rights. Specific mitigation measures should be developed to address the impacts on people without formal

**IMAGE 14.1. Residence and Business Access during Construction: Quito Metro, Ecuador**



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property rights, including residents of private land without legal title; tenants and subtenants; squatters on public and private land, rights-of-way, and other areas (including drains, riverbeds, and dumping sites); informal or semiformal business owners; and street vendors and marketplaces (World Bank 2004).

### *Informal Businesses*

The treatment of cases without formal rights and tenure over land becomes a point of contention in most urban rail projects. There is no easy solution to these challenges. The first step in addressing informal businesses and land tenure is to complete an inventory of such activity in the station or other construction site. Since these activities are poorly captured in traditional census or other data, alternative passive forms of data collection such as aerial drone imaging can

**IMAGE 14.2.** Use of Drones for a Rapid Assessment of Street Vendors near a Station Site: Lima Metro, Peru



Source: © Social Capital Group, Lima Metro. Reproduced with permission; further permission required for reuse.

help to establish quick and inexpensive estimates of the scale of informal business in the area (see image 14.2). These passive scans can then be complemented by in-person interviews or focus groups to understand those affected.

Many countries do not have clear legal provisions for handling informal commercial activity in project implementation. The problem arises when property rights are poorly established and multiple land occupation arrangements are made over time. In this context, the existence of individuals and businesses with customary rights, but no formal legal standing over the land, is a complicated legal topic. In practice, merely considering informal activity for a possible mitigation and compensation mechanism is problematic for public officials, who argue that, without a legal framework, any expenses related to informality are neither viable nor legal and may establish a negative precedent. However, what is not viable for sustainable and conflict-free project implementation is to believe that an urban rail system or any other urban transport project can be built without considering the fact that streets in cities, particularly in low- and middle-income countries, are used by the informal economy and are de facto marketplaces for the poor (Munoz and Paget-Seekins 2016).

In the special case of street markets, particularly where a high concentration of vendors extends beyond sidewalks and street corners, the need for relocation should be minimized as much as possible. If relocation cannot be avoided, there are two alternatives: (1) permanent relocation of the street market or (2) integration of the street market in the overall design of the rail station. These two alternatives have important implications for social risk management because relocation is a daunting task for even the most experienced project staff.

Temporary or permanent relocation of street vendors or markets requires identification of a new area. If the number of informal businesses to be relocated is large, this relocation should be considered as a separate project. It involves issues related to coordination and timing among different public and private entities, as well as negotiations with affected parties. In practice, relocation of informal economic activities is extremely complicated and therefore has to be undertaken well in advance of any construction activities. If relocation cannot be avoided, the following options should be considered:

- On-site relocation to nearby vacant land
- Self-relocation for those who prefer to settle in a place of their choice that perhaps offers better business opportunities
- Relocation to a project-selected site, which is, in most cases, the most common option (Mathur 2016). Informal businesses may accept relocation to a

different site if it provides the opportunity to continue or improve the vendors' livelihood if it comes with improved basic services (for example, electricity, water, or gas) or more formal rights to occupy the land.

### *Mitigation Measures during Construction*

Critical activities to minimize and mitigate economic displacement impacts during construction include the definition of construction areas and responsible parties for communication and stakeholder engagement, timing of construction works, clear advertisement of access restrictions, and direct and indirect compensation mechanisms.

Legal contracts or concession agreements should define the area for construction and clarify the roles and responsibilities of the project-implementing agency and the construction firms and private contractors. Determining who handles direct communication with affected households and businesses is an important step in reducing the potential risk for conflict. In general, it is good practice to set up communication channels and define grievance mechanisms for handling complaints. In many projects, depending on the institutional arrangements and coordination among key stakeholders, direct communication with affected parties is led by municipalities, ministries of transport, or contractors.

In many cases, street closings are scheduled in advance and before construction begins. Flexibility of closing dates can help with community engagement, especially during difficult negotiations with business owners. Furthermore, setting construction schedules that allow work to proceed during the night and on weekends can also help to ease the impact on business owners. Above all, careful staging of construction works to minimize construction time at any single site is critical for reducing negative social impacts, particularly economic displacement (see chapter 11).

Construction work represents different types of access restrictions for different businesses and households. Basic services such as health centers, schools, and churches deserve special treatment (see box 14.3), but the rule of thumb is to guarantee access to business as much as possible and to identify alternatives during construction. Alternatives include assistance and space to place signs and advertising for customers, such as "Yes, We Are Open During Construction," to facilitate new access roads, to adjust or change construction areas, and to develop direct and indirect compensation mechanisms or assistance in the form of social programs that target the affected parties. Examples of these mechanisms include agreements with businesses to supply products and services to construction firms; temporary or permanent relocation of businesses to nearby areas; job creation associated with the areas affected by construction; and tax breaks during construction to alleviate any impact on business.

**BOX 14.3.****Relocation of No. 28 Junior High: Nanchang, China**

During the site survey and early social impact assessment (SIA) for the Nanchang Rail Transit Line 2 corridor project, it was determined that construction and property development of Qingshanlukou Station required the demolition of major teaching facilities of Nanchang No. 28 Junior High School. In developing the resettlement action plan for the project, the project management office and the Expropriation and Compensation Office of Donghu District worked with the Nanchang Education Bureau, Education Bureau of Donghu District, No. 28 Junior High, and Nanchang Education College to reach an agreement to resettle No. 28 Junior High in the adjacent facilities of Nanchang Education College. The new facilities are no

more than 1,000 meters from the former location of the school, meaning little disruption to the commuting habits of teachers, students, and student families. The school was relocated during vacation so that classroom schedules were not disrupted. Finally, Nanchang Education College was already equipped with comprehensive resources, including multimedia and audiovisual classrooms, a computer room, laboratories, electronic reading rooms, a network center, classrooms, a cafeteria, and a sports ground. This meant that the new location was fully equipped for No. 28 Junior High to start normal teaching and learning activities as soon as the move was completed (NCRT Project Management Office 2013).

*Adding Value for Local Communities*

In addition to mitigating negative impacts during construction, the project-implementing agency should consider how to build in long-term value for local businesses in the planning and design of the project. For example, the project could include improvements of the premises or business areas such as better access to new urban rail stations, pedestrian walkways and plazas, and renovations of facades, among others. These improvements are particularly important in station areas and are mutually beneficial for both the community and the project-implementing agency. Highlighting how these longer-term improvements can compensate for the inconveniences generated during construction offers a crucial opportunity for stakeholder engagement and coalition building.

**Visual Impacts**

Whether the urban rail project is at-grade, elevated, or underground, visual impacts should be considered, particularly in the case of rail stations and other major structures such as pump and ventilation wells and emergency exits. An important task is to define the urban rail system's visual character in terms of scale, form, and materials, considering the urban context of stations and integration with public space (FHWA 2015):

- *Scale* refers to the length of rail lines as well as the number of stations and their location within the city.



**IMAGE 14.3.** Downtown Station Integrating Brick Materials, Colors, and Texture to Minimize Visual Impact and Increase Compatibility with Existing Architecture: Metro de Medellín, Colombia



Source: © Metro de Medellín 2016. Reproduced with permission; further permission required for reuse.

- *Form* refers to station designs and how they are integrated into the urban landscape.
- *Materials* refer to the colors and textures used in the physical construction and their compatibility with the visual character of the surrounding area (see image 14.3).

Beyond its character and attributes, an urban rail system's visual impact is measured against the changes it brings to the existing environment and the sensitivity and degree of those impacts on viewers.

### **Cultural Heritage**

Cultural heritage refers to any natural or man-made areas, structures, features, or objects valued by a people or identified to be of spiritual, historical, or archeological significance (Quiroga and Milewski 2007). Cultural heritage assessments for urban rail projects include treatment of not only archeological remains, but also paleontological and historical findings, including architecture and

**IMAGE 14.4.** Excavation of Suspected 1665 Great Plague Pit at the Liverpool Street Site: Crossrail, London, United Kingdom



Source: © Crossrail, Ltd. Reproduced with permission; further permission required for reuse.

landscapes such as colonial city centers, buildings, and monuments with cultural and scientific importance. Landmarks, sites, or street features where important historic events took place can be considered living heritage. An urban rail project's construction and operation can extend into places of value and, if not properly mitigated, damage historic and culturally significant buildings, parks, archeological sites, and sacred lands such as cemeteries. Therefore, the management of cultural heritage in urban rail system development is critical.

Important archeological discoveries have been made during construction of urban rail systems around the world (see image 14.4). In fact, archeological excavations and the protection of historic and cultural assets on the surface have defined the architectural and design features of the metro systems in Athens and Mexico City. International policies and procedures are in place for managing the impacts on cultural heritage, particularly those recognized by the United Nations Educational, Scientific, and Cultural Organization (UNESCO). World Bank safeguards requirements provide guidance on (1) managing resources of historical and cultural value and (2) including chance-find procedures in environmental and social management plans for construction of tunnels and stations.

Similar to managing visual impacts, considering cultural heritage impacts for urban rail projects requires an initial assessment of the characteristics of cultural assets along the project's area of influence, including their uniqueness, irreplaceability, significant importance, value to communities, and spatial context. For urban rail projects, the spatial context of the location of cultural assets plays an

**BOX 14.4.****Examples of Cultural Heritage Assessment: Lima Metro, Peru and Quito Metro, Ecuador****A dedicated cultural heritage assessment: Lima Metro**

At the Lima Metro in Peru, the project-implementing agency completed a cultural heritage assessment as a dedicated addendum to the environmental and social impact assessment (ESIA). This cultural heritage assessment classified all pre-Columbian archeological areas (*huacas*) and historical buildings and monuments along the area of influence of the rail lines. The area around the planned Paseo Colón Station was deemed of particular cultural heritage importance due to the number of historic buildings with a similar architectural style.

Following the cultural heritage assessment, the project-implementing agency developed an inventory of historical, colonial, and republican-era buildings in the area around Paseo Colón Station to assess potential direct impacts and to meet key requirements of the Ministry of Culture and the municipality. This in-depth assessment identified cultural patrimony assets in the area of the future Paseo Colón Station, including the Plaza Bolognesi, Museum of Italian Art, Museum of Art of Lima, and Park of the Exposition. This detailed cultural heritage information enabled the project-implementing agency to consider design alternatives—such as the depth of tunnels and the construction methods used for

tunnel segments and stations—that would reduce potential impacts on any historical and cultural buildings on the surface.

**The importance of detailed archeological investigation: San Francisco Station, Quito Metro**

To detect potential risks and identify impacts of the project on historical and cultural resources, it is critical to develop a census of historical buildings and archeological sites. Such an investigation can be based on national registries, when available, but more often must be conducted as part of the project. At the San Francisco Station in the Quito Metro, many archeological and technical studies and exploratory excavations were done well before construction began to avoid any direct contact with relevant archeological sites. Initial studies included detailed inventories of historic buildings as well as geotechnical and hydrological studies. In general, although sites or buildings may be identified by surface remains or suggestive topography, the characteristics of a site and its cultural importance cannot be identified based solely on surface examination. Therefore, initial surface studies and inventories should be complemented by direct excavations involving archeological experts at particular sites identified through the inventories (see images B14.4.1 and B14.4.2).

*(box continues next page)*

**BOX 14.4.****Examples of Cultural Heritage Assessment: Lima Metro, Peru, and Quito Metro, Ecuador** *(Continued)***IMAGE B14.4.1. Archeological Surface Studies at San Francisco Station**

Source: © Carlos Pérez-Brito. Reproduced with permission; further permission required for reuse

**IMAGE B14.4.2. Direct Excavation of Archeological Findings at San Francisco Station**

Source: © Robert Montgomery. Reproduced with permission; further permission required for reuse.

important role in design and construction because a structure could have a significant visual impact on the character of the area. Depending on whether construction sites are within UNESCO World Heritage Sites, cultural heritage assessments for urban rail require compliance with national and international regulations for archeological preservation and protection, particularly in cities with high expectations for findings and a long history of human settlements. Comprehensive historical and archeological studies before construction work begins and careful planning and coordination of construction are also required (see box 14.4).

**Gentrification and Changes in Neighborhood Composition**

The lack of an integrated approach to improving transport services and developing sufficient and equitable housing has, in many cases, resulted in the urban poor being pushed farther from centers of economic and social activity (Litman 2016). The term “gentrification” has been used in the United States since the 1970s to describe the changes in neighborhood composition and the displacement of lower-income households as land values increase around new rapid

transit developments that are not accompanied by inclusive and sufficient land use planning and residential development.

Although land value increase offers an opportunity for the city to capture new sources of revenue to reinvest in affordable housing and transit-oriented development (see chapter 16), the potential for gradual displacement of lower-income, transit-dependent residents is often overlooked during transport project planning (Barton 2016). Improving access to public transport services drives up property values, which can disproportionately affect low-income households. A poor household can end up being asset rich and cash poor because the urban rail line brings an increase in value of the household's property but not in their income. In other words, properties adjacent to the rail project might increase in value, but the income used to pay additional taxes is stagnant unless higher income households move into the neighborhood. Although increasing property values is beneficial for land value capture and other financing mechanisms, the gentrification that can result should not be ignored.

Project-implementing agencies have a poor understanding of gentrification and displacement of low-income households due to improvements or investments in new neighborhood infrastructure. The complexity of gentrification and the need for specific mitigation measures to address it present a challenge in managing the social impacts and risks of urban rail projects. Further analysis is needed to understand the dynamics of gentrification, to identify good practices, and to incorporate them in the design and implementation of urban rail projects, particularly in a context of growing urbanization.

**TABLE 14.1. Indicators for Analyzing Gentrification and Changes in Neighborhood Composition**

INDICATOR	DESCRIPTION	POTENTIAL IMPACTS	DATA SOURCE
Change in property values and rent	Sales value, property value, and rent prices	Lack of housing and transport affordability; longer travel times	Local government tax authority
Neighborhood investment	Number of building permits and renovation permits	Increase in land values and rent prices	Jurisdiction's building or planning departments
Change in tenure and demographic changes	Demographic data on in- versus out-movers (race, ethnicity, age, income, employment, educational achievement, marital status)	Changes in neighborhood dynamics and social networks	Census, voter registration, real estate directories, surveys, driver's license records
Investment potential	Neighborhood and building characteristics (for example, age and square footage, and improvement-to-land ratio)	None	Tax assessor, census, deeds

Source: Modified from Zuk et al. 2015.

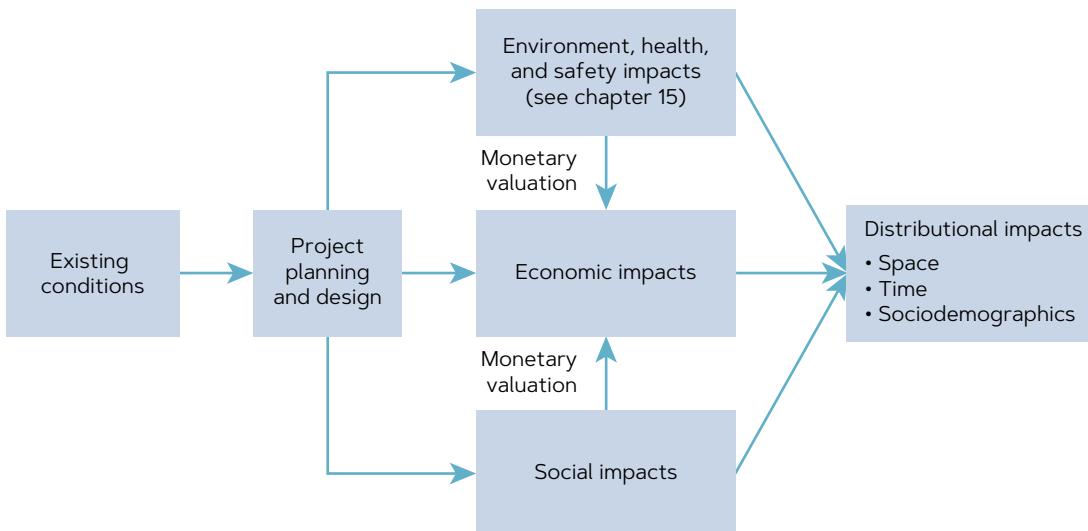
Table 14.1 identifies a series of indicators that are useful for detecting neighborhood changes that could lead to gentrification and other negative social impacts. The key to combating these negative impacts is to take an integrated approach, coupling the planning of urban rail infrastructure with sound land use and development planning around stations (see chapter 16).<sup>1</sup>

### Methods for Assessing and Mitigating Social Impacts

When it comes to urban rail projects, social impacts need to be identified at different scales; aggregate impacts along corridors should be disaggregated by segment and station. Segments or stations should be analyzed separately, accounting for each project area's unique environmental, social, and economic characteristics to identify potential distributional impacts with regard to different sociodemographic groups, space, and time (see figure 14.2).

Project impacts rarely fall homogeneously across an urban area. Their effects are often distributed unequally in space (stations, neighborhoods), in time, and across different social groups (age, income, gender, ability). For this reason, they are better identified and understood when analyzed as part of a broader appraisal framework (Jones and Lucas 2012). Although many tools and rating systems are available for considering social and other aspects of sustainability in

**FIGURE 14.2. Assessment of Distributional Environmental, Social, and Economic Impacts**



Source: Adapted from Jones and Lucas 2012.

**BOX 14.5.****Guides and Rating Tools for Sustainability of Infrastructure and Transport Projects**

In recent years, there has been a proliferation of guides and rating tools aimed at improving sustainability of infrastructure projects. However, only a few are widely known and used. These include the following (Pollalis et al. 2012):

- Comprehensive Assessment System for Built Environment Efficiency (CASBEE), a method for evaluating and rating the environmental performance of buildings and the built environment (<http://www.ibec.or.jp/CASBEE/english/>)
- Leadership in Energy and Environmental Design (LEED) (<https://www.usgbc.org/leed>)
- Cascadia (<https://access.living-future.org/cascadia>)
- Green Globe, a global certification for sustainable tourism (<https://greenglobe.com/>)

Transport agencies, particularly in the road sector, have developed more specific tools, including the following:

- Envision (<https://sustainableinfrastructure.org/>)
- CEEQUAL, an international evidence-based sustainability assessment, rating, and awards scheme for civil engineering (<http://www.ceequal.com/>)
- The U.S. Federal Highway Administration's Infrastructure Voluntary Evaluation Sustainability Tool (INVEST), a web-based self-evaluation tool composed of voluntary sustainability best practices (called criteria),

which cover the full life cycle of transportation services, including system planning, project planning, design, construction, and operation and maintenance (<https://www.sustainablehighways.org/>)

- Greenroads Rating System, a simple way to measure and manage the sustainability of transport projects that goes above and beyond minimum environmental, social, and economic performance measures and is evaluated by an independent, expert, third-party review (<https://www.greenroads.org/publications>)
- GreenLITES, a self-certification program that distinguishes transport projects and operations based on the extent to which they incorporate sustainable choices; it is primarily an internal management program for the New York State Department of Transportation to measure performance, recognize good practices, and identify room for improvement (<https://www.dot.ny.gov/programs/greenlites>)

The private sector has also developed a few approaches to assessing sustainability and social inclusion issues in projects such as Shared Value and Equator Principles. In addition, the International Finance Corporation's Performance Standards are used to safeguard vulnerable populations, mitigate potential negative impacts from infrastructure development, and provide a formal communications channel for those affected by the project.

**BOX 14.6.****The World Bank Environmental and Social Framework**

The World Bank's Environmental and Social Framework approved in 2016 provides environmental and social standards designed to avoid, minimize, and mitigate adverse impacts from World Bank-supported investments. It is the first policy that requires a separate social impact assessment (SIA); it places a stronger emphasis on broader social issues such as social inclusion, gender, and labor and working conditions and introduces free prior and informed consent for indigenous peoples. The framework also integrates a risk management approach to projects with greater emphasis on stakeholder engagement, adaptive risk management, and the borrower's environmental and social management frameworks (World Bank 2016).

In particular, the framework outlines a five-step risk approach that considers

1. The nature of the urban rail project;
2. Third-party actions, such as interinstitutional coordination for social and environmental compliance;
3. Broader contextual risk that can be associated with specific legacy issues, such as lack of trust in public entities, political opposition, and conflict over public space;
4. Vulnerability or adverse impacts that may fall disproportionately on poor or vulnerable groups, for example, street vendors; and
5. Capacity and commitment that are critical to managing social and environmental issues of projects effectively and that include social management systems, a grievance redress mechanism, and reporting and supervision plans, among others.

In sum, the complex context of urban rail projects calls for having a flexible and adaptive social and environmental management system in which the level of effort for managing risks is proportionate to the degree of risks in the infrastructure projects.

transport projects (see box 14.5), the key framework for any urban rail project should be the ESIA.

**Environment and Social Impact Assessment**

An ESIA is a critical tool for identifying and mitigating the potential negative impacts of any urban rail project. The completion of an ESIA is required for multilateral bank-sponsored projects in compliance with safeguards standards and policies (see box 14.6). The first step is to identify the potential negative impacts that infrastructure projects can generate through a robust and participatory SIA that can be combined with the ESIA or be a separate document. The SIA identifies the social issues of project development and their management plans and processes. It includes the effective engagement of affected communities in participatory processes of identification, assessment, and management of social



impacts (Vanclay et al. 2015). Social impacts include all issues associated with a planned intervention (for example, urban rail project) that affect or concern people, whether directly or indirectly, and that may accumulate over time (Vanclay 2003). These assessments can be done at different times during project planning and design. However, the goal is to identify all possible impacts and to minimize and mitigate potential future negative effects of the project before construction and operation.

To mitigate myriad social issues and potential cost overruns in urban rail projects, project-implementing agencies should consider SIA as early as project planning and sketch design. In some cases, an alternative route layout, station design, or location, if identified up-front with the input of local communities, can reduce the need for land acquisition or involuntary resettlement activities, lessen project opposition, and reduce the need to compensate communities for economic displacement.

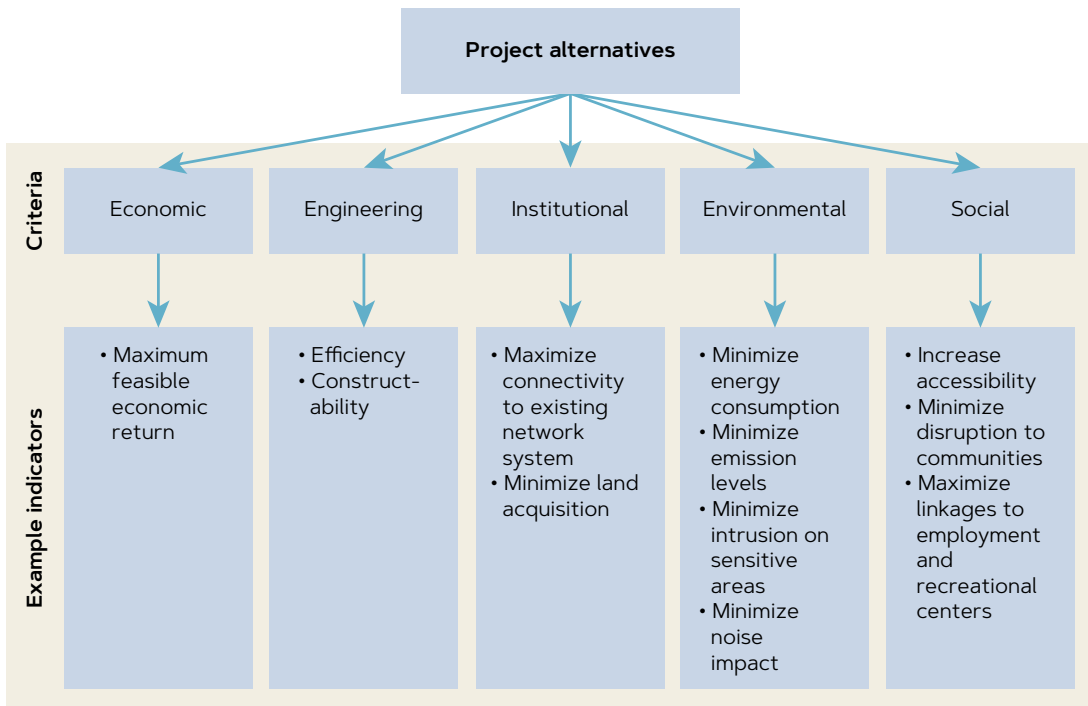
### *Benefit-Cost Analysis*

Benefit-cost analysis (BCA) and multicriteria analysis (MCA) techniques are used to assess the environmental and social impacts of transport investments. BCA during the alternative analysis and feasibility study step of urban rail project development tends to focus mainly on engineering, economic, and financial analysis and often overlooks social impacts, which are complex and, at times, difficult to monetize. In early project planning, identification of social costs is often limited to land acquisition costs. Chapter 3 discusses the utility of the BCA tool for understanding the positive and negative impacts of urban rail and other rapid transit projects. For assessing social impacts at a more detailed and disaggregated level, MCA is more suitable than BCA. This is because BCA only includes monetary values, while MCA can include both qualitative and quantitative considerations, better describing the nature of most social and environmental effects that are sometimes difficult to monetize.

### *Multicriteria Analysis*

The use of MCA techniques that give equal considerations to social, institutional, economic, and engineering aspects of urban rail projects can minimize negative social issues, including land acquisition (Sharifi et al. 2006). Figure 14.3 illustrates the various economic, engineering, institutional, environmental, and social considerations that go into developing an MCA and presents a series of potential alternatives to guide project-implementing agencies to make the most adequate decisions for planning, constructing, and operating urban rail projects.

MCA techniques require detailed studies for each segment of the urban rail line and its area of influence. For each segment, an MCA represents major project

**FIGURE 14.3.** Analysis of Project Alternatives under a Multicriteria Analysis Framework

Source: Adapted from Sharifi et al. 2006.

objectives, integrates different socioeconomic baselines, and prepares inventories of physical, social, and cultural properties and environmental features. Although MCA analyses are essential for understanding trade-offs between economic and engineering considerations and environmental and social impacts, they often require varied and extensive data. Project-implementing agencies in metropolitan regions undertaking their first urban rail project may be lacking such data or the available data may be obsolete. The existing data sources have to be investigated as a first task of the various analyses. In some cases, project-implementing agencies may have to wait for the results of new surveys; in others, they may have to collect new data themselves, which requires time and resources.

### **Environmental and Social Management Systems**

An ESMS is a structured tool comprising a set of policies, procedures, and processes to manage environmental and social risks and impacts. ESMS is an iterative process of reviewing, correcting, and improving the way a project's risks are

**TABLE 14.2. Main Components of an Environmental and Social Management System**

COMPONENT	DESCRIPTION
Policy	Summarizes the commitment that the project-implementing agency and/or contractor has made to managing environmental and social risks and impacts and establishes the expectations for conduct in all related aspects of the project; policies may refer to key national laws and internationally recognized standards (for example, International Finance Corporation Performance Standards)
Identification of risks and impacts	Identifies the potential negative environmental and social impacts in order to develop the appropriate strategies to address them
Management programs	Employs action plans and procedures to avoid, minimize, or compensate for the risks and impacts that were identified
Organizational capacity and competency	Entails having trained, committed people, with adequate resources
Emergency preparedness and response	Ensures preparedness to respond effectively to prevent and mitigate any harm to workers, community, and the environment
Stakeholder engagement	Entails engaging with affected communities to identify and manage negative impacts; is an opportunity to build trust, credibility, and support and also to identify opportunities to enhance positive impacts
External communications and grievance mechanisms	Refers to establishing and maintaining a publicly available, easily accessible channel for stakeholders to contact the project (phone number, e-mail, website); grievance mechanisms are put in place to establish a way for individuals or groups affected by the project to register an inquiry, a concern, or a formal complaint
Ongoing reporting on affected communities	Refers to keeping affected communities informed of what the project is doing, which is a critical element for building and maintaining positive and productive community relations
Monitoring and reviewing	Checks the system and allows management to make adjustments

Source: IFC 2014.

managed (IFC 2014). Its basic components aim to assess, control, and improve environmental and social performance of the project on an ongoing basis (see table 14.2).

### Environmental and Social Management Plans

The environmental and social management plan is a tool used to manage environmental and social issues. The ESMP defines the specific environmental and social management procedures and activities for different components of the project and different project stakeholders, accounting for any relevant national and local laws and regulations and concession contracts. Where there is international financing, the ESMP may also include the standards of the financial

**BOX 14.7.****The Value of Managing Social and Environmental Risk in Infrastructure Projects**

Approaching environmental and social risk management as a fundamental dimension of sustainable project development unlocks significant value for the project. First and foremost, adequate social and environmental risk management can facilitate attaining the social license to operate, which can result in lower business costs. In addition, it can reduce project delays, cost overruns, and reputational risk to investors (Stapledon 2012).

In Latin America, some countries have put in place relevant policies and procedures to address social sustainability in infrastructure projects, but there is still a long road ahead. The social sustainability dimensions of project implementation is still poorly understood or improperly analyzed. Social considerations are still of low importance to decision makers unless they pose a direct threat to project implementation (Geurs, Boon, and

van Wee 2009). As a result, feasibility studies in Latin America (as well as other regions) tend to focus on engineering as well as economic and financial analysis, often overlooking robust environmental and social impact assessments (ESIAs), alternatives analysis, stakeholder engagement, and free, prior, and informed consent.

Attention to these issues would help to avoid, reduce, or compensate for any negative impacts. In the World Bank's experience, feasibility studies sometimes fail to assess adequately project sites, unforeseen site conditions, including social and economic activities, existing utilities, and, most important, contextual risk. Feasibility studies need to integrate the project's unique environmental and social characteristics in order to analyze properly their potential distributional impacts on diverse social groups, both spatially and temporally.

institutions (for example, the World Bank's Environmental and Social Framework, International Finance Corporation's Performance Standards, and European Bank for Reconstruction and Development's Performance Requirements).

The social management plan can be a stand-alone document or be integrated with the environmental management plan. The social management plan of urban rail projects should consider all steps of the project development process, starting from planning and design. Detailed field investigations, impact identification, and social objective setting should be carried out during alternatives analysis and early project planning, which can reduce risks and identify management programs (see box 14.7). During construction, a series of plans should be in place to communicate how the project-implementing agency will manage social issues ranging from handling involuntary resettlement to addressing claims and complaints. Last, during operations, plans and programs should be monitored regularly.

## The Importance of Stakeholder and Community Engagement

Stakeholder engagement is critical for any project categorized as a megaproject—a large-scale investment characterized by complexity in both technical and human terms. Urban rail projects are considered megaprojects that integrate a significant number of stakeholders, including different levels of government and multiple public sector agencies, private sector partners such as construction companies, contractors and subcontractors, as well as communities with both residents and businesses. Stakeholder engagement is an ongoing communications process that involves disclosure of information, consultation with affected and nonaffected communities, and the establishment of communication channels and grievance mechanisms.

The quality and degree of stakeholder and community engagement and the degree of social risk can drive cost increases or even failure in urban rail projects. Identifying and systematically engaging with stakeholders by inviting their participation can provide an opportunity to improve project designs, mitigate risks, and build trust, credibility, and local support for the project. Furthermore, it can help to lower risks for rejection and potential disruptions that could lead to higher costs (IFC 2014). Maintaining a channel of communication presents opportunities to mitigate technical, financial, and political difficulties. Therefore, stakeholder engagement should be approached as an opportunity to add value by tailoring the project to the needs of local communities and as an avenue for proactively mitigating opposition and building support.

### *Stakeholder Identification*

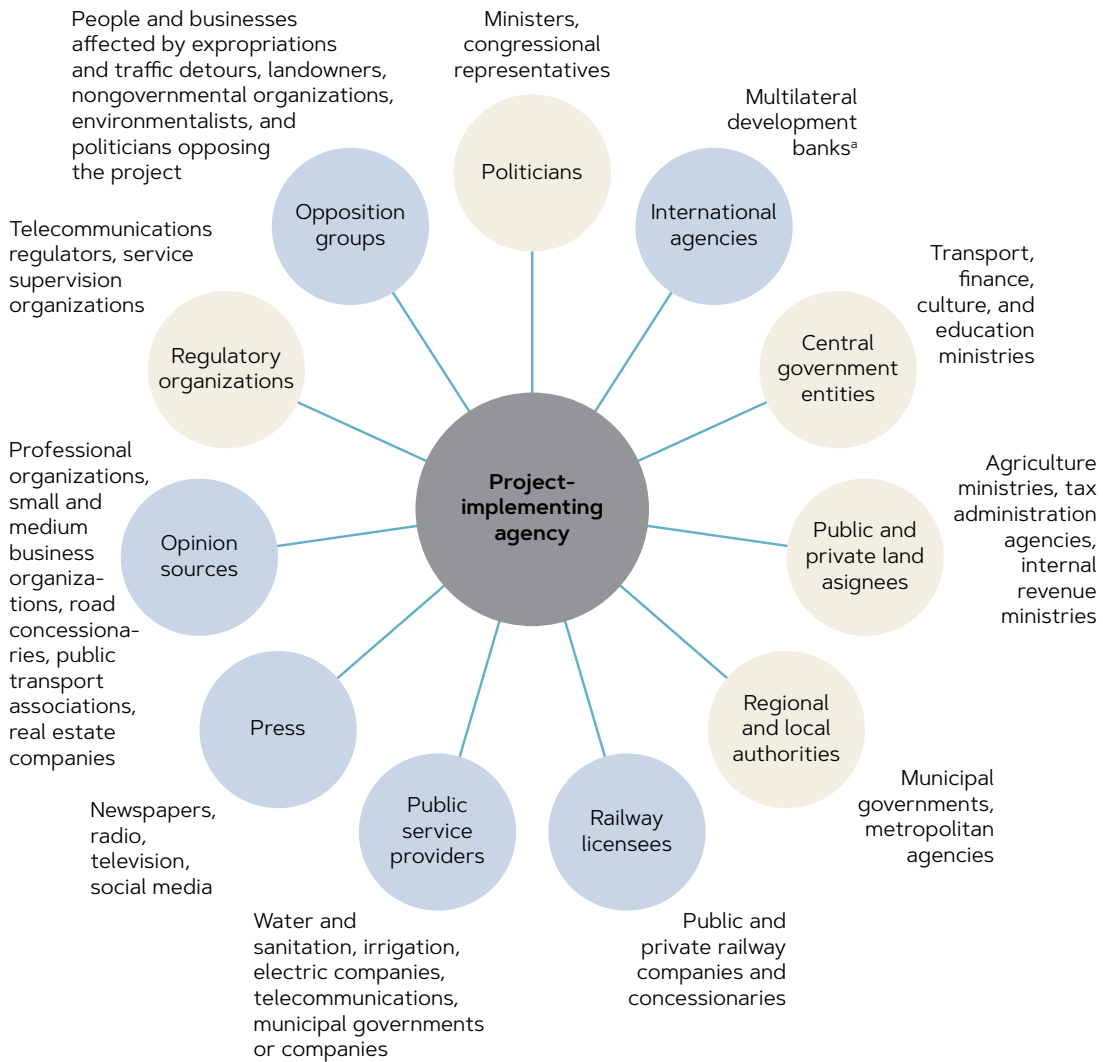
Identifying and mapping the main project stakeholders and their objectives is the first step to building a successful relationship and to maintaining strategic communication channels (see figure 14.4). Stakeholders—from nongovernmental organizations to subject matter experts—should be included in the planning and general development of the project.

The next step is to develop a strategic engagement plan, which will help to guide the project-implementing agency on how to engage with each of the stakeholders. The engagement plan should communicate positive and negative aspects of the project, providing stakeholders with enough information to understand how they will be affected by the project.

### *Strategic Consultation and Communications*

After engaging with the public, an iterative process of consultation, from early project planning through operations, becomes one of the most important aspects of project management. Consultation provides a way for potential

**FIGURE 14.4. Complex Stakeholder Relationships for an Urban Rail Project**



a. Multilateral development banks include the World Bank, International Bank for Reconstruction and Development, Development Bank of Latin America, Inter-American Development Bank, German Development Bank, and the French Development Agency.

beneficiaries (rail users) or cost bearers to raise their concerns and state their views about a specific project. Consultations are useful for identifying potential risks and opportunities for improving urban rail design, construction, and operation. For effective consultation with affected stakeholders, it is important to consider the following:

- Start early.
- Disclose meaningful and accurate information.
- Use culturally appropriate means to reach your audience.
- Provide opportunities for two-way dialogue.
- Keep track of issues raised and implement grievance redress mechanisms.
- Report back on how stakeholders' input has been used and considered (IFC 2014).

Communications play a central role during planning, design, construction, and operation of urban public transport systems. Strategic communications solutions that provide a systematic approach to communicating and marketing transport services to users and nonusers are often part of a stakeholder engagement plan. During planning and design, changing the public's perception of public transport is fundamental to building project support (ITDP 2017). During project construction, communications play an important role by providing updates on construction activities, alternative routes, and other traffic disruptions. Effectively planned and designed projects feature strategic communications plans to do the following:

- Inform affected citizens of relocation and economic activity displacement during planning.
- Inform and monitor construction impacts and traffic detours.
- Communicate changes in public transport services.
- Develop community outreach activities to communicate to citizens the process for receiving and managing complaints. Project-implementing agencies need to develop strategic communications plans before beginning construction of the urban rail line.

A successful strategic communications plan includes the use of mass media (television and radio) and social media, print communications (brochures and posters), and the implementation of a permanent information office and sites. In many cases, project-implementing agencies also provide communications

**IMAGE 14.5. Office of Information:**  
Lima Metro, Peru



Source: © Carlos Pérez-Brito. Reproduced with permission; further permission required for reuse.

**IMAGE 14.6. Permanent Information Booth:**  
Quitumbe Metro Station, Quito, Ecuador



Source: © Metro de Quito. Reproduced with permission. Further permission required for reuse.

services in strategic locations such as future stations or interregional bus stations (see images 14.5 and 14.6).

Developing relationships with the media can improve how customers view public transport systems (Weber, Arpi, and Carrigan 2011) and potentially attract nonusers. Strategic advice to transit operators for improving public relations and communications includes the following:

- Tailor the communications to journalists interested in different topics, such as health, environment, and operations.
- Invite journalists on study tours.
- Get endorsements from public transport champions.
- Anticipate and avoid criticism by giving communities as much information as possible and allowing two-way communication channels.
- Manage expectations of future riders without overestimating the benefits.
- Devise an extensive public relations plan to inform about project implementation (Weber, Arpi, and Carrigan 2011).

A successful model of strategic social and corporate communications and branding is Medellín's "metro culture" project (see box 14.8).



**BOX 14.8.****Building a Metro Culture: Medellín, Colombia**

The metro culture in Medellín is the result of the social, educational, and cultural management model that Metro has built, consolidated, and delivered to the city. The objective was to generate a culture based on shared principles, values, language, and behavior that represent responsibility and harmony. Since 1994, the Metro Company proposed to generate a new culture in the inhabitants of the Medellín metropolitan area, consolidating trusting relationships with neighboring stations and subway lines to generate a sense of belonging, caring, and preservation of the rail system. The Metro system's goal was to become not only a transit operator, but also an agent of transformation for mobility in the city.

This model was created to build a new civic culture—living together in harmony—featuring good behavior in (and out) of the transit system, solidarity, respect for basic rules for the use of public space, and self-respect, among other things.

The creation of such a culture has resulted in a citizen philosophy that incentivizes respect in the use of public space, respect for others, and a sense of harmony in the city (see image B14.8.1). Metro de Medellín even goes a step further, providing training for users to incentivize good behavior, promoting help to and respect for others, providing cultural events to educate users and nonusers, and holding other community events to incentivize and reinforce the metro culture.

**IMAGE B14.8.1. Passengers Respectfully Waiting for a Metro Train: Medellín, Colombia**

Source: © Metro de Medellín. Reproduced with permission; further permission required for reuse.

Developing an effective communications plan can be extremely useful during operations to inform users about the features of urban rail services and to explain service disruptions. For example, developing good narrative and visual communication materials can inform urban rail users about a malfunctioning elevator and let them know that the operator is working hard to repair it. Riders are more likely to tolerate inconveniences if they are informed and feel that their needs are being considered.

## Conclusions and Recommendations

Managing the social impacts of urban rail projects presents considerable challenges, but also opens up rare opportunities for engaging local communities to add value to project designs and garner project support. Project-implementing agencies and decision makers need to address and manage stakeholder communication and social impacts from the early stages of the project. The socio-technical complexities of urban rail projects require strong social analyses, solid mitigation measures, careful monitoring, and rigorous management systems. Although multilateral financial organizations such as the World Bank can help their clients in this process, a commitment to social sustainability is required from all parties involved in the execution of rail projects. Social impacts of a project cannot be addressed as an afterthought; managing the social risks and impacts of urban rail projects is a priority, as demanded by the social contexts in which the projects are planned, designed, constructed, and operated. The following are some of the main recommendations for assessing social risks and impacts of urban rail projects.

*Urban rail projects feature considerable social impacts in their implementation given their linear and urban nature.* Urban rail projects are intricately linked with urban and spatial dimensions. For this reason, part of the social assessment should consider different impacts and risks across space (stations, neighborhoods), time (temporal impacts such as construction time, noise, labor influx), and population groups (age, income, gender, disabilities). These characteristics pose important challenges to identifying social impacts because they can take on many forms and vary from one segment or station to another.

*It is critical to identify and address potential negative impacts from urban rail projects early in the design process.* The goal is to avoid social impacts, to reduce negative effects where avoidance is not possible, and to implement activities that can restore, rehabilitate, or remediate affected environments and

social activities. Some of the most recurrent social impacts in urban rail projects include the following:

- Land acquisition and resettlement
- Economic displacement of formal and informal businesses
- Visual impacts
- Historical and cultural heritage impacts
- Changes in accessibility for various areas of the metropolitan region, times of day, or sociodemographic groups

***Addressing and managing social and environmental risks can reduce implementation barriers, delays, and costs.*** In many cases, urban rail projects overlook robust ESIA, alternative analysis, stakeholder engagement, and free, prior, and informed consent. In the World Bank's experience, feasibility studies sometimes fail to adequately assess project sites, unforeseen site conditions that include social and economic activities, existing utilities, and, most important, contextual risk. Paying attention to these issues can help to avoid, reduce, or compensate for negative environmental and social impacts.

***Multicriteria analysis is useful for capturing the social and environmental effects of urban rail projects that are difficult to monetize.*** To mitigate myriad social issues and potential cost overruns in urban rail projects, project decision makers and implementing agencies should consider developing an analysis of alternatives to reduce the need to purchase land or to carry out involuntary resettlement activities and avoid possible economic displacement. The use of MCA techniques that give equal consideration to social, institutional, economic, and engineering aspects of urban rail projects can effectively minimize important social issues, including land acquisition.

***Stakeholder and community engagement is of utmost importance for identifying and mitigating social impacts of urban rail projects and for building project support.*** Stakeholder engagement is a major topic in urban rail projects. These projects are megaprojects that integrate a significant number of stakeholders, from national and local government to private sector companies and communities. Stakeholder engagement is an ongoing process involving disclosure of information, consultation with affected and nonaffected communities, and the establishment of communication channels and grievance mechanisms.

***Implementation of an environmental and social management system is required for any urban rail project.*** The ESMS is a structured tool composed of

a set of policies, procedures, and processes for managing environmental and social risk impacts. The ESMS enables project-implementing agencies to continue the process of reviewing, correcting, and improving the way a project's risks are managed.

## Notes

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1. The World Bank and the World Resources Institute have recently published a learning module on how to leverage transit-oriented development, land value capture, and reinvestment in affordable housing to combat gentrification (<http://wricitieshub.org/sites/default/files/Module%207%20-%20Inclusive%20TOD%20Final.slides%26notes.pdf>).

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## ENVIRONMENT, HEALTH, AND SAFETY MANAGEMENT

Robert Montgomery

Urban rail projects provide a sustainable transport option that can contribute to economic development and provide other benefits to the community. However, these complex projects involve major infrastructure construction that requires a large labor force and significant operational facilities and activities. Thus, they can have significant environment, health, and safety (EHS) impacts and risks, which have to be managed carefully throughout the project development process. For this reason, EHS impacts must be assessed—along with social impacts (chapter 14), economic development and land use along the alignment (chapter 16), and climate resilience (chapter 17)—throughout the early steps of project development, including alternatives analysis (chapter 3), project planning (chapter 4), and design (chapter 5).

Executing urban rail projects in low- and middle-income countries poses special challenges to effective and efficient EHS management. These projects involve construction in densely populated areas, many of which have significant cultural heritage, archeological sites, and relatively limited public and green spaces that are highly valued by the community. In addition to the disruptive nature of construction in urban areas (see chapter 11), certain ambient environmental conditions—for example, traffic congestion, poor local air quality, and presence of contaminated soil and

*Photo:* Clearing the track of rubbish: India, 2015. *Source:* John Samuel via Flickr (CC BY-NC 2.0).

groundwater—can be key issues related to EHS management in urban rail projects. Finally, urban rail projects involve the participation of a wide range of public sector entities, private sector companies, and financial institutions, each with varying responsibilities or roles related to EHS management (for example, compliance with regulatory requirements or protection of the environment, workers, and community).

Sound EHS management of urban rail projects provides numerous benefits. These include (1) protecting natural resources, the environment, workers, and the community; (2) facilitating compliance with regulatory and contractual requirements in a more efficient manner; (3) providing more effective resolution of EHS problems; (4) increasing environmental benefits; (5) reducing project costs and financial risks; (6) reducing the use of materials; (7) improving pollution prevention; (8) improving community relations and project perceptions; and (9) improving viability for the financing of the project.

The goal of EHS management is to handle all EHS impacts and risks effectively and efficiently and to improve the environmental sustainability of the project. Integration of EHS aspects in all steps and decisions of project development is essential, starting with planning and design. The project-implementing agency completes thorough assessments of all potential direct, indirect, and cumulative EHS impacts, risks (technical and financial), and sustainability opportunities. A mitigation hierarchy approach for EHS management is recommended (1) to anticipate and avoid risks and impacts; (2) to minimize or reduce risks and impacts to acceptable levels where avoidance is not possible; (3) to mitigate such risks and impacts once they have been minimized or reduced; and (4) to compensate where significant residual impacts occur (World Bank 2016).

EHS management includes a range of components, including plans, procedures, monitoring and supervision, reporting, definition of roles and responsibilities, and establishment of appropriate terms and conditions in bids and contracts. These components are documented in the project's environment and social management plan (ESMP) and EHS management system (EHSMS), which is used to manage EHS aspects, fulfill compliance and financial obligations, and address risks and opportunities. An adaptive EHS management approach—in which various project details are defined and finalized over time—is recommended. EHS management adapts by responding to, correcting, and improving on the results of extensive supervision activities and data from EHS monitoring programs.

This chapter provides an overview of EHS management in urban rail projects, including assessment and management of potential EHS impacts and risks during project planning, design, construction, and operations. EHS and social

impacts and risks have to be managed continuously in an integrated manner. However, for this handbook, EHS management is presented separately in this chapter, while management of social aspects is presented in chapter 14. This chapter highlights key aspects of EHS management and overall sustainability related to urban rail projects in low- and middle-income countries.

## **Environment, Health, and Safety in Project Planning and Design**

EHS aspects need proper consideration throughout the project development process, particularly during planning and design. Participation of technically qualified EHS specialists in early project review and decision making is critical for obtaining adequate understanding, consideration, and management of project EHS impacts, risks, and opportunities. This participation should be ongoing and collaborative, involving other project specialists such as planners, engineers, and operators as well as financial, legal, and procurement teams. In cases where EHS technical capacity within the project-implementing agency is limited, external experts should be involved as early as project planning to ensure effective EHS participation. Decisions made during design—such as the chosen construction method (see chapter 11) and type of emergency response and monitoring equipment—can help to prevent, minimize, and mitigate potential negative EHS impacts and risks. Three important areas of EHS consideration during project planning and design—alternatives analysis, environmental sustainability, and EHS project-related costs and financial risk management—are discussed in the next section.

### **Alternatives Analysis**

Consideration of EHS during the analysis of alternatives is critical. Alternatives analysis includes alternative transport modes, routes and site selection (horizontal alignments), and vertical alignments and construction methods. The alternatives analysis is needed to determine the appropriate rapid transit system to meet future demand given the city's characteristics, based on various technical, EHS, social, and economic criteria (see chapters 3 and 14). This analysis must adopt a multicriteria analysis framework to capture both quantitative and qualitative benefits and costs of the different alternatives. During project planning, the assessment compares feasible project alternatives, including a no-build scenario, for their potential EHS and social impacts and risks and their economic and financial feasibility. EHS criteria are included in the terms of reference for project feasibility and alternatives analysis studies to ensure adequate consideration of potential EHS impacts, risks, benefits, and costs.

The following are examples of important criteria to include: (1) land requirements, especially for sensitive environmental areas, (2) archeological and cultural resources, (3) potential site contamination, (4) community perceptions, (5) materials management (for example, selection, use, reuse, and recycling), (6) use of energy and water, (7) environmental enhancements, (8) reuse and disposal of extracted soil, (9) innovative impact and risk mitigation and protection measures, (10) waste management, (11) reduction of temporary impacts (staging areas and haul roads), (12) contractor management, and (13) local employment.

Regarding EHS aspects, key alternatives to be assessed include (1) urban rail alignments; (2) station, ventilation, and emergency exit locations; and (3) construction methods for the stations and the track sections between stations (see chapter 11). Alternatives should be assessed to reduce potentially significant EHS impacts or risks. For example, the use of tunnel boring machines for underground construction in historic areas creates less vibration and ground settlement of buildings than other underground construction techniques. Minor station realignments can significantly reduce impacts on trees of patrimonial importance (see box 15.1). Additional alternatives might include avoiding or reducing impacts on archeological and cultural heritage sites, reducing the time of traffic diversions associated with station construction, and reusing and disposing of extracted soils.

Project planning needs to include an adequate estimate of the costs and benefits of EHS and environmental sustainability. Relevant EHS conditions need to be defined for inclusion in the project construction or concession bid documents and contracts for independent construction supervisors. Project financing—for example, from multilateral development banks or private commercial banks—should include clear EHS aspects.

### **Environmental Sustainability**

Project design is a critical step for integrating environmental sustainability actions into the project. Sustainable infrastructure design enables sound economic development, job creation, and the purchase of local goods and services; it also promotes more effective and efficient use of financial resources. Improved environmental sustainability can produce financial and economic benefits, such as reduced waste and use of materials (for example, energy or water), prevention of pollution, better labor management (for example, improved retention and productivity), and improved community relations and project perceptions (Hirsch, Montgomery, and Schirmer 2015).

Many options are available for improving environmental sustainability throughout the urban rail project development process. For example, significant

**BOX 15.1.****Environment, Health, and Safety Issues: Quito Metro Line 1, Ecuador**

In July 2013 the World Bank approved a loan for US\$205 million to support the construction and acquisition of equipment needed to implement Quito Metro Line 1. The project design improved urban mobility, increased access for public transport users, and reduced operational costs, while still mitigating environment, health, and safety (EHS) impacts:

- The alternatives design study proposed the use of public spaces (for example, parks and open spaces) for some station locations (see images B15.1.1), minimizing social and environmental impacts related to land acquisition and resettlement, which saved costs and time during preconstruction. Furthermore, the site rehabilitation planned for these stations after construction will provide improved public spaces and produce positive social and environmental benefits for local communities.
- The design also enhanced environmental sustainability by reusing significant amounts of excavated materials for constructing a park at the site of the old airport.
- Slight modifications in station location during final design—a collaborative effort between the design contractor and the project-implementing agency—reduced the number of affected patrimonial trees and thus reduced environmental impacts, costs, and community complaints.
- Implementation of a phased soil and ground contamination investigation, apart from the environmental and social impact assessment (ESIA) process, identified a significant environmental liability associated with one

**IMAGE B15.1.1. Use of Public Green Space (left) and Intra-Road Space (right) for Station Locations**

Source: © Robert Montgomery. Reproduced with permission; further permission required for reuse.

*(box continues next page)*

**BOX 15.1.****Environment, Health, and Safety Issues: Quito Metro Line 1, Ecuador***(Continued)*

station location. Adaptive EHS management provided a solution.

- Some delays were experienced in construction of the Plaza San Francisco Station, a United Nations Environmental, Scientific, and Cultural Organization (UNESCO) World Heritage site, due to significant archeological finds during construction. However, the project's adaptive environmental and social management plan and process accounted for and was able to respond appropriately to such finds.
- The project-implementing agency directly implemented portions of the environmental monitoring program, facilitating access to

financing due to its relatively strong EHS capacity.

The assessment also should evaluate alternative EHS mitigation measures for their capital and recurrent costs, suitability under local conditions, and associated institutional, training, and monitoring requirements. It should also consider different allocations of responsibilities for managing project-specific impacts and risks, such as preexisting conditions (soil and groundwater contamination and presence of archeological and historic sites), EHS monitoring, and management of interventions (see box 15.2).

*Source:* Adapted from Gesambconsult 2012.

*Note:* For more information, see the project documentation at <http://projects.worldbank.org/P116170/sao-paulo-metro-line-5-project?lang=en&tab=overview>.

**BOX 15.2.****Considering Environment, Health, and Safety Management Responsibilities: São Paulo Line 5, Brazil**

In 2010, the World Bank approved a loan for US\$650.4 million to improve the mobility of public transport users in the Capão Redondo–Largo Treze–Chácara Klabin corridor in São Paulo, Brazil. The World Bank supported the acquisition of rolling stock for the extension of 12 kilometers of rail and the associated electronic signaling systems.

The project procurement strategy divided construction into eight contracts, which were

awarded to eight different contractors. All of these contracts were subject to the project's environmental and social impact assessment (ESIA) and environmental and social management plan (ESMP). However, environment, health, and safety performance between contractors differed. Supervising eight contractors required more resources than supervising just one, and contractors often disagreed on who was responsible for the actions laid out in the ESIA or ESMP.

opportunities during construction include (1) the beneficial reuse of extracted soil (for enhancement or development of park or green space, construction projects needing fill material, and proper closure of mines), (2) waste management (for example, minimization, recycling, and reuse), as well as (3) reuse of water from groundwater pumping and storm water runoff. Other design decisions and the use of new technologies, processes, and products can provide long-term environmental benefits during operations, such as reduced consumption of energy through regenerative braking technology, the use of more environmentally friendly cement, asphalt, or base materials, or the use of renewable energy sources such as solar panels for station lighting (see chapter 5).

The project also should explore options for increasing the economic, environmental, and social benefits of the investment. These benefits include local employment and purchase of local goods and services. Another example is the improvement of parks and recreational areas not only in areas directly affected by the construction of stations, but also in public areas adjacent to the tracks. This improvement around urban rail alignments can have significant positive impacts on adjacent communities, even for citizens who do not use the new rail system (see chapter 16). During construction of stations, especially in areas of more significant cultural heritage, the opportunity should be taken to improve adjacent buildings and facades. Furthermore, station area enhancements such as repaving streets and pedestrian walkways can improve access to the new rail system and quality of life in the neighborhood. Actions can also be taken to improve microeconomic development in the vicinity of stations through support for nearby storekeepers. These positive impacts are important for some citizens near the project location, building community support and positive project opinions.

The terms of reference for the project design should require explicit consideration of environmentally sustainable criteria and actions. It is critical to create a culture within the project-implementing agency and its contractor regarding environmental sustainability and community engagement. Involving local communities and environmental activists and experts in the design discussion of even small mitigation measures can add significant value to a project, build larger support coalitions, and avoid costly disagreements and delays (see box 15.3).

### **EHS Project Costs and Financial Risk Management**

An accurate estimate of project EHS costs is needed to ensure adequate consideration of EHS impacts and risks in feasibility and alternatives analysis. It also is needed to inform budget decisions and project cost estimates, so that financial resources are adequate for managing EHS impacts and risks properly.

**BOX 15.3.****Protecting Endangered Species and Mitigating Environmental Impacts:  
Silver Line, Washington, DC, United States**

Over the summer of 2015, contractors working on the Silver Line extension to Dulles Airport outside of Washington, DC, learned that construction sites in the region had to be surveyed to see if they contained any northern long-eared bats roosting and raising their young. These bats, a recent addition to the U.S. Fish and Wildlife Service's list of endangered species, had been decimated by white-nose syndrome, a fungus that infects the environments where bats hibernate. Facing the possibility of a moratorium on construction to protect potential

habitats of the species, the project undertook a week-long nighttime survey in the construction sites, using nets to capture bats, identifying their species, and then setting them free again. The nightly vigils produced a lot of bats (see image B15.3.1), but not a single northern long-eared bat. Embracing their environmental responsibility and partnering with local scientists, the project received praise for being at the forefront of endangered species protection and avoided significant and costly delays to project construction.

**IMAGE B15.3.1. Bat Captured at the Dulles Airport Rail Yard Construction Site**



Source: © Dulles Metrorail Corridor Project; reproduced with permission.



A key to developing useful cost estimates is to consider the full range of potential EHS costs (Montgomery 2015):

- Anticipated EHS costs, consisting of capital costs (planning, design, and construction) and recurring costs (operation and maintenance [O&M]). Some of the key components of EHS costs are mitigation, monitoring, institutional capacity, training, regulatory compliance (permits), and insurance.
- Additional EHS costs, consisting of estimated costs to resolve an EHS risk event should it occur, such as a spill and accidents.

Various EHS risks can pose significant financial risks (that is, additional costs) that could affect the viability of the project. Box 15.4 provides some examples of potential EHS issues that can cause relevant financial risks (Montgomery 2014). These risks need to be identified and assessed, and this information needs to be considered by the relevant project decision makers.

#### **BOX 15.4.**

#### **Representative Financial Risks Associated with Environment, Health, and Safety**

- Higher capital expenditures or operating costs related to compliance with environment, health, and safety (EHS) standards or regulations
- Claims paid for damages to third parties
- Additional costs due to retraction of, or delays in obtaining, environmental permits
- Additional costs (including time delays) required to obtain modified or new environmental permits
- Recent or pending changes in EHS laws or regulations that require additional measures and thus entail higher costs
- Regulatory noncompliance that results in fines, penalties, project delays, or shutdown
- Environmental mitigation measures that fail to mitigate impacts adequately, thus requiring additional measures and expenditures
- Unforeseen environmental impacts that result in lawsuits or higher expenditures (for example, newly discovered cultural and historical sites, health effects on workers or third parties, and disposal of contaminated soil or groundwater)
- Poor labor practices that result in construction inefficiencies (higher unit costs of production) or out-of-pocket expenses to cover worker accidents and deaths
- Human health issues for workers and the surrounding community related to routine exposure and accidental or unplanned releases or discharges into the air or water
- Natural resource damage (including damage to flora of significant value) that must be remediated
- EHS accidents that may decrease production, reduce equipment value, or cause damage to workers or the environment
- Social issues and possible security-related problems that cause work stoppages or slowdowns, which can increase costs
- Public objections and protests, leading to delays in construction

The typical project ESIA, which many government entities use as the primary (or only) instrument of EHS assessment, normally does not fully or adequately identify all potential EHS risks (for example, soil and groundwater contamination and interference with public utilities). The effect and risk management of project EHS depend on the project and financial structure and type of financing (loan, guarantees, equity, or bonds). Additionally, the materiality of the financial costs or risks given the total project cost or investment and the designation of an entity to assume the financial risk (project entity or company, contractor, or financial institution) are key factors. The allocation of risk has to be defined within the project contract and financial structure, and not every party to the project will necessarily have a direct responsibility for or concern about an EHS financial risk. These conditions and other EHS risk mitigation measures are established in the project concession agreement, construction contracts, and loan agreements. Box 15.5 presents an example of EHS-related financial risks in an urban rail project in Brazil.

#### **BOX 15.5.**

### **Upgrading and Greening the Urban Rail System: Rio de Janeiro, Brazil**

In 2011, the World Bank approved additional financing of US\$600 million to improve operations and reduce the environmental impact of the urban rail system in the Rio de Janeiro metropolitan area. A main component of the project was the acquisition of new electric trains and asset maintenance to improve safety and increase efficiency.

Significant environment, health, and safety-related financial risks were present:

- Social and related conflicts in areas immediately adjoining the right-of-way (ROW) caused significant difficulties in carrying out track repairs.
- Ongoing illegal disposal of solid waste in the ROW resulted in significant additional costs for collection, disposal, and public education programs.
- Discharge of untreated domestic wastewater into the drainage along the rail (in ROW)

caused additional costs for remediating construction works and protecting worker health and safety.

- Additional time and costs were needed for rehabilitation of one station because the existing building was considered of historical (cultural) value.
- Wastewater from the rail car maintenance facility required pretreatment to meet regulatory requirements before being disposed in municipal sewer systems.
- Contaminated soil in existing rail car maintenance facilities had to be remediated.

By working with environmental and social specialists from the World Bank, the urban rail operations concessionaire was able to identify and manage these risks as part of project financing, preparation, and implementation.

Source: Adapted from Supervia 2008.

In addition, various project risks common to urban rail projects can have a direct and significant impact on EHS management, including increasing potential EHS risks or indirectly reducing the budget for EHS management. These risks might include changes in aspects of the project design, construction cost overruns that can reduce EHS management budgets, construction time delays that can increase EHS risks and impacts, delays in contract payments both to the primary construction contractor and to service and goods subcontractors, or changes in contractors (see box 15.6). Other factors include problems with security or safety in the urban environment immediately around project sites, natural disasters (for example, seismic activity, significant rainfall, and floods) (see chapter 17), and community complaints related to the project. Therefore, all project risks need to be monitored and considered as part of ongoing EHS project management (see chapter 7).

While significant changes in design or roles and responsibilities often lead to delays in project implementation, cost overruns, or EHS management issues, having some design flexibility can lead to reduced EHS impacts and risks and be an opportunity for engaging the community, building local support for the project, and identifying complementary neighborhood investments that can enhance the accessibility and economic development benefits of the urban rail project.

Associated with EHS cost estimates are recommendations to reduce anticipated costs, such as by implementing environmentally sustainable measures and approaches for managing the risk of additional EHS costs. Ideally, EHS cost estimates should be separated by item, and a responsible party (project-implementing agency, construction contractor, or operator) should be assigned to each. The basis of cost estimates should be stated, including what the cost does and does not include, what data are used to make cost estimates, whether future costs have been discounted, and potential uncertainties. Where cost uncertainties are significant, the project-implementing agency should consider additional monitoring or studies to reduce the possibility of cost overruns. In order to assist in bidding and preparing construction contracts, it is advantageous to state unit prices (for example, for pollution control equipment) and to provide suggestions for managing EHS risks that could be considered in the relevant project contracts.

Estimates of EHS costs have to build on detailed sources of information. In practice, EHS cost estimates developed early in the project development process as part of the ESIA are often too uncertain to make informed decisions regarding EHS management. Therefore, building EHS cost details and recommendations on more detailed design estimates is recommended, as EHS cost estimates are likely beyond the scope of a country's normal regulatory ESIA.

**BOX 15.6.****The Need to Maintain Environment, Health, and Safety Management through Project Delays and Changes in Contractors: São Paulo Metro Line 4 (Phase II), Brazil**

In 2010, the World Bank approved a loan of US\$130 million to integrate the rail system better with the bus system and to extend São Paulo Line 4 by 12.8 kilometers, adding four more stations. The program sought to improve mobility and access while also improving operations.

The project suffered significant delays, eventually leading the contractor to cancel the contract. As this process evolved, the environment, health, and safety (EHS) management budget was reduced, leading to a lack of full EHS mitigation and monitoring and an increase in EHS impacts and risks. As construction ceased, some of the worksites were left unmonitored and unprotected. Various EHS issues arose at these worksites, including (1) public health issues related to the control

of waterborne diseases due to standing water (such as dengue fever and Zika) and the appearance of disease vectors and urban pests (such as scorpions and rodents) due to waste and uncontrolled vegetation (see images B15.6.1) and (2) improperly stored chemical compounds, accumulation of solid waste, improper disposal of materials that could have been reused, and accumulation of hazardous waste and contaminated packaging. All of these EHS issues incurred additional costs and had to be resolved once the new contractor was retained. This experience highlights the importance of maintaining EHS management through any project delays and timely reallocation of EHS management responsibilities in the case of changes in contractors.

**IMAGE B15.6.1. Illegal Solid (left) and Liquid (right) Waste in Rail Right-of-Way**



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## Environment, Health, and Safety Impact and Risk Assessment

In order to develop project-specific plans and systems for EHS management, an assessment of the potential EHS impacts and risks is required. This section summarizes key aspects of the ESIA, which is a principal means of assessing potential environmental and social impacts and risks for urban rail projects.

### Environmental and Social Impact Assessment

An ESIA is a principal means of ensuring that projects are environmentally and socially sustainable and that environmental and social considerations inform the decision-making process. The project ESIA is an instrument for minimizing and mitigating negative impacts from project implementation, while maximizing long-term benefits of the urban rail system for local communities.

An ESIA assesses the environmental and social risks and impacts throughout the project development process. It includes (1) an accurate description and delineation of the project and any associated aspects; (2) a description of environmental and social baseline conditions at a level of detail sufficient to inform characterization and identification of risks, impacts, and mitigation measures; (3) an evaluation of the project's potential direct, indirect, and cumulative environmental and social risks and impacts; (4) an assessment of project alternatives; (5) an environmental and social management plan; and (6) a stakeholder engagement and communications strategy (World Bank 2013b, 2016). The ESIA is based on the project's detailed technical and design studies, including an evaluation of alternatives, geologic investigations, feasibility study, and project design.

A project's ESIA is the principal document for soliciting environmental regulatory licenses or permits as well as for obtaining financing from financial institutions. Therefore, the ESIA has to comply with all applicable in-country environmental requirements and should be developed to meet the policies and requirements of the financial institution that will finance the project. If it is prepared without meeting financial institution requirements, additional ESIA-related work may be needed, potentially causing delays and requiring additional resources for enhanced mitigation measures and monitoring programs. In this case, a supplemental ESIA or EHS action plan may be needed (see box 15.7).

Although the required content of an urban rail project's ESIA may vary by country, it is good practice to address each of the key components required by international financial institutions:

- *ESIA framework.* The ESIA should be developed with consideration of the requirements of international financial institutions, international standards, and good or best practices (Equator Principles Association 2013; World Bank 2016; World Bank Group 2007a, 2007b) (see box 15.8).

**BOX 15.7.****Supplemental ESIA or EHS Action Plan to Comply with Financial Institution Requirements: Lima Metro Line 2, Peru**

In 2015, the World Bank approved a US\$300 million loan to the government of Peru for construction of Line 2 and a section of Line 4 of the Lima Metro. The project's objective was to provide a major east-west axis to connect Ate with the Callao port area through the Lima City Center. It also included a branch to connect Line 2 with Jorge Chávez International Airport.

Peru's environmental regulatory agency required an environmental and social impact assessment (ESIA) that did not fulfill the environmental and social safeguard policies of the international financial institutions involved with the project. Their policies required the development of a complementary study (supplemental ESIA), which resulted in additional costs, issues with financing, and challenges with the environmental regulatory agency and the project's original environmental permit. The government agency responsible for contract supervision hired an independent supervisor that was given specific environment, health, and safety (EHS) responsibilities. This third-party supervision helped the project to demonstrate compliance with the EHS requirements of financing institutions.

In addition to this additional EHS supervision, the construction contract also called for the contractor to develop and present final designs for each project component and to propose enhancements to the approved environmental and social management plan (ESMP [part of the ESIA]) based on this final design. Additional enhancements to the project were to occur based on the results of contractually required technical studies (for example, groundwater studies). While both concepts were good approaches in theory, in practice, implementation did not result in the desired EHS management enhancements. The project experienced delays during final design because of a lack of coordination between the concessionaire and various government agencies with EHS responsibilities.

This experience highlights the importance of defining clear roles and responsibilities for EHS management and mitigation and for understanding and complying with national, local, and financial rules and regulations regarding EHS management from the beginning of the project.

*Source:* Adapted from Environmental Resources Management 2014.

- *Alternatives analysis.* At the time of ESIA preparation, most of the technical work on alternatives analysis already should be completed. An adequate summary of these studies needs to be included. The analysis should consider all relevant environmental, social, health, and safety risks, including the capital and recurrent costs of alternative mitigation measures and their suitability under local conditions.
- *Baseline conditions.* The baseline should include not only existing information or data, but also data collected as part of ESIA preparation in order

**BOX 15.8.****Environmental and Social Impact Assessment Good Practice: Nanchang Urban Rail Project, China**

In 2013, the World Bank approved a loan for US\$250 million to support the construction and acquisition of equipment for the Urban Rail Line 2 corridor in Nanchang, China. Given its nature, scale, and location, construction of the urban rail in Nanchang faced extensive environmental, social, and safety challenges. The environmental and social impact assessment (ESIA) addressed these challenges in an integrated way through screening and scoping, alternatives analysis, impact analysis, development of mitigation measures, public consultation, and monitoring (World Bank 2013a). Some lessons from this project's ESIA process are noteworthy:

- The cumulative impact assessment for this project was the first for an urban rail project in China. The assessment identified the sensitive receptors to noise or vibration and led to enhanced mitigation measures during design, changes that would have been too expensive or disruptive to adopt during operations.
- Nanchang Municipality established a project-leading group chaired by the vice mayor to ensure strong commitment, smooth communication, effective coordination, and efficient response to address key issues and concerns from the public and other stakeholders.
- The project took concrete steps to reinforce the institutional arrangement and capacity for safety management by allocating adequate resources, establishing clear responsibilities, and raising the awareness of risk and safety management among all stakeholders.
- Nanchang Urban Rail Company prepared its own method for risk management, which incorporated domestic specifications and the World Bank's environment, health, and safety goals. This document provides a systematic risk management approach covering the definition of risk, coverage, procedures, degree of risk, breakdown of responsibilities, and regular meeting and communication mechanisms.
- The resettlement plan was prepared based on extensive and in-depth public participation. Project information and compensation policies were disclosed in various forms and by multiple means. This practical plan and transparent process resulted in more harmonious land acquisition and house demolition (NCRT Project Management Office 2013).

*Source:* Adapted from World Bank 2013a and NCRT Project Management Office 2013.

to provide an adequate, representative, and project-specific description. Key environmental baselines required include meteorological conditions, air quality, noise levels, traffic levels, geotechnical conditions, natural hazards (seismic, faults, sink holes, flooding, hurricanes, and tornadoes), water resources (surface and groundwater), flora (especially trees, wetlands, and sensitive habitats), fauna, endangered and threatened species (including sensitive species and economically important species), natural

parks or protected areas, archeological resources, and cultural and historical resources.

- *Impacts.* The ESIA needs to quantify (through the use of mathematical models) key impacts such as noise, vibrations, traffic, air quality (dust and particulate material), and groundwater. These impacts should be compared with both local regulatory limits or criteria and internationally acceptable limits or criteria (World Bank Group 2007a, 2007b). The impact assessment needs to address indirect and cumulative impacts and consider associated facilities (for example, primary material supply sites or facilities, concrete plants, and extracted soil disposal sites).
- *Risks (contingencies).* The ESIA needs to include an adequate assessment of all EHS risks, including those posed to local communities and workers.
- *Stakeholder engagement.* Consultation with the public needs to satisfy the requirements of international financial institutions and good international practice, including disclosure of and consultation on the draft ESIA, adequate planning for stakeholder participation during construction and operation, and the establishment of appropriate communication channels and grievance mechanisms (see chapter 14).
- *Cost.* The cost estimates should address all mitigation, monitoring, and other measures.
- *General.* Adequate time schedules and budgets are needed to develop an acceptable ESIA to meet financial institution requirements and good industry practice.

### **Potential EHS Impacts and Risks**

The identification and assessment of potential EHS impacts and risks due to the project are a key step toward defining the impact and risk management strategy. This assessment needs to include the direct, indirect, and cumulative impacts of each EHS risk during each step of the project development process. Table 15.1 indicates key potential negative environmental impacts from urban rail projects.

As part of the ESIA for urban rail projects, certain impacts will likely warrant a detailed assessment, including the collection of field data or mathematical modeling:

- Inventory of trees that may be affected by the project, including species of potential significance (patrimonial)
- Investigation (literature review, including local laws and maps, and field research) for the presence of cultural, historical, or archeological sites in the area of direct and indirect influence of the project



**TABLE 15.1. Major Potential Direct Negative Environmental Impacts in Urban Rail Projects**

PROJECT STEP	POTENTIAL DIRECT EHS IMPACT
Construction	<ul style="list-style-type: none"> <li>• Elevated levels of particulate materials due to excavation and soil-related works</li> <li>• Elevated levels of air pollutants and greenhouse gas emissions (sulfur oxides, nitrous oxides, carbon oxides) from construction equipment and machines</li> <li>• Increased noise levels due to equipment, machines, and construction works</li> <li>• Increased vibrations due to tunneling and excavation works</li> <li>• Increased surface water contamination due to sedimentation from soil erosion or spills</li> <li>• Decreased groundwater levels due to groundwater pumping to allow for construction and impacts on nearby groundwater uses and possible subsidence</li> <li>• Increased traffic due to road closures and rerouting around construction sites and due to truck traffic to and from sites</li> <li>• Potential soil and groundwater contamination due to improper management of construction solid and hazardous wastes</li> <li>• Impacts due to extracted soil disposal, including truck movement, loss of disposal site capacity, and improper management of disposal site</li> <li>• Change in land use, temporary or permanent, at site locations (for example, stations, emergency evacuation)</li> <li>• Effects on soil stability or subsidence during tunnel excavation</li> <li>• Loss of flora (vegetation), temporary or permanent, at site locations, including trees of historical value</li> <li>• Impacts on fauna (animals) due to construction works</li> <li>• Impacts on protected areas (parks, green spaces) if sites are located there</li> <li>• Impacts on buildings and cultural heritage sites due to construction and tunneling works</li> <li>• Loss of or impact on archeological resources due to construction excavation works</li> <li>• Temporary loss of services (for example, potable water or wastewater disposal) due to relocation of utilities with site construction</li> <li>• Improper disposal of contaminated soil and groundwater</li> <li>• Worker occupational safety and health risks due to construction works (see image 15.1)</li> <li>• Community safety risks due to construction works</li> </ul>
Operation and maintenance	<ul style="list-style-type: none"> <li>• Elevated levels of air pollutants and greenhouse gas emissions from equipment and machines</li> <li>• Increased noise levels due equipment and trains</li> <li>• Increased vibration due to trains</li> <li>• Increased surface water contamination due to sedimentation from soil erosion or spills</li> <li>• Decreased groundwater levels due to groundwater pumping and impacts on nearby groundwater uses and possible subsidence</li> </ul>

*(table continues next page)*

**TABLE 15.1. Major Potential Direct Negative Environmental Impacts in Urban Rail Projects**  
(Continued)

PROJECT STEP	POTENTIAL DIRECT EHS IMPACT
Operation and maintenance (continued)	<ul style="list-style-type: none"> <li>• Improper solid and liquid waste management of rail car maintenance facilities</li> <li>• Potential soil and groundwater contamination due to improper management</li> <li>• Change in land use at site locations (stations and emergency evacuation)</li> <li>• Impacts on buildings and cultural heritage sites due to trains and movement of people at stations</li> <li>• Risk of emergency events (fires and explosions)</li> <li>• Worker occupational safety and health risks</li> <li>• Safety risks to users of rail project</li> <li>• Community safety risks around site facilities</li> </ul>

Note: EHS = environment, health, and safety.

**IMAGE 15.1. Heavy Machinery Presenting One Occupational Health and Safety Risk during Construction: Lima, Peru**



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- Inventory of potential existing or new sites for the disposal or reuse of extracted soil from tunnel and station construction
- Assessment of vibrations, including possible baseline monitoring at sensitive locations (buildings) and use of mathematical models to estimate potential effects

- Assessment of groundwater, including models to estimate the effects of groundwater pumping for construction
- Assessment of noise, including possible baseline monitoring at sensitive receptors and mathematical modeling to estimate potential effects
- Assessment of environmental liabilities due to soil or groundwater contamination (for example, due to gasoline stations and car or vehicle repair shops) at sites requiring soil excavation (see image 15.2)

Many potential direct environmental impacts and risks are typical of urban infrastructure projects and are localized, of short duration, and readily mitigated with standard measures. However, some potential impacts and risks will typically warrant additional evaluation and possible modifications to planned mitigation measures after completion of the ESIA. These modifications should

**IMAGE 15.2. Pavement Perforation to Test Soil and Groundwater Contamination at Gas Station along Rail Right-of-Way: Quito, Ecuador**



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be incorporated into the final design and construction sequence of works. For urban rail systems, such modifications may include the following:

- Assessment and site-specific measures for controlling noise, dust, and illumination during construction (for example, when working 24 hours a day)
- Additional preconstruction field investigations, if there are known or a significant likelihood of archeological sites or finds in the project's direct area of influence
- Final selection of a disposal or reuse site for extracted soils from construction and assessment and determination of truck routes from project sites to disposal or reuse site
- Additional investigations in areas identified as having contaminated soil or groundwater to define the degree and extent of contamination and alternatives for soil and groundwater disposal
- Works in public parks or green spaces and potential tree removal, especially involving patrimonial trees of special significance
- Additional assessments of vibration, such as visual inspections of buildings and baseline monitoring in areas with sensitive buildings (often of cultural or historical significance)
- Modification of EHS measures to allow emergency access to sensitive sites such as cultural resources, schools, churches, hospitals, and health clinics around the construction and ventilation of stations

### **Environment, Health, and Safety Management**

While the project ESIA is a critical instrument for assessing potential impacts and risks, sound EHS management of urban rail projects requires more than just the ESIA. An EHS management system is part of overall project management and is used to manage EHS aspects, fulfill compliance obligations, and address risks and opportunities. The fundamental EHS management instruments for urban rail projects are the (1) ESMP, which is developed as part of the project ESIA associated with obtaining the project environmental permit, and (2) EHSMS, which is developed by the project-implementing agency or construction contractor (as a requirement in the construction contract). These instruments include EHS monitoring and supervision programs, definition of roles and responsibilities for EHS management, and EHS reporting. Other key aspects are the inclusion of EHS terms and conditions in project bids and

contracts and the implementation of an adaptive EHS management approach. These concepts are summarized in the following subsections.

### **EHS Management Plan**

The project ESIA includes an ESMP, which consists of a set of mitigation, monitoring, and institutional measures to be taken during implementation and operation of a project to eliminate adverse environmental and social risks and impacts, offset them, or reduce them to acceptable levels. An ESMP should include detailed descriptions of (1) all necessary environmental and social mitigation measures and monitoring activities; (2) specific methods of supervision to ensure that all measures and programs are implemented completely and properly by all responsible parties; (3) training to support timely and effective implementation of environmental and social project components and mitigation measures, including, as needed, measures to strengthen environmental and social management capability in the agencies responsible for implementation; (4) routine reporting actions; (5) ongoing activities to ensure adequate disclosure of information and consultation with the local population affected by the project; and (6) an estimated cost, schedule, and assignment of responsibility for implementing each mitigation measure, monitoring program, and all other ESMP activities (World Bank 2013b, 2016).

The ESMP consists of numerous specific environmental and social mitigation and monitoring programs. For example, an ESMP for urban rail projects should include programs and measures for solid and liquid waste, excavated materials, air emissions, noise, vibrations, flora (vegetation), fauna (animals), parks and protected areas, archeological and cultural resources, community health and safety, environmental liabilities, worker health and safety, traffic management, infrastructure services, spills and contingencies, emergencies, training and capacity building, monitoring, supervision, community participation, local contracting, purchase of local services, and construction closure. The ESMP may include, or reference, more detailed project plans such as health and safety plans, contingency plans, or spill prevention and counter-control plans.

All EHS programs and measures are necessary; however some aspects of ESMP programs are critical for urban rail projects in low- and middle-income countries (see table 15A1 in the annex to this chapter). These programs or measures may be different for a project to develop new infrastructure than for a project to upgrade the environmental, health, or social sustainability of an existing urban rail system (see box 15.9).

Some impacts and risks in urban rail projects will require additional assessment and may require modifications to an ESMP. These modifications can be

**BOX 15.9.****Safety Improvements for an Existing Suburban Rail System: Mumbai, India**

Mumbai's suburban rail system provides an economical and fast transportation option for many persons in the city, but for years it was plagued by an increasing number of accidental deaths and injuries to passengers and trespassers on its three main railway corridors. In 2012, more than 3,600 accidental deaths were documented (an average of more than 10 deaths a day) (World Bank 2017). Recognizing the problem, Mumbai Rail Vikas Corporation undertook a study of accessibility issues, reasons for trespassing, and existing facilities at railway stations. The study identified numerous reasons for trespassing, including

(1) insufficient platform space at stations during peak hours; (2) poor connectivity, insufficient capacity, lack of aesthetic appeal, and effort required to use existing foot-over-bridges (FOBs); (3) lack of information boards, signage, and announcements regarding changes in service schedules and departing platforms; and (4) inadequate height of fencing between tracks and adjacent settlements (see image B15.9.1) (Sir JJCOA Consultancy Cell 2012). With the results of this study, Mumbai Rail Vikas Corporation produced a trespassing and safety action plan that called for the provision of trespassing control

**IMAGE B15.9.1. Trash and Trespassers on the Tracks of the Mumbai Suburban Railway Prior to the Project, 2009**

Source: World Bank.

**BOX 15.9.****Safety Improvements for an Existing Suburban Rail System: Mumbai, India (Continued)**

measures for track midsections and in-station areas.

Some of the actions outlined in this plan were implemented as part of a World Bank-financed project, Mumbai Urban Transport Project 2A, which aimed to improve passenger carrying capacity, operational efficiency, and level of comfort of the suburban rail system in Mumbai. The project provided new, more environmentally friendly electric multiple unit rolling stock, converted the power supply from direct to alternating current, and improved signaling and telecommunication networks supporting the rail system. Trespassing and safety infrastructure improvements at 12 suburban rail stations

were added to the project activities, which included (1) new FOBs; (2) extending, widening, and improving interconnections among FOBs; (3) new station platforms; (4) widening and extending of existing platforms; (5) installation of escalators and elevators; and (6) construction of compound walls and fencing, track barricading, and green patches. Although the rate of accidents remains high, data from 2016 suggest that the number of fatalities is declining (World Bank 2017). Such safety improvements are critical not just for the operational efficiency of rail service, but also for the health and basic safety of rail users and citizens living adjacent to the urban rail lines.

Source: Adapted from World Bank 2017.

addressed as part of the EHSMS and its associated components. Adaptive management is fundamental to the success of these EHS mitigation measures and monitoring programs.

**EHS Management System**

An EHSMS contains all components required for the adequate management of EHS impacts and risks. It is fundamental for complex projects such as the development of new urban rail or the upgrading of existing rail systems.

The system may consist of either one integrated EHSMS or two separate management systems—one for the environment and the other for health and safety. The EHSMS is developed by the project-implementing agency, construction contractor, or O&M contractor (as applicable to the project), but it should be consistent with the principles and concepts of internationally acceptable standards, such as International Organization for Standardization (ISO) 14001 for the environment (ISO 2015) and Occupational Health and Safety Management Systems (OHSAS) 18001 for health and safety (British Standards Institute 2017).

For example, an EMS under ISO 14001 covers the following: (1) context of the organization (scope of the EMS and general requirements); (2) leadership (environmental policy, roles, responsibilities, and authorities); (3) planning (environmental aspects and impacts, compliance obligations, risks, objectives, and targets); (4) support (resources, training, document control, and records management); (5) operation (control of environmentally significant processes, change management, emergency planning, and response); (6) performance evaluation (monitoring of environmental performance, internal audits, compliance reviews, and management review); and (7) improvement (corrective and preventive action). An EHSMS is documented through policies, plans (including ESMP), procedures, performance indicators, responsibilities, training, and periodic audits and inspections. It should include written EHS prevention, protection, and control requirements for all project components. It also should include written procedures on when and how an assessment of potential environmental impacts or worker health and safety risks will be performed on each component or activity.

In the context of urban rail projects, the EHSMS needs to include the mitigation measures and monitoring programs established in the (1) ESMP in an approved project ESIA; (2) project environmental permit and other EHS regulatory requirements; (3) concession agreement or construction contract; and (4) project financier legal agreement. The EHSMS also needs to include appropriate labor aspects (see World Bank Group Performance Standard 2 on labor and working conditions) as part of human resources management and to incorporate EHS aspects into the management of subcontractors and purchases of goods and services (World Bank Group 2012). Another component of the EHSMS includes a social communication and grievance mechanism. The associated costs for implementing these requirements also need to be included.

The EHSMS is updated, as needed, to reflect final project modifications and designs as well as the results of additional EHS impact or risk evaluations or monitoring and specific engineering studies (for example, of vibrations, groundwater, and geotechnical conditions) that may be required under the concession agreement or construction contract.

### **EHS Monitoring and Supervision Programs**

An EHS monitoring program should collect EHS data systematically to determine the actual EHS effects (impacts) of a project, compliance with the project EHS requirements, and degree of implementation and effectiveness of EHS mitigation measures. The information generated by the monitoring program provides the feedback necessary to determine whether or not mitigation and control measures have been effective in helping to achieve the established



objectives. The monitoring program also helps to identify unanticipated impacts and to assess the adequacy of corrective actions.

For urban rail projects, key monitoring programs include air quality (particulate material), noise, vibrations, surface and groundwater, soil, cultural resources, archeological resources, waste, worker health and safety conditions, and accident or incidents. The EHS monitoring program should provide descriptions and technical details of recommended measures, including the (1) parameters to be measured, (2) specific sampling locations, (3) frequency and time of measurements, (4) sample collection and analysis methods, (5) detection limits where appropriate, (6) standards to be applied, (7) definition of thresholds that identify the need to take correction actions, and (8) quality control and assurance procedures. The program needs to comply with any applicable regulatory or normative standards for sample collection and analysis. The environmental parameter threshold levels should reflect the project-specific limits as specified in the EHS requirements. The program should describe the anticipated approach for analyzing, reviewing, and reporting data and the approach for including conclusions drawn from the monitoring program in the ESMP and EHSMS mitigation measures. Given the varying site-specific conditions, the monitoring program should allow for potential in-field modifications of sample location, for example, to reflect actual conditions and areas of concern (such as the presence of dust due to wind direction or the level of noise due to specific works under way).

One key question is who should perform the EHS monitoring. It can be advantageous to have all EHS monitoring done by the concessionaire or construction company; however, there are noteworthy alternatives in which the project-implementing agency performs some monitoring, directly subcontracts for these services, or allocates monitoring among different project parties (for example, some to the construction company and some to the independent project supervisor). Due to the complexity of urban rail projects, EHS-related supervision will likely be undertaken by various entities, including the project-implementing agency, contractor or other private partner (as part of their EHSMS), project financial institutions, and any government entities responsible for contract oversight and EHS regulatory compliance. Each entity will have a clearly defined focus and objectives based on its regulatory or contractual responsibilities. It is critical that all aspects of the EHS requirements are fully supervised and that roles and responsibilities do not have substantial overlap.

The level of supervision required for urban rail projects is significant. For example, urban rail projects can include multiple construction sites with significant civil works implemented simultaneously and likely on a 24-hour, seven-day-a-week basis. They also have extensive and detailed EHS requirements covering a wide range of technical issues that require multidisciplinary expertise to manage.

Given the scope of EHS responsibilities and the number of parties involved, an established written plan or procedure is required to define clearly what EHS supervision responsibilities will be implemented by whom. This plan needs to be complemented by coordination among these entities and by an established approach synthesizing the results from all supervision in order to establish a definitive assessment of and statement on the project's EHS compliance.

Fundamental to monitoring and supervision is a defined approach to using the information collected to resolve identified EHS deficiencies (such as non-compliance or unmitigated impact or risk) and improve EHS performance. Dealing with EHS issues that arise during construction and operation requires an established approach for reviewing and analyzing EHS supervision information and monitoring data and a process for incorporating the conclusions into corrective actions or improved mitigation measures. These corrections should be made directly at the time these deficiencies are identified (in the field), to the extent practicable. Others may require more thorough analysis and decisions on the appropriate action.

Two other aspects of urban rail projects are important, given the large amount of EHS documents and monitoring data that will be generated:

- *An established, functional, well-organized document management system.* The system should provide storage of all project EHS documents—including all plans, studies, permits (including applications), status or performance reports, supervision documentation, and monitoring reports—and have adequate staff to maintain the system.
- *An information technology tool for managing all of the project EHS monitoring data, including data storage, analysis, and reporting.* Projects collect a large amount of data over time. Given that EHS monitoring is intended to assess performance and use the results to make changes in EHS management, an effective and efficient way of conducting routine data analysis and reporting is needed. This is particularly relevant for statistics on construction of tunnels (gas, water, soil, and vibrations) and stations (noise and air quality), transport and disposal of extracted material, and worker health and safety.

### **EHS Roles and Responsibilities**

Due to the size, institutional and project delivery structures, and financing arrangements of urban rail projects, responsibilities for EHS management will likely be distributed among government entities and private sector companies. The exact responsibilities will be determined in the project's construction or O&M contracts (as applicable). This distributed responsibility presents a major

challenge in ensuring full, effective, and efficient implementation of all EHS requirements and adequate mitigation of all project EHS impacts.

Clear definition of responsibilities is crucial and should be done as part of project planning, design, and risk allocation. Effective coordination and communication are vital, as is commitment to identify and address issues proactively and to understand that all stakeholders have a role in ensuring sound EHS management regardless of established legal or contractual responsibilities. The project financial institutions and local communities also have a role in EHS management.

The following subsections summarize some key issues associated with the EHS roles and responsibilities of government entities, a supervision firm, private sector contractors, and institutions providing financing to the project.

### *Government Entities*

The project-implementing agency has to retain some EHS responsibilities. These responsibilities include (1) EHS in project feasibility and designs, (2) initial environmental permitting (preparing the ESIA and obtaining regulatory approval), (3) project supervision of EHS, (4) coordination and reporting on EHS performance to other government entities that have EHS responsibilities, and (5) coordination and reporting to project financiers. The project-implementing agency may also directly implement some specific EHS management programs, such as management of traffic during construction, assessment and disposal of existing environmental liabilities (contaminated soil), or coordination of the EHS management of supplementary or associated works (including station enhancements, facilities for nonmotorized access, and multimodal integration). The project-implementing agency needs to have technically qualified staff—including employees or consultants that specialize in EHS, cultural resources, and social impacts—and resources (budget) to manage and monitor EHS. Dedicated technical staff are needed, as are established relationships to provide them with support (for example, the review of a specific technical report or issue), when needed. Other government agencies or consultants should provide this support.

Some government entity (the Ministry of Environment or analogous) will be responsible under national legislation for reviewing and approving the project ESIA, issuing environmental permits, and supervising the project's environmental permit and regulatory requirements. Similarly, a government entity will be responsible for ensuring compliance with worker health and safety regulations.

Some government entity will also be responsible for supervising the project contract(s), including the EHS requirements. A private sector supervision firm is often hired to augment existing capacity within the government entity and, as part of the contract terms of reference, is often required to staff one or more

EHS specialists. The supervision firm's key activities include field supervision and monitoring as well as document review of plans, procedures, studies, and EHS aspects of construction performance or status reports. A written EHS supervision plan needs to include (1) staffing (number, technical capacity, responsibilities, and clear lines of reporting); (2) routine (monthly) reports on project EHS status and performance; (3) methods of EHS technical review of relevant plans, studies, and reports; and (4) format, content, and use of daily supervision reports. Although this supplemental external expertise is useful, the government entity needs to have some internal staff capable of understanding the EHS aspects related to the project so that they can provide appropriate oversight of and direction to the contracted supervision firm.

Other government entities likely involved in EHS management of an urban rail project include those responsible for (1) approving activities involving archeological resources and associated permitting, if required; (2) control and management of traffic; (3) management of soil disposal areas; (4) approval of the management or disposal of contaminated soil or groundwater; and (5) management of urban parks and green spaces and the cutting of trees.

Given the various government entities involved, some form of interinstitutional agreement is needed to define each entity's specific responsibilities, involvement time frame, and resource contributions. These agreements should clearly require compliance with all applicable in-country EHS regulatory requirements, including having all necessary permits. The agreement also should indicate (1) the principal government entity with the right to perform site visits to assess the status and performance of EHS management; (2) the executing agency designated to present relevant information related to EHS management, EHS permits, and status or performance reports; and (3) a schedule for meetings and discussions of EHS management. If there are significant differences between the in-country EHS requirements and those established in the policies and requirements of financial institutions, then an approach is needed for undertaking additional measures required by the financiers.

An additional procedure is needed to define the actions to be taken in case of noncompliance or the detection of significant risk in the field (inspections). The procedure needs to be based on in-country regulatory requirements and responsibilities and project contractual responsibilities. It needs to cover actions such as stopping work due to an EHS issue, investigating and resolving noncompliance, and issuing notification of significant EHS events.

The government agencies' capacity and ability to execute their responsibilities and manage the relevant EHS aspects will likely vary. In many cases, these agencies may have limited or no experience with construction and operation of a major urban rail project. Therefore, some additional capacity and training may

be recommended and required throughout the project development process, particularly when first establishing project management plans (see chapter 4). This capacity building should be established in a plan and supported financially, as needed (for example, from public sector loans to the government entity responsible for the project).

### *Private Sector Contractors*

A private sector company or likely a consortium will be responsible for project construction and also, potentially, for O&M according to the project contract. The contract will establish the project-specific EHS requirements, but also include (1) compliance with all applicable country regulatory requirements, government-approved project ESIA (and ESMP), and environmental permits and (2) development and implementation of an EHSMS consistent with international standards (such as ISO 14001 and OHSAS 18001). The contract also may include compliance with the EHS requirements of financial institutions. It should establish that all subcontractors will have to (1) comply with the defined EHS requirements; (2) provide EHS training to workers; (3) routinely (monthly) present project status or performance reports, including EHS aspects; and (4) maintain certain types of insurance for project EHS risks.

Even when EHS management is delegated to the private entity, the project-implementing agency or other government entity will have to retain some supervisory and approval responsibility to ensure that the project is compliant with applicable regulatory and financial institution EHS requirements. The supervision entity and the private sector company should meet regularly (weekly or biweekly) to discuss EHS aspects.

### *Financial Institutions*

Coordination and routine EHS performance reporting are also needed with the project financiers. In particular, financial institutions may need to review and register a formal no-objection to key concessionaire EHS plans, significant proposed modifications to the ESMP or EHSMS, or changes in project design that could result in new or not previously assessed EHS impacts and risks.

For projects, such as urban rail, that are likely to involve multiple financiers, the financiers will need to coordinate among themselves to establish an effective and efficient approach to EHS implementation that meets each financier's needs without resulting in burdensome efforts by the client. This approach includes (1) one environmental and social performance report to be prepared by the client for all lenders, (2) a combination of supervision missions by lenders, and (3) coordination among financial institutions on presenting comments to the client. It also should address how financiers will

coordinate their reviews of any applicable plan or report and their supervision visits to the project site.

### **EHS Reporting**

During EHS performance monitoring and supervision, various EHS performance reports are generated, for example, by the private sector concessionaire or construction contractor and also by the government entity (or supervisory firm working on its behalf) responsible for supervising the project contract(s). The EHS report often is part of a broader monthly report, on project status as well as technical and other aspects. Additional EHS audit reports may have to be performed annually to meet environmental permit requirements, regulatory requirements, requirements from financiers, or policies of the private company (or companies) in the project contract.

The EHS performance or status reports present a comprehensive, accurate summary of the project's EHS status according to standardized formats. An effort should be made to coordinate the various reports to ensure consistency in the results reported and to minimize duplication of efforts. The report should include, at a minimum, (1) a description of project compliance with the EHS requirements; (2) a description of any significant project-related impacts on human health, the environment, or social factors (worker accidents or deaths, spills, or releases) that occurred since the last monitoring report; (3) a summary of key results or data from the EHS monitoring programs during the reporting period; (4) a description of any existing or potential EHS-related impacts or risks that have not been mitigated properly or compensated and any existing EHS-related legal claims or material complaints, demands, or claims; and (5) a summary description of all significant issues, findings, and recommended actions. Recommended actions should be presented in tabular format and include some measure of significance (for example, level of impact, risk, or non-compliance) in order to prioritize and monitor implementation. The report should define the measures needed to address or resolve existing issues, including action(s), timing, responsibility, cost, and status (including confirmation of actions completed or issue resolved). Ideally, in order to assist decision makers, the report should include some form of summary or overall EHS risk and performance ratings.

The following are examples of potential key issues to be reported: (1) a non-compliance order from the environmental or worker safety regulatory agency of legal EHS claims; (2) noncompliance with actions established to resolve a previous noncompliance, key issue, or recommended action in the last report; (3) project changes that will have a negative EHS impact or risk and require adjustments to the ESMP and EHSMS; (4) any significant results regarding implementation of

EHS plans or procedures (ineffective mitigation or control measures); (5) any inadequacy of the EHS monitoring program; (6) significant issues related to time schedules (measures not implemented as planned) or EHS cost (significant increase in actual versus budgeted expenditures); and (7) key issues or activities that are required in the upcoming time period.

### **Bids, Contracts, and Contract Management**

EHS management has to be included in the project's bid and contract documents, including in contracts covering (1) project feasibility assessment, (2) project design, (3) ESIA development, (4) infrastructure delivery, (5) independent project contract or construction supervisor, or (6) operations. In particular, project feasibility and design contracts need to assess alternatives considering EHS aspects, identify key potential EHS risks and associated costs, and suggest methods to improve environmental sustainability. Key aspects for ESIA bids and contracts and for independent project construction supervisors are highlighted earlier in this chapter, including technical capacity, scope of work (office, field supervision, and monitoring), reporting, and resources. The inclusion of EHS management in contracts should be based on the input and oversight of qualified technical EHS specialists and should incorporate sound contract management practices.

Various potential EHS requirements for urban rail project contracts arise due to their size and scope and need for international financing. The EHS requirements include those established:

- As part of applicable in-country (national, state or province, or municipal) legislation, including all applicable permits and authorizations, approved project ESIA (or analogous) and associated ESMP (or analogous), and established EHS regulatory limits (for emissions, discharges, and ambient conditions, among others)
- In the project construction or O&M contract, which should include the selected contractor's technical proposal
- By the financiers involved in the project (multilateral development banks, export credit agencies, or private commercial banks), including requirements established in the project's legal or loan agreement

Other potentially applicable requirements include those established (1) in international treaties, conventions, or agreements ratified by the country; (2) by good international industry practice, such as international standards or guidelines (ISO 14000 or OHSAS 18001); and (3) in the EHS policy adopted by the project contractor.

Different EHS terms and conditions need to be included in the project contracts depending on the specific project's delivery model, risk transfer structure, and financing. Table 15.2 presents a list of key EHS terms and conditions.

The project bid and contract documents should request the preparation of a project environmental sustainability management plan that establishes how a contractor will implement sustainability measures, including equipment and technologies, and how it will measure and report on actual implementation, such as fuel, energy, and water consumption and handling of primary materials (cement, base materials, hazardous materials, and waste). Contractual requirements should specify the type of sustainability actions expected throughout the project or based on the achievement of a particular level or result. Sustainability actions could be expressed as "best effort" clauses, and there would be no

**TABLE 15.2. Representative EHS Terms and Conditions for Urban Rail Project Contracts**

CONTRACT AREA	TERMS AND CONDITIONS
Definitions	<ul style="list-style-type: none"> <li>Define key EHS terms in the contract, such as EHS requirements, ESIA, ESMP, EHSMS, EHS claims, and EHS performance report.</li> </ul>
Covenants	<ul style="list-style-type: none"> <li>Design, construct, operate, maintain, and monitor the project in compliance with all EHS requirements and otherwise ensure that all project impacts or risks relating to environmental and social matters have been mitigated adequately or compensated: (a) if the project design changes, obtain any additional environmental permit or modification to an existing permit and make adjustments in the ESMP and EHSMS to implement these changes and (b) ensure that all relevant subcontractors and operators comply with EHS requirements.</li> <li>Implement an EHSMS and conduct adequate ongoing information disclosure and public consultation.</li> <li>Provide, on a routine basis, EHS performance reports and promptly notify of any significant event or noncompliance related to EHS matters.</li> <li>Receive all project-related EHS studies and plans and verify that such information is true, complete, and not misleading.</li> <li>Submit, in form and substance, all EHS-related studies and the project ESMP, EHSMS, and environmental permits as established in the contract.</li> <li>Make no significant changes to the ESMP or EHSMS without written consent.</li> </ul>
Payments or disbursements	<ul style="list-style-type: none"> <li>Certification from contractor that project is in compliance with EHS requirements.</li> <li>Confirmation or certification from the independent supervisor that, in relation to the project and all project parties, (a) there is compliance with EHS requirements, (b) there are no adverse impacts or risks with respect to EHS matters that have not been mitigated adequately or compensated, and (c) there are no known EHS claims or material EHS complaints other than those already identified in the EHS performance reports.</li> </ul>

*(table continues next page)*



**TABLE 15.2. Representative EHS Terms and Conditions for Urban Rail Project Contracts** (Continued)

CONTRACT AREA	TERMS AND CONDITIONS
Other considerations	<ul style="list-style-type: none"> <li>• Define responsibilities for (a) implementing specific EHS programs (for example, mitigation or monitoring) as specified in the ESMP or elsewhere and (b) handling potentially unknown EHS risks, including archeological, contaminated soil and groundwater, and geologic conditions.</li> <li>• Define project-specific EHS financial risk measures, such as required type and amounts of insurance and use of financial mechanisms (performance bonds, contingency accounts, and project sponsor support) to control EHS risk by ensuring compliance and providing additional resources as needed.</li> <li>• Prepare an environmental sustainability plan.</li> <li>• Satisfy EHS requirements for technical completion of the project, such as submittal of acceptable final EHS construction report and EHSMS for O&amp;M confirmation or certification of compliance with EHS requirements from the independent supervisor.</li> <li>• Contract an independent supervisor (engineer or consultant) to supervise EHS requirements.</li> <li>• Specify indemnifications related to potential EHS claims.</li> <li>• Grant permission for the project owner or financial institution to contract an independent consultant to perform an independent EHS audit.</li> </ul>
Additional conditions for financial institution loan agreement: representations and warranties	<ul style="list-style-type: none"> <li>• No past or existing EHS liabilities associated with the project and the project site.</li> <li>• No past or existing environmental claims or material complaints.</li> <li>• No past or existing noncompliance with in-country legal requirements, financial institution policies, or transaction requirements.</li> <li>• Receipt of all project-related EHS studies and reports and verification that such information is true, complete, and not misleading.</li> </ul>

penalty if the contractor fails to fulfill them. Alternatively, sustainability actions could include (1) penalties if the contractor fails to fulfill the established requirements or (2) financial incentives or other rewards if the contractor fulfills or exceeds the requirements. While providing an environment that better aligns contractor interests with EHS considerations, the project-implementing agency needs to dedicate significant time and resources to monitoring and verifying whether or not the established requirements have been met.

This is particularly true when EHS requirements are governed by multiple documents, contracts, and permits and when multiple entities are assigned responsibilities for various actions. Thus, it is essential to summarize all of the relevant EHS requirements in one document (table) to ensure that all required EHS actions are implemented completely, effectively, and efficiently. The table

should state clearly who is responsible for implementation and, to the extent applicable, the timing of each requirement. The table also should state the project-specific limits associated with EHS criteria, including air, water, noise, vibrations, waste, and worker health and safety.

### **Adaptive EHS Management**

An adaptive EHS management approach is recommended for urban rail projects because the definition and finalization of project details can change over time. The complexity and size of urban rail projects and the wide range of conditions that can be encountered mean that supervision activities and environmental monitoring programs will need to adapt. This flexibility not only helps with response to changing conditions, but also unlocks opportunities to implement environmental sustainability measures that lead to lower costs and improved benefits.

Although planning and design are very important, the uncertainties surrounding urban rail projects mean that up-front analysis often is not sufficient. Supervision and monitoring are needed during implementation (when issues actually arise and impacts occur) to promote efficiency and effectiveness, ensure adequate management of all project impacts and risks, develop more environmentally sustainable projects (use fewer materials or generate less waste), and achieve more positive impacts. Adaptive EHS management accomplishes this by incorporating data or information collected, new technologies or approaches, and input received from local communities and other stakeholders.

Adaptive management is consistent with various international EHSMS standards and good industry practices that do the following:

- Define the approach for continuous review, update, and improvement through the EHSMS
- Provide the means to account for project timing, such as design details known at the time of conducting the ESIA versus at the time of starting project construction
- Establish a mechanism for adjusting mitigation measures (or monitoring programs) that are not working
- Develop a framework for EHS monitoring by providing an approach for routine analysis of data to assist in decision making and adapting of the ESMP and EHSMS
- Establish an approach for addressing changes in the project, unanticipated changes or changes in impacts or risks, and new laws or regulations

- Use a corrective action plan to resolve issues (such as noncompliance or deficiencies)
- Establish contingency, emergency, and spill plans such that the documented measures can be adapted in the field given the actual details and conditions associated with a specific event

During design, the project will be optimized to improve cost efficiencies (see chapter 6). Although this optimization of design and construction works focuses on the reduction of project costs, it is important to ensure that changes do not exacerbate negative environmental impacts. Optimization has to consider the associated environmental impacts and risks and make adjustments to the EHS management plans and systems accordingly.

A project-specific decision-making process or framework for adaptive management needs to be established. The following are key elements of this process:

- *Efficiency.* Ensure that all positive changes or needed actions occur in a streamlined fashion (particularly difficult for large institutions).
- *Scale.* Define the degree of modification requiring review or approval. This definition should be based on significance, which is consistent with effective management systems and, where applicable, environmental regulations and licensing.
- *Data.* Use EHS monitoring data or field observations as the basis for assessing and making a modification; the amount of data certainty needed should be proportionate to the level of impact or risk or opportunity for improvement.
- *Responsibilities.* Define who makes the assessment and decision (for example, project-implementing agency, environmental regulatory agency, independent supervisor, or private contractor).
- *Means.* Define the means of documenting or authorizing changes or actions. For example, documentation could be included in corrective action plans, could modify the existing ESMP and EHSMS, or could part of a broader contract or project requirement.
- *Resources.* Decide whether additional resources are needed and determine their sources (for example, assignment of risk to an entity in a contract, contingency financing, bonds, insurance, and additional financing).

A key to successful EHS management and development of environmentally sustainable urban rail projects is knowledge sharing and capacity building among

**BOX 15.10.****Knowledge Platform on Environmentally Sustainable Infrastructure Construction in Latin America and the Caribbean**

The World Bank Group, with financial support from the Spanish Fund for Latin America and the Caribbean, has developed a free bilingual (English and Spanish) web-based Knowledge Platform on Environmentally Sustainable Infrastructure Construction (KPESIC) to promote better environmental and social management in infrastructure projects in Latin America and the Caribbean. KPESIC supports knowledge transfer, capacity building, innovation, and lesson learning in the construction of environmentally sustainable infrastructure and is a forum for ideas and solutions. KPESIC organizes its information and resources according to the following:

- Sectors and themes (with relevant technical reports, studies, guidance documents, training materials, and case studies)
- Materials, technologies, and equipment
- Countries (laws and regulations, environmental permitting, entities, and environmental data)
- News and events (news, conferences or symposiums, and workshops)
- Knowledge exchange (topics and forums for discussion, working groups, webinars, e-learning, interviews, and training materials)

Note: See KPESIC website, <http://www.kpesic.com>.

the various specialists and entities involved (see box 5.10). Therefore, the project ESMP and EHSMS need to include arrangements for staff in the project-implementing agency to build internal capacity, learn from existing knowledge of experts and experience from other projects, and incorporate these good practices and lessons learned. The effective use of external experts and the explicit inclusion of knowledge transfer in contracts can be major benefits for project-implementing agencies in low- and middle-income countries that may lack the technical capacity to address all aspects and opportunities of EHS management and environmentally sustainable infrastructure development (see also chapter 4).

**Conclusions and Recommendations**

The goal for EHS management in urban rail projects is the effective and efficient management of all EHS impacts and risks and enhanced environmental sustainability, both of which lead to better project results and benefits. The following recommendations highlight key components for achieving this goal.

***It is important to consider EHS impacts, risks, and sustainability opportunities early and often in the project development process.*** Early and ongoing participation of technically qualified EHS specialists throughout project development (planning, design, construction, and O&M) is critical for project success. This process should start with a thorough consideration of EHS aspects during project planning, including a range of alternatives related to alignments, station locations, construction methods, and measures to reduce and mitigate EHS impacts and risks. A sound and thorough assessment of all potential direct, indirect, and cumulative EHS impacts, risks (technical and financial), and sustainability opportunities, starts prior to development of the project ESIA and continues after its completion.

***It is critical to invest in an EHSMS that adapts to changing project conditions.*** Every project should have a comprehensive EHSMS that includes plans, procedures, responsibilities, resources, training, monitoring, supervision, contractual terms and conditions, and contract management. This management system should embrace an EHS impact-risk hierarchy approach: avoid, minimize or reduce, mitigate, and compensate. Such an EHSMS should develop and update a complete and accurate estimate of project-related costs and financial risks and appropriate risk management measures (since EHS risks can cause significant financial risks and affect project viability). An adaptive EHS management approach that responds to project changes, actual results, and performance will ensure optimal EHS impact and risk management and environmentally sustainable outcomes.

***EHS management should be embraced as an opportunity for complementary improvements and value added.*** EHS management includes identifying and implementing measures to improve the project's environmental sustainability (for example, use of fewer materials, pollution prevention, and more positive environmental and social benefits). Such measures, if integrated into all steps of project development, produce better projects, use financial resources more efficiently, and improve community relations and perceptions.

***Clear and informed communication and stakeholder coordination are critical for EHS management.*** It is essential to establish strong coordination mechanisms among the various government entities and private sector companies or consortiums involved. To this end, it is important to evaluate options for assigning responsibilities based on capacities and risks (similar to risk allocation among parties in contracts). Well-defined environmental sustainability and safety policies can help to secure the commitment of senior management to use the EHSMS, including communication with and training of staff and subcontractors.

All entities involved have a role to play in addressing issues and ensuring sound EHS management and results, even if they are not formally or legally responsible. Therefore, knowledge sharing and capacity building among the

various specialists and entities involved are needed and can be developed by building on the existing knowledge and experience of other projects and incorporating good practices and lessons learned.

## Annex 15A. Details on Specific ESMP Programs in Urban Rail Projects

**TABLE 15A.1. Important Aspects in Select ESMP Programs in Urban Rail Projects**

ESMP PROGRAM OR AREA	COMMENTS
Soil reuse and disposal	<ul style="list-style-type: none"> <li>• Adaptive plan, given that final selection of site(s) may need concessionaire or contractor input</li> <li>• Focus placed on reuse, but also on coordination of timing (for example, generation vs. reuse, including any environmental permits)</li> <li>• Truck transport and driver procedures, with supervision and monitoring</li> </ul>
Truck and driver management	<ul style="list-style-type: none"> <li>• Analysis of principal alternatives completed as part of design and revised in conjunction with concessionaire or contractor (who purchases or rents trucks and hires drivers or subcontracts the provision of trucks and drivers to other companies)</li> <li>• Control, inspection, and documentation of trucks prior to leaving site, including removal of soil on tires</li> <li>• Definition of allowable routes, speeds, and times (day or week)</li> <li>• Driver requirements and controls, including prework medical (and blood tests) and physical inspections, ongoing monitoring (of visual and alcohol or drug use), driver training, daily total allowable work time, and allowable deviations</li> <li>• Driver contracts with clearly specified requirements and remedies for noncompliance</li> <li>• Use of electronic monitoring (GPS), driver training, and stops</li> <li>• Procedure for truck maintenance, including selection of service providers considering EHS aspects, routine maintenance (including assurance of proper engine operations related to emissions and noise), and disposal of used oil and other fluids, batteries, and tires</li> </ul>
Vibrations	<ul style="list-style-type: none"> <li>• Adaptive plan built on site-specific conditions (building and receptors) and assessments (baseline monitoring and mathematical models)</li> <li>• Actions required prior to start of construction works to assess and document status of buildings</li> <li>• Monitoring required during construction, including field observations and measurements</li> <li>• Procedure to receive, evaluate, and compensate (if applicable) damages due to construction and establishment of financial resources to cover this expense</li> <li>• Definition of responsibilities among multiple project entities involved</li> </ul>

*(table continues next page)*

**TABLE 15A.1. Important Aspects in Select ESMP Programs in Urban Rail Projects (Continued)**

ESMP PROGRAM OR AREA	COMMENTS
Tree cutting	<ul style="list-style-type: none"> <li>• Mitigation hierarchy: prevent, minimize, mitigate</li> <li>• Plan to avoid cutting patrimonial trees, including adjustments in project design to minimize effect on such trees</li> <li>• If unavoidable, implementation of acceptable plans for transplanting (to the extent technically and economically viable) or replacing such trees and for their short-term maintenance and care</li> <li>• Adequate coordination with applicable government regulatory authorities</li> <li>• Stakeholder communication to avoid or minimize public concerns or protests</li> <li>• Exploration of options for positive enhancements, such as park enhancements, to help to offset impact</li> <li>• Definition of adequate budget and contingencies as well as financial resources to cover all related costs</li> </ul>
Archeological and cultural heritage	<ul style="list-style-type: none"> <li>• Sound evaluation of alternatives in feasibility study, technical design, and ESIA</li> <li>• Adaptive management during final design with contractor, including site locations (stations, emergency exits, ventilation shafts, and construction staging areas)</li> <li>• Compliance with applicable legislation (permits and procedures) and good international practice</li> <li>• As applicable, additional archeological monitoring after ESIA, but prior to construction</li> <li>• Archeological monitoring during construction stage, including specialists in field with authority to stop work</li> <li>• Archeological rescue and protection in case of chance finds</li> <li>• Specific measures (reporting, monitoring) in UNESCO site</li> </ul>
Waste management	<ul style="list-style-type: none"> <li>• Mitigation hierarchy: avoid, reuse, recycle, donate, dispose</li> <li>• Procedures for minimizing waste segregation, reuse, temporary storage, recycling, donation, and disposal</li> <li>• Field inspections, monitoring, and documentation of waste cycle</li> <li>• Selection of waste disposal service providers (transport, recycling, and disposal) based on EHS criteria (including compliance with all regulatory requirements, no documented EHS issues related to materials at operation or site facilities, and agreement to provide access for site visits to discuss EHS management)</li> </ul>
Groundwater management	<ul style="list-style-type: none"> <li>• Update of plan based on final contractor-defined estimated volumes and timing for groundwater pumping</li> <li>• Confirmation of potential uses of groundwater and pumping impacts (for example, settlement or subsidence)</li> <li>• Mitigation hierarchy: minimize, reuse, dispose</li> </ul>

*(table continues next page)*

**TABLE 15A.1. Important Aspects in Select ESMP Programs in Urban Rail Projects** *(Continued)*

<b>ESMP PROGRAM OR AREA</b>	<b>COMMENTS</b>
Groundwater management <i>(continued)</i>	<ul style="list-style-type: none"> <li>• Groundwater monitoring, including pump rates and volume, groundwater quality, and aquifer status</li> <li>• Disposal in compliance with applicable regulatory requirements</li> <li>• Definition of contingency measures, such as pumping of additional volumes, contaminated groundwater, and aquifer impacts (on other users or surrounding soils)</li> </ul>
Contaminated soil and groundwater	<ul style="list-style-type: none"> <li>• Adaptive management, in particular, regarding contamination during construction</li> <li>• Assessment of potentially contaminated soil and groundwater at site locations where soil works and excavations will be performed; assessment should include (a) a phase 1 assessment based on existing information and site observations to identify potential sources, such as industries, gas stations, dry cleaners, car and truck repair shops, and municipal waste water collectors and (b) a phase 2 assessment, as needed, to collect monitoring data (for example, soil, groundwater, and vapor gas)</li> <li>• If there is a reasonable likelihood of contamination, then a specific management plan that includes (a) monitoring during construction consisting of visual inspections, on-site and in-situ monitoring to detect and confirm levels of contamination (and supplemented as needed by laboratory analysis), (b) on-site temporary storage and treatment, (c) final disposal (both for water and soil), and (d) worker health and safety procedures</li> <li>• Definition of all regulatory approvals necessary for management and disposal and specific criteria (contaminant concentration limits) for decisions</li> <li>• Specific training for workers on process implementation</li> <li>• Detailed supervision documentation of plan implementation</li> <li>• Definition of financial resources needed and source</li> <li>• In order for construction to start, implementation of treatment or remediation and then pursuit of cost remuneration from the party responsible for the contamination</li> </ul>
Traffic management	<ul style="list-style-type: none"> <li>• Need for overall plan and for site- or station-specific plans and measures</li> <li>• Impact and risk prevention measures, such as establishing construction site works to minimize the entrance and exit of vehicles at stations during peak traffic</li> <li>• Adaptive management that includes field inspections and monitoring during plan implementation and adjustments, as needed, to reflect actual traffic congestion or related issues</li> <li>• Real-time communication to public prior to site-specific work (for example, via signs, radio, and newspaper) and during key periods of traffic interference or peak traffic</li> <li>• Incorporation of community safety considerations into plan design</li> <li>• Coordination among various government agencies with direct responsibilities and those with direct consequences (for example, municipality)</li> <li>• Understanding that some actions cannot be implemented by a private construction company, but need to be implemented by applicable government entity</li> </ul>

*(table continues next page)*



**TABLE 15A.1. Important Aspects in Select ESMP Programs in Urban Rail Projects (Continued)**

ESMP PROGRAM OR AREA	COMMENTS
Community safety	<ul style="list-style-type: none"> <li>• Integration of risks and management measures from other key plans, such as health and safety and traffic management</li> <li>• Adaptive management that monitors, adjusts, or adds measures to reflect actual community risks</li> <li>• Important measures to reduce community risk, such as fence and related protection around work sites (including strength and visual protection), education and awareness signs and information, and placement of safety risks (explosive and flammable materials, generators)</li> </ul>
Interference and complementary works	<ul style="list-style-type: none"> <li>• Planning for and management of protection and relocation of utilities, such as water and wastewater pipes, electricity lines, telecommunication lines, and natural gas lines; inclusion of required EHS management measures, supervision and monitoring of implementation, and final report and confirmation that construction works were properly closed (for example, all waste was removed or repavement was completed as required)</li> <li>• A plan or procedure to assess and manage EHS in any complementary works of the project, including a procedure for assessing specific EHS impacts and risks and establishing necessary mitigation and monitoring measures, including addressing any regulatory compliance issues</li> </ul>
Material supply	<ul style="list-style-type: none"> <li>• Procedure for selecting major material suppliers of soil, gravel, and cement, with EHS criteria for their selection (or exclusion)</li> <li>• Procedure for confirming during contract that there are no significant EHS issues with the operations of material supplier facilities</li> <li>• Documentation of results from procedure implementation</li> </ul>
Contractor management	<ul style="list-style-type: none"> <li>• Integration of EHS contractor management into broader project management, procurement, human resources, legal, and financial management</li> <li>• “Prevention through design”: assessment of what prime contractor does versus what subcontractors do; decisions on material supplies and equipment; contractor prequalification (when, if, and for what); use of information technology tools (identification cards and tracking and reporting systems for personnel and training)</li> <li>• Contracts required but not sufficient—contractor management incorporates “adaptive management” to monitor and adapt over time; integration with sustainable procurement approach or concepts</li> <li>• Building culture and commitment by demonstrating the importance of EHS management to the president or director of project-implementing agency and president or director of subcontractor; including EHS aspects in routine senior management project contractor meetings and reports, reflecting both criticisms or suggestions and praise; designating responsibilities of EHS staff (for example, work stoppage); requiring strong and consistent training and participation of managers; acknowledging managers’ participation in on-site supervision and resolution of issues; and providing awards, recognition, and incentives</li> <li>• Training and quality control plans</li> </ul>

*(table continues next page)*

**TABLE 15A.1. Important Aspects in Select ESMP Programs in Urban Rail Projects (Continued)**

ESMP PROGRAM OR AREA	COMMENTS
Tunnel or river works	<ul style="list-style-type: none"> <li>• Procedure or plan for tunnel works that pass under contaminated rivers with moderate to significant flow (for example, significant amounts of untreated municipal wastewater)</li> <li>• Special worker health and safety procedures (for contact with contaminated water and works taking place over water), river diversions and slope stability, and local community stakeholder communication</li> </ul>
Labor management	<ul style="list-style-type: none"> <li>• Compliance with appropriate labor requirements (for example, country labor legislation, ratified International Labour Organization conventions, World Bank Group Performance Standard 2), and a human resource policy or plan</li> <li>• Prohibition of child labor, including prohibition of persons under 18 years old from working in hazardous conditions (which includes construction activities) and from working at night; medical examinations required to determine that persons under 18 years old are fit to work</li> <li>• Elimination of discrimination with respect to employment and occupation, to be defined as any distinction, exclusion, or preference based on race, color, sex, religion, political opinion, trade union affiliation, national extraction, or social origin</li> <li>• Human resource policy or plans that establish (a) the rights and responsibilities of project company employees and any contractor employee working in the project regarding remuneration, working conditions, benefits, disciplinary and termination procedures, occupational safety and health, promotion procedures, and training and (b) the rights, responsibilities, and requirements in contractor or subcontractor agreements related to worker rights</li> </ul>
Health and safety management	<ul style="list-style-type: none"> <li>• Update of ESMP by construction contractor prior to start of work, based on detailed construction work plan and associated occupational health and safety risks and established in contractor health and safety management system</li> <li>• Incorporation of community safety considerations (such as warning signs, location of equipment and hazardous materials, and fence protection around the sites) into plan design</li> </ul>

Note: EHS = environment, health, and safety; ESIA = environmental and social impact assessment; ESMP = environmental and social management plan; GPS = global positioning system; UNESCO = United Nations Educational, Scientific, and Cultural Organization.

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## IMPROVING ACCESSIBILITY AND SHAPING URBAN FORM

Felipe Targa and Jean Paul Vélez

The development of a new urban rail line represents one of the largest investments that any city, region, and sometimes even country will undertake at any given time (see box 16.1). In countries where public resources are limited, such high levels of expenditure imply hard choices and trade-offs among many possible investments. For example, the construction of a new urban rail line might use resources that would otherwise be spent to improve housing and basic infrastructure for marginalized communities, to build new schools and day care facilities, or to develop new hospitals and improve public health programs. Considering these trade-offs, urban rail investments are much more than the delivery of infrastructure or transport to a neighborhood. They are part of a much larger context of urban activities and, thus, need to be planned carefully and aligned with a long-term, integrated, multisector vision for city development and urban form (see chapter 3).

Although excess expenditures should always be avoided, in the long run, failing to invest in the optimal transport and strategic urban development from the outset can be more expensive for developing cities in terms of negative externalities and opportunity costs. Although urban rail projects are often viewed simply as the delivery of civil works and operational systems, complementary policies and

*Photo:* Construction of new transit-oriented development transforming the area around the Wiehle-Reston Station, Silver Line, Washington, DC. *Source:* © Dulles Metrorail Corridor Project. Reproduced with permission; further permission required for reuse.

**BOX 16.1.****Scale of Urban Rail Investment and Its Ability to Shape Urban Form: Metro Line 2, Lima, Peru**

Now under construction, Metro Line 2 is not only the largest infrastructure project for Lima, but also the largest for Peru as a whole. At a total cost of US\$5.3 billion, Line 2 alone commands 6 percent of the national government's total capital expenditures during its construction phase, which amounts to approximately 1.9 percent of the country's gross domestic product.

When completed, Line 2 aims to reach a daily ridership of 660,000 passengers, improving travel times for approximately 5 percent of daily trips carried out in Lima's metropolitan area of 9 million citizens. Critics may use these figures to dismiss the Line 2 project as having a marginal impact on the city's overall mobility given its high cost—more so in the context of a city in the developing world. Yet, the government's vision is

that Line 2 will also provide the city with a 35-kilometer backbone to concentrate and catalyze strategic urban and economic development across its rapidly growing metropolitan area. In this sense, the project's beneficiaries are not only Line 2's projected 660,000 daily passengers, but also the 2.3 million people living and working along those 35 kilometers. Lima's urban development strategy has the potential to leverage the US\$5.3 billion in infrastructure investment to add further value to the city: to create more efficient and sustainable urban development patterns, to promote the development of new commercial districts and employment hubs that stimulate innovation, and to improve the quality of public spaces and create more attractive and vibrant neighborhoods for local citizens and tourists alike.

expenditures—such as multimodal integration facilities or improvements in public space around urban rail stations—are essential to delivering the full benefits of an urban rail project. Therefore, implementing an urban rail project is as much about devising a vision and implementation strategy to reap the most benefits from accessibility gains brought by the project as it is optimizing the technology, infrastructure, and services.

Rapid transit infrastructure, particularly urban rail, helps to shape city form and the distribution of housing and job market densities. Local planners and project managers need to understand and guide the transformation of transport, economic, and land use patterns along the urban rail corridor in the long run. This means carrying out a very careful alternatives analysis of the project's economic benefits with regard to corridor alignment, construction methods, and selection of technology, among other aspects (see chapters 4 and 5). It also means taking a proactive approach in pursuing potential joint (re)development opportunities beyond the urban rail corridor and stations that could bring new revenues to the operator and support a more economically vibrant, inclusive,



and sustainable urban development pattern for a metropolitan region and for local communities. Several barriers, from institutional coordination to legal and regulatory frameworks, need to be addressed in order to unlock the urban rail system's potential to shape the urban form and bring additional value and revenue to the city or the project. Most important is the decision to be bold so as not to discard the opportunity to shape the city's future urban development by thinking of urban rail systems only as transport infrastructure and service.

This chapter offers a practical guide for local practitioners planning or implementing a new urban rail project or upgrading an existing line or station on how to develop a broader vision of the project as a tool for shaping sustainable, prosperous, and inclusive urban development. Based on an integrated economic, land use, and transport vision, a new urban rail project has the potential to generate a broader urban value. This value, in turn, can be capitalized and used to finance public infrastructure, including rail-associated infrastructure, and to develop a more sustainable and inclusive urban form.

To that end, the chapter introduces the broad concept of accessibility and presents a basic explanation of how accessibility gains are the result of not only transport mobility improvements, but also a combination of land use policy and design of the public realm in areas adjacent to urban rail stations. This conceptual framework is presented using simple and common examples of station area characteristics, building on existing methodologies and frameworks around the concept of transit-oriented development (TOD). These examples offer practical strategies that local practitioners can use to increase the broader urban and economic value that can be generated from urban rail investments.

The chapter provides practitioners with evidence of the relationship between the attributes that increase value and the potential to finance, through value capture, the local infrastructure improvements that generate increased value. This chapter presents the most common barriers to implementing TOD and the strategies to unlock financing for it. The last section presents recommendations to build a support coalition for TOD implementation, focusing on the social and economic actions that sustain and reinforce the value-generating mechanisms with broader strategies for community development.

### **Thinking of Urban Rail Systems Beyond Improving Mobility**

Typically, the principal objective of any new urban rail project is to improve urban mobility by enhancing public transport services between different areas of a city. In low- and middle-income countries faced with increasing levels of congestion and motorization and typically poor-quality public transport services, urban rail

systems are deployed to provide more efficient, reliable, safe, high-quality, and high-capacity transport. In many developing cities, the majority of the population travels on public transport (including urban rail). In particular, lower income urban residents rely disproportionately on public transit services (see chapter 2). To the extent possible, a new urban rail line also expects to attract some percentage of car users (middle- to high-income citizens) by leveraging urban rail's improved safety, faster travel speeds, and higher quality of service and by advertising potential savings on fuel and parking.

The most visionary and impactful urban rail projects are conceived not only to improve mobility and transport-related performance indicators, but also to transform urban development patterns and thus improve accessibility, sustainability, social inclusion, economic vibrancy, and livability of the city. Therefore, urban rail projects include both infrastructure investment and complementary policies that integrate transport, economic, and land use development. Historically, rail projects hailed as “best practices” in integrated transport and land use planning (for example, Copenhagen; Hong Kong SAR, China; Singapore; Stockholm; and Washington, DC) have had a significant impact in shaping urban development (Suzuki, Cervero, and Iuchi 2013, 49–94). These examples highlight the importance of dense, compact, and mixed land use development with attractive design of the public realm that supports walking and cycling and facilitates the emergence of vibrant communities (ITDP 2017). By improving transport services, these projects move people more efficiently about the city (improve mobility); by bringing origins and destinations closer together through new patterns of land use and urban development, they also facilitate nonmotorized travel and generate more trips (improve accessibility). Accessibility, rather than mobility, ought to be the goal of any urban rail project.

Accessibility by urban rail should be considered at three levels—regional, local, and universal—all of which need to be balanced to achieve optimal results for users and the city as a whole. The following subsections explore each of these three levels of accessibility in more detail.

### **Regional Accessibility**

At a regional level, the concept of accessibility refers to the ease with which people can access desired opportunities (for example, jobs, schools, health care centers, shopping, and recreational facilities) in a given travel time. The concept of regional accessibility often focuses on how to achieve optimal combinations of transport and land use that deliver efficiency of a transport system in serving the daily commute to work. Many elements make up a thriving metropolitan area, and it is also possible to consider ease of access to metropolitan-level facilities such as health, education, or recreation in addition to access to jobs.

However, because the economic success of a city is built on the strength and vibrancy of its labor markets, access to jobs is considered the most common and fundamental measure of regional accessibility. Recent research suggests that the strength and vibrancy of a city are correlated not with the sheer size of the labor market, but rather with the number of jobs per worker accessible within a one-hour commute (Bertaud 2014, 11). Since vibrant labor markets are essential to development, this regional level of accessibility (to jobs) is most prominently considered in the four “As” framework—availability, accessibility, affordability, and acceptability—for considering the distribution of benefits from an urban rail project (see chapter 2).

Urban rail systems are planned and built along corridors with the highest current and future travel demand in the metropolitan region. In addition, urban rail systems can support higher concentrations of jobs and population along the corridor and around stations, proactively driving additional activity and travel demand. Developing urban rail infrastructure with complementary land use policies can improve the financial sustainability of urban rail operations and increase economic productivity and make cities more competitive as a result of agglomeration effects.

The challenge is to develop residential land use and employment hubs in proximity to one another and to connect them with the most efficient means of transport. One of the best examples of how the land use and mobility master plans for a metropolitan area are co-orchestrated is the Planetary Cluster Plan in Stockholm, Sweden, where jobs and housing are intermixed along rail corridors (see box 16.2). However, changes in land use patterns and urban development at the metropolitan or city scale usually take a generation to materialize. Similar to Stockholm’s case, the metropolitan- and city-scale transport and land use co-orchestrated models of Copenhagen; Hong Kong SAR, China; and Washington, DC, took decades to develop and consolidate. In the short term, a new urban rail line will improve regional accessibility to jobs by leveraging urban rail’s exclusive right-of-way, fast travel speeds, higher capacity, and better quality of service to reduce travel times between existing origins and destinations.

### **Local Accessibility**

At a neighborhood scale, the concept of local accessibility refers to ease of access and egress to local destinations, including urban rail stations and other neighborhood amenities. The degree of local accessibility is determined by the distribution and intensity of land uses and how the design of the public realm and built environment are shaped around rapid transit infrastructure. It also refers to the concept of last mile for station areas and how the stations and their surroundings favor intermodal transport connections, particularly in offering a pedestrian- and

**BOX 16.2.****Balancing Demand through Targeted Mixed-Use Development: Stockholm Planetary Cluster Plan, Sweden**

Similar to the Finger Plan in Copenhagen, Denmark, the Planetary Cluster Plan in Stockholm, Sweden, reduced commutes by intermixing jobs and housing along rail corridors. As part of an integrated land use and transportation strategy for the metropolitan region, corridors for channeling growth from the urban centers were defined early in the planning process, and rail infrastructure was built, often in advance of demand, to steer growth along desired growth axes (see figure B16.2.1). As important, greenbelt areas were set aside as agricultural preserves, open space, and natural

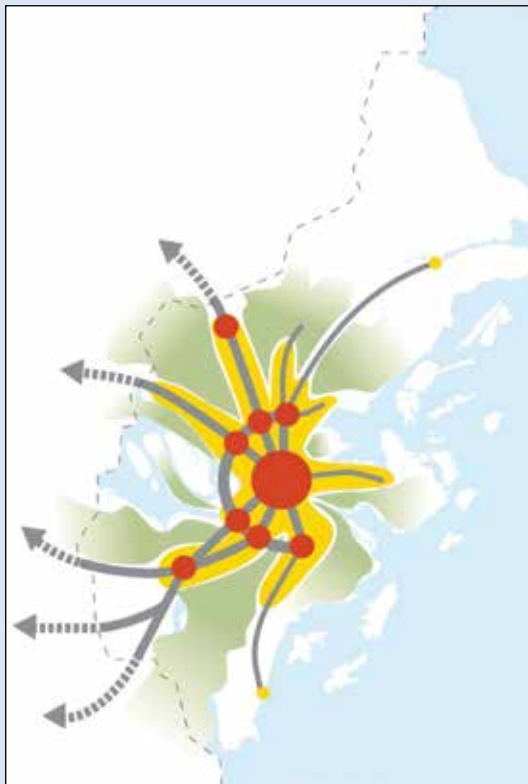
habitats, and major infrastructure was directed away from these districts.

The mixing of land uses along linear corridors helps to balance bidirectional passenger flows, leading to more efficient use of urban rail infrastructure and more reliability in operations. During peak hours, 55 percent of commuters are typically traveling in one direction on trains, while 45 percent are heading in the other direction (Cervero 2006). Stockholm's transit mode share is high, even compared with larger rail systems in European cities (see image B16.2.1).

**IMAGE B16.2.1. Many Passengers Waiting to Travel in Both Directions at Stockholm Central Station: Stockholm, Sweden**

Source: Gustav Gullberg via Wikimedia Commons.

*(box continues next page)*

**BOX 16.2.****Balancing Demand through Targeted Mixed-Use Development: Stockholm Planetary Cluster Plan, Sweden** *(Continued)***FIGURE B16.2.1.** Integrated Land Use and Mobility Plan for the Stockholm Region

Source: Brattström and Lindquist 2015.

bicycle-friendly environment. Infrastructure and technology improvements that promote a seamless integration from the user perspective—such as intermodal bus-rail transfer facilities offering physical integration, integrated fare and operational policies among different modes, and bicycle paths and parking facilities—will reduce the time, cost, and burden for last- and first-mile trips (see image 16.1).

**IMAGE 16.1. Bicycle and Pedestrian Access at Kamppi Central Station: Helsinki, Finland**

Source: © Felipe Targa. Reproduced with permission; further permission required for reuse.

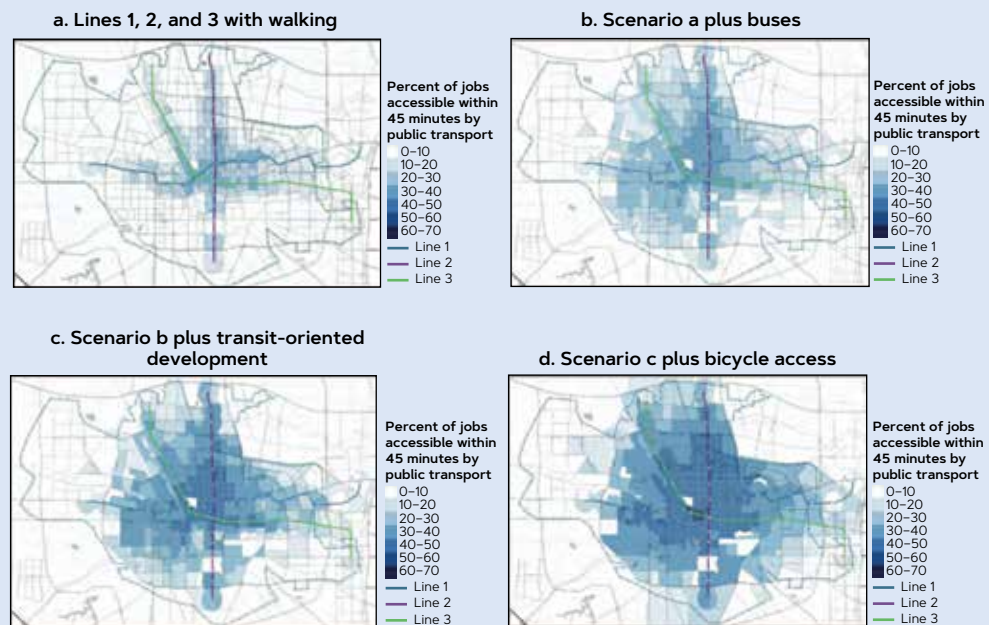
Last- and first-mile trips add significant time and cost to users of urban rail systems. Addressing access and egress to the urban rail system is critical to harness its potential accessibility gain over other modes of travel. The relative change in accessibility gains is what determines the project's potential to capture value. Local accessibility characteristics—particularly physical (as well as operational) integration with feeder bus systems and nonmotorized forms of access—are, therefore, also essential to enabling the full benefits of regional accessibility.

Local practitioners often underestimate the importance of investing in local accessibility improvements along with urban rail infrastructure. They tend to think that providing fast, reliable, and high-capacity rapid transit service is sufficient for improving mobility (and accessibility). Job accessibility analysis conducted for the Zhengzhou's Metro network in China, using different land use and enhanced inter-modal bus and bicycle integration scenarios, shows the importance of these local strategies for achieving regional gains in accessibility (see box 16.3).

**BOX 16.3.****Job Accessibility Analysis with Local Accessibility Improvements:  
Zhengzhou Metro, China**

Accessibility analysis conducted for the Zhengzhou Metro in China demonstrated the importance of local accessibility improvements in contributing to the regional accessibility benefits of urban rail expansion. From the base scenario (three metro lines), the average proportion (weighted by population) of the job market accessed by transit within a 45-minute travel time window is 28 percent (see map B16.3.1). Adding three more metro

lines will increase job accessibility by just 4 percentage points (from 28 to 32 percent). Implementing TOD strategies (doubling population and job density around stations) will increase job accessibility by 11 additional percentage points (from 32 to 43 percent); providing bike infrastructure integration facilities along with TOD around stations will increase job accessibility by 8 additional percentage points (from 43 to 51 percent).

**MAP B16.3.1. Accessibility to Jobs under Different Multimodal Integration Scenarios in  
Zhengzhou, China**

Source: Li et al. 2016.

The capitalization of (regional and local) accessibility benefits generates the appetite for (re)development in rail-adjacent neighborhoods. This appetite for (re)development, in turn, has the potential to deliver improved access to local amenities, services, and jobs associated with local economic development around the consolidation of new urban centralities. Such distribution varies with the real estate market potential of each site or neighborhood and its location within the region, with different neighborhoods serving different strategic functions. No matter the type of neighborhood, one of the key ingredients of better local accessibility is the agglomeration and mix of land uses—in particular, both residences and job opportunities in proximity—so as to avoid as many long-haul trips as possible and enable access by walking and biking. The most efficient and inclusive neighborhoods also bring together markets, drugstores, restaurants, day care and schools, parks, and other key facilities that address most of the basic needs of daily life, thus making traveling outside the neighborhood often unnecessary (see image 16.2).

**IMAGE 16.2.** Residential, Commercial, and Work Spaces Combined within the Same or Adjacent Blocks and Connected with High-Quality Pedestrian Infrastructure: Tianhe District, Guangzhou, China



Source: Luc Nadal. Reproduced with permission under CC license by ITDP.



Therefore, local accessibility improvements serve a twofold objective. First, they contribute to the overall accessibility gains brought by urban rail systems, easing the time, cost, and burden of last- and first-mile trips. Additionally, they generate the appetite for real estate markets to (re)develop a neighborhood area with compact, mixed-use, pedestrian- and bicycle-friendly urban development, with job opportunities and community amenities that enable people to live, work, shop, and play in their neighborhood without having to undertake long-haul trips for their daily needs. It is critical for decision makers to understand that accessibility gains are the result of improved transport mobility combined with land use and local economic development policies and with careful and high-quality design of the public realm in the station area.

### **Universal Accessibility**

Universal accessibility focuses on the ways in which the built environment and transport infrastructure and services accommodate the mobility needs of the widest range of potential users, including children, the elderly, people with mobility and visual impairments (disabilities), and people with other special needs (Victoria Transport Policy Institute 2014). The goal of universal accessibility is to build more egalitarian cities that work for everyone. Keeping in mind that people with disabilities and other vulnerable populations are more likely to repress travel due in part to transport barriers, planning for universal access also constitutes a social and economic inclusion strategy to improve regional productivity by activating often-neglected sectors of the population. Planning for regional and local accessibility, as laid out above, is a central tenet of delivering universal accessibility. However, additional efforts need to be made to enhance universal accessibility—including communicating information about transport services in visual, audio, and tactile formats; designing infrastructure and vehicles to allow for seamless movement from the home, to the sidewalk, to transit vehicles; creating special services for transit deserts—by incorporating the needs of special communities during the planning, design, construction, and operations of any project (see image 16.3).

Universal accessibility is often considered within the local accessibility improvements of intermodal transfer facilities offering physical integration across different modes and access to stations, including ramps, elevators, and signage. New urban rail project interventions are usually limited to the station infrastructure and the immediate station areas. However, practitioners ought to plan and design infrastructure, signage, and other elements in a buffer area that may go beyond 400 or 800 meters from the rail station. Universal access should be considered not only for times of regular service, but also for emergencies or evacuations.

Any new urban rail project has the potential to improve accessibility in all three dimensions—regional, local, and universal—yet that impact also has

**IMAGE 16.3. Accessible and Wheelchair-Friendly BRT Stations: Lima, Peru**

Source: © Aceplan Accesibilidad S. L. Reproduced with permission; further permission required for reuse.  
 Note: BRT = bus rapid transit.

certain boundaries. On average, people will only walk approximately 400 meters to a regular bus stop and approximately 800 meters to a rapid transit service, such as a rail station. As such, locations within an 800-meter buffer along the new urban rail line are bound to perceive a tangible improvement in their accessibility. This catchment area of perceived accessibility gains could be extended if adequate intermodal bus-rail and bicycle-rail transfer facilities and pedestrian-friendly access were offered, combined with other fare and operational integration policies. This is why considering accessibility improvements, land use, economic and multimodal integration policies, and urban form and built environment characteristics are important when making alignment and station location decisions early in project planning and design.

### **Capitalization of Accessibility Benefits**

Empirical evidence based on the spatial equilibrium framework indicates that improvements in accessibility typically manifest themselves as premiums in property values within the new urban rail line's area of influence (Alonso 1964; Mills 1972; Muth 1969). A new urban rail project lowers the cost of transport for properties around the stations. The benefit of accessibility, in turn, creates a locational advantage that makes people and firms place higher value on the land, generating a bid-rent gradient that peaks at rail stations (Brueckner 1987; Debrezion, Pels, and Rietveld 2007). Over the past decades, an extensive

literature has shown how new rapid transit infrastructure produces land value premiums around stations, although the magnitude of the results differs based on research methods, transit technologies, and local characteristics of the built environment around stations in each case (Debrezion, Pels, and Rietveld 2007; Higgins and Kanaroglou 2016; Mohammad et al. 2013).

Altogether, empirical evidence demonstrates that new urban rail lines will only deliver a premium in property values in their area of influence if the urban rail project brings a gain in accessibility compared with other modes of transport in the area. For instance, if the area is highly congested and job accessibility by all modes of travel is low, an urban rail project offering substantial gains in relative accessibility will likely capitalize these accessibility benefits as increasing land values near stations. Conversely, urban rail projects that do not provide a competitive advantage in terms of accessibility compared with other modes of travel in the project area will not have the same effect. Furthermore, urban rail projects offering similar regional accessibility gains as other modes of transport may have considerably different effects on land property premiums, depending on the local accessibility and TOD characteristics of each station and other complementary factors, such as regional or local economic growth dynamics and policies that incentivize development.

These TOD characteristics are often the most neglected areas of urban rail implementation due to lack of allocated resources. Thus, a key message from the extensive body of literature and its empirical evidence is that investment in station area improvements in an urban rail project can be justified by their associated land value premiums. These benefits come from the amenities and characteristics of the built environment that make local transit-oriented neighborhoods more livable, economically vibrant, cleaner, less noisy, and, overall, more desirable places to live.

A recent comprehensive and critical review of more than 130 analyses across 60 studies completed in North America over the past 40 years (Higgins and Kanaroglou 2016) found that a fundamental source of variability in the land value premiums is a lack of specificity and understanding of the proximity effects in which accessibility benefits are capitalized. Most of the evidence fails to account for these proximity effects, leading to the potential for omitted variables and unobserved relationships related to drivers of urban value, such as relative accessibility gains and TOD characteristics. Although proximity to urban rail stations or rights-of-way may bring accessibility benefits, it can also be associated with negative externalities such as noise, vibration, pollution, or crime in dense urban areas or a lack of economic vibrancy and place functions due to the large presence of parking lots, highways, and vacant land, which may be more common around commuter or suburban stations.

The differentiated impact on accessibility gains, land value premiums, and urban development transformation is evident in a comparison of urban rail systems or stations with different land use and local economic development policies or design standards for the public realm (see box 16.4). Successful cases are those that have undertaken proactive planning to achieve the goals of accessibility and increased urban development and activity. Proactive planning requires a lot of upstream integrated transport, economic, and land use planning to deliver all three levels of accessibility. These efforts start by defining the project's alignment and the vision for transforming areas of strategic value into thriving centralities within the city and then going into the smaller details of improving accessibility at a local level and promoting projects that have the potential to catalyze broader urban (re)development processes. The next section summarizes different frameworks and strategies available for practitioners to understand and take positive action toward generating value from urban rail investments around the concept of local accessibility and TOD.

#### **BOX 16.4.**

### **Planning for Accessibility and Increased Urban Value: The Mass Transit Railway Corporation in Hong Kong SAR, China**

Out of the numerous cases in the literature, the construction of new metro lines had little to no impact on property values in places with low population or job densities, segregated land uses, and streetscapes designed primarily for cars (Gatzlaff and Smith 1993, 54–66; Medda 2011, 42–52) (see image B16.4.1). In these cases, metro projects were only conceived as mobility projects and did not consider broad urban development impacts that could bring additional benefits by shaping urban form. Sometimes, transit-adjacent developments (TADs) have the potential to provide regional accessibility, but they fail to capitalize on proximity. As a result, the new metro lines connected fewer people and places of interest, have lower ridership, and do not bring major accessibility benefits or related increases in property values.

Conversely, in Hong Kong SAR, China, one of the densest cities in the world and where

the public realm caters to the needs of pedestrians, up to 90 percent of all motorized trips are carried by public transport. With a long history of integrated transport and land use planning, the development of each new metro line has been successful in improving accessibility and increasing property values. In fact, the city's metro company, the Mass Transit Railway Corporation (MTRC), has established its own property development and property management businesses that bring in more than half of MTRC's revenues every year. The land value capture (LVC) scheme associated with metro infrastructure development has also included 600,000 public housing units, a key result for local planners interested in counterbalancing the negative effects of gentrification associated with land property premiums and the displacement of renters and low-income local populations (see image B16.4.2).

**BOX 16.4.****Planning for Accessibility and Increased Urban Value: The Mass Transit Railway Corporation in Hong Kong SAR, China** *(Continued)***IMAGE B16.4.1. Warm Springs/South Fremont Bay Area Rapid Transit Station Surrounded by Parking Lots: Fremont, California, United States**

Source: © Joanna Moody. Reproduced with permission; further permission required for reuse.

**IMAGE B16.4.2. High-Density Residential and Commercial Development: Mass Transit Railway Corporation Kowloon Station, Hong Kong SAR, China**

Source: Diego Delso, License CC BY-SA via Wikimedia Commons.

## Transit-Oriented Development: Capitalizing on Attributes That Generate Value

The concept of TOD is one of the trademarks of integrated transport and land use planning for rapid transit infrastructure. It serves as a tool for planners to identify the attributes that help to increase accessibility and generate broader value around rail stations. TOD is a planning and design strategy for achieving compact, mixed-use, pedestrian- and bicycle-friendly urban development closely integrated with transit stations that generate value from all dimensions of accessibility. It embraces the ideas that locating amenities, jobs, shops, and housing around transit hubs promotes sustainable nonmotorized travel and transit use and that careful place making softens the perception of density and facilitates the emergence of vibrant communities (Salat and Ollivier 2017). Thus, TOD can support a socially inclusive lifestyle with a lower carbon footprint than traditional development.

If properly planned and implemented, the potential benefits of TOD include an increase in urban rail ridership, savings in travel time and cost, reduction of greenhouse gas emissions and local air pollutants, joint development opportunities, neighborhood revitalization, and economic development. The ability to deliver higher transit ridership is perhaps TOD's core benefit, as basically all other benefits related to TOD are derived from its ability to concentrate higher passenger volumes on a less energy-intensive rapid transit system. Some empirical studies have found that transit stations with high-quality TOD characteristics may explain between 100 and 300 percent of additional ridership compared with similar stations without TOD design and local amenities (Rodriguez and Vergel-Tovar 2017). Studies in the United States have found that people living near TOD stations spend 37 percent of their income on housing and transportation compared with 51 percent for other people (Haas et al. 2010). Moreover, households may reduce their greenhouse gas emissions by 43 percent simply by living in a central location near transit or by as much as 78 percent by living in the most location-efficient transit zones (Haas et al. 2010; Reconnecting America 2009). In fact, Hong Kong SAR, China; Stockholm; and other locations with high-quality rapid transit infrastructure complemented by extensive TOD have been successful in decoupling economic growth from greenhouse gas growth per capita (Rode et al. 2013).

TOD can also serve as a catalyst for neighborhood redevelopment efforts, bringing new economic vibrancy to previously overlooked city areas.<sup>1</sup> Closely related to neighborhood revitalization is the ability of TOD to attract investments and businesses to areas around transit stations, creating new and better-paying jobs. New employment, in turn, can have a multiplier effect, spinning off other local employment opportunities.

Concentrating development in an 800-meter or 1-kilometer radius around rail stations is one of the most successful and unique opportunities for shaping cities and making them more sustainable, livable, and inclusive. Local practitioners can take supportive measures to prioritize development around stations and should measure and monitor the percentage of jobs and residents within a radius of stations and the percentage of new development taking place in those well-connected areas as opposed to other parts of the city as a core performance benchmark. They can support this concentration by prioritizing new public infrastructure in well-connected and transit-accessible areas, while restricting development in other areas. They can also encourage greater economic opportunities by supporting a mix of uses and income groups. Around stations, cities can facilitate the creation of health, education, shopping, and recreation facilities to enable local communities to thrive (Salat and Ollivier 2017). The most common and effective value-generating strategies for TOD are discussed later in this section.

TOD also facilitates the ability of governments or transit agencies to recuperate part of their investments in building an urban rail line to fund or finance part of the neighborhood improvement amenities around transit stations (see chapter 10). Typically, this improvement takes place by capturing a portion of the increase in land values realized due to the capitalization of accessibility benefits and new development opportunities around the urban rail station—hence, the name land value capture (LVC).

Cities, however, are not uniform spaces; as such, development of a new urban rail line will not add value uniformly along its alignment. Promoting TOD principles does not mean delivering the same urban forms at every station. Instead, local planners need to understand the variety of contexts throughout their city and to embrace the diversity of possibilities for leveraging the investment in a new urban rail line to increase property values and strengthen local communities in context-specific ways. Not all stations are equal in their development potential. Generally about 15 percent of station areas are expected to achieve very high densities depending on the city. Other areas may not have the commercial value or market potential required for such development. There is no “one size fits all” to TOD throughout a city. Early projects often focus on greenfield sites, where development is easier, or on central locations and highly accessible transit hubs, where high-density development is supported by high land values. Other types of opportunities exist outside these major areas, but they require tailored approaches (Salat and Ollivier 2017). Overall, cities that decide to build an urban rail project are polycentric urban areas, with half or two-thirds of the jobs located outside the core urban area. Even station areas on the periphery of the network, not as economically vibrant as the fast-growing core stations,

provide opportunities for creating TOD, especially if those stations can be connected to the local community and commercial context of the area.

Today, local practitioners have a wide variety of tools and frameworks with which to differentiate the opportunities offered by different urban rail stations in a network and to understand where, when, and how to create potential value. The following subsections describe TOD-station typologies and some of the commonly used strategies to reap the potential benefits of TOD interventions on different urban rail station areas.

### **TOD Typologies**

Academics and practitioners have long developed TOD typologies based on their observations of past TOD development strategies and their results in different cities. Bertolini's (1999) theoretical node-place model and the empirical analysis conducted in multiple rapid transit systems led to the concept of the "3Ds"—density, diversity, and design (Cervero 2002; Cervero and Kockelman 1997). The "3Ds" were then adapted to the "5Ds" by including destination and distance to transit as additional dimensions (TCRP 2004).<sup>2</sup> More practical frameworks were also developed to identify TOD typologies to support a city's strategic planning based on the real estate development opportunities (Haas et al. 2010). All of these frameworks describe the potential benefits of TOD and practical strategies for increasing the broader urban and economic value that can be generated from urban rail investments. A new contribution to this literature is the "3V" approach (Salat and Ollivier 2017), which generalizes these international approaches based either on a node-place model or a marketplace model. The "3V" approach identifies three values that can characterize an urban rail station and its conceptual relationship to accessibility: node value, place value, and market potential value.

#### *Node Value*

Node value describes the importance of a station in the public transport network based on its volume of passenger traffic, intermodality, and centrality. Highly connected multimodal hubs, such as Tokyo Station in Japan or Atocha Station in Madrid (see box 16.5), have a high node value. Node value is also correlated with the regional and local accessibility characteristics of any urban rail station. From the regional accessibility perspective, node value indicates the potential of users at the given station to reach any regional destination due to the station's network connectivity. Likewise, extending the concept of the network to the integrated rail-bus transit network (including service, fares, and information) and the pedestrian and bicycle infrastructure facilities at the local level, node value is also relevant to local accessibility. In addition to enhancing



**BOX 16.5.****Node Value and Place Making at Atocha Station: Madrid, Spain**

Atocha Station is the largest railway station in Madrid, serving commuter and high-speed intercity trains. Atocha Station is a complex consisting of two buildings. The new station is used for rail traffic, the high-speed rail terminal, long-distance trains, and local services; it is connected to local buses and is accessible by nonmotorized transport. This intermodal connectivity provides Atocha Station with high node value.

In addition to being a multimodal hub, Atocha Station is also the stop for the Royal Botanical Garden of Madrid. The old station

building was converted into offices for rail operations and a shopping and leisure complex. To connect the station to the attractions of the local community and support a sense of place, the old station building houses a 4,000-square-meter botanical garden with more than 7,000 plants of at least 400 different species. Travelers can stop and watch turtles in their sanctuary, sit on a bench among the flora, or shop and dine under the gorgeous architecture (see image B16.5.1). Atocha Station is an excellent example of how to incorporate place-making concepts into rail station design.

**IMAGE B16.5.1. The Interior Plaza of Old Atocha Station with Shops, Restaurants, and Small Botanical Garden: Madrid, Spain**

Source: Wikimedia Commons.

local accessibility, seamless multimodal integration and last-mile connectivity solutions at the station level play key roles in the creation of node value.

The higher the hierarchy of the transit network, the fewer the opportunities for local practitioners to influence node value. This opportunity will only come early in the project development process as decisions are made regarding the urban rail network layout, line alignment, and station location. Although these decisions are primarily driven by the layout and hierarchy of the city's centralities and economic concentration, local planners and project managers could also influence node value, to a lesser degree, through the lower-hierarchy modes (including the multimodal bus-rail integration network), fare integration policies, and nonmotorized transit facilities, and other improvements to the station and its surroundings.

### *Place Value*

Place value describes the urban quality of a place around a rail station and its attractiveness in terms of local amenities and ease of access to jobs, shopping, schools, and other social and economic services on foot or bicycle. It often refers to the quality of the urban fabric and built environment around rail stations described previously in the context of improvements in local accessibility that create livable and vibrant neighborhoods (see image 16.4). The concept of place value is related directly to the concept of local accessibility and TOD characteristics described in the "3Ds/5Ds," the TOD Standard guidelines of the Institute for Transportation and Development Policy (ITDP 2017), the Urban Land Institute's Ten Principles for Building Healthy Places (Eitler, McMahon, and Thoenig 2013), the University of Delaware's Complete Communities Toolbox (Scott, Patterson, and Nau 2013), and the UN-Habitat's City Prosperity Initiative (2015), among others.

For local practitioners, place value is at the core of the opportunities to generate value around stations and involves not only the quality of the urban fabric, including land use zoning and design of the public realm, but also the economic development and sociocultural activity that supports place-making strategies for the benefit of local communities.

### *Market Potential Value*

Market potential value refers to the unrealized market value of urban rail station areas. It is derived through market analysis (the study of demand for and supply of real estate development) and is measured through a composite index that includes (a) major drivers of demand, including current and future residential and employment densities and current and future number of jobs accessible by transit within 30–45 minutes (regional accessibility), and (b) major drivers of supply, including developable land, potential changes in zoning, such as increasing floor area ratios (FARs), and market vibrancy.

### Applying the “3V” Approach

The “3V” approach to characterizing urban rail stations looks forward rather than backward. Local practitioners (project managers and TOD planners) need first to understand the potential market value of each station and then to identify the current conditions of different places and their potential for future transformation. This analysis will ultimately determine the form that TOD could take and its potential to generate value.

Local practitioners interested in opportunities to generate value around urban rail stations may first identify the imbalances between connectivity, accessibility, place quality, and market potential values. Addressing these imbalances creates high potential for economic value creation—by, for example, creating place value around an important intermodal node or bringing additional connectivity to a booming area (see box 16.6). Transit-adjacent development like TOD happens near transit, but unlike TOD it fails to capitalize on this proximity with local accessibility or place value improvements. A key message for practitioners

#### **IMAGE 16.4. Place Value Increased by Pedestrian-Friendly Public Space and Commercial Development around Hakata Station: Kyushu, Japan**



Source: Wikimedia Commons.

**BOX 16.6.****Activating the Potential of an Unbalanced Node: King's Cross Railway Station, London, United Kingdom**

The King's Cross railway station is one of London's major transport hubs, providing connectivity at the city (London), national (United Kingdom), and international (Europe) levels through a variety of rail lines and services. Specifically, King's Cross connects 6 metro lines and 17 bus routes at the local level with 2 rail stations for national and international rail services. Crossrail, a major subway extension in London, will add a seventh metro line at King's Cross by 2018. Additionally, five international airports are within a one-hour rail ride from King's Cross, including three connected to King's Cross through direct services.

That level of connectivity and accessibility grants high *node value* to King's Cross, but the 27 hectares of neighboring undeveloped land indicated that its *place value* and *market value* had not yet been properly exploited. As such, a strategy was put in place to maximize the long-term value of the existing public assets (land) and to deliver broader benefits to the public. Under the supervision of the

Department for Transport, public properties have been put forth as equity to participate in joint venture development companies around the King's Cross and Stratford railway stations. The area's new master plan places great importance on offering a high-quality public realm, which will include 20 new streets and 10 new public spaces, including 5 squares (see images B16.6.1). Overall, 40 percent of the site will be high-quality public space, while the other 60 percent will support 280,000 square meters of new workspaces; 46,000 square meters of retail, bars, restaurants, and leisure facilities; 2,000 new homes; a new university; and educational, hotel, and cultural facilities.

By 2020, up to 50,000 people will be living, studying, and working in King's Cross, which represents a combined residential and job density of nearly 200,000 people per square kilometer. Google has spent about £650 million to buy and develop a 1-hectare site, and the finished development will be

**IMAGE B16.6.1. Pedestrian-Friendly Public Spaces and Development around King's Cross Station: London, United Kingdom**

(box continues next page)

**BOX 16.6.****Activating the Potential of an Unbalanced Node: King's Cross Railway Station, London, United Kingdom** *(Continued)***IMAGE B16.6.1.** Pedestrian-Friendly Public Spaces and Development around King's Cross Station: London, United Kingdom *(Continued)*

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worth up to £1 billion. Google's presence is expected to draw other technology companies to King's Cross and to help to develop a local innovation cluster. After development, the new balance between a high node value

and a high place value is expected to foster a high market value with higher rent and real estate performance (and associated government tax revenues) than the rest of London.

is that once a development is built, transitioning from TAD to TOD typically takes a major push from local government in partnership with the private sector, and retrofitting is almost always more expensive and complex than starting with a proper plan of TOD and station area interventions from the beginning of the urban rail project (Salat and Ollivier 2017). Incorporating TOD and other land use planning from the outset of the project may also create greater interest and opportunities for private participation in the development of urban rail infrastructure or station areas.

The “3V” approach and other performance-based TOD typology guidelines allow local practitioners to categorize each existing or planned urban rail station within a typology and to consider the best strategies for generating value according to each type of station. Every community around a station has a different market profile as well as a distinct set of opportunities and challenges. Three types of station-planning strategies—infill, intensification, and transformation—should be adapted to each station’s specific context. For instance, suburban rail stations have limited near-term market development potential, but substantial land opportunities. Infill station-planning strategies and implementation efforts are needed in three areas: planning for long-term higher densities, multimodal integration, and equity for vulnerable communities through the provision of affordable housing. Intensification station planning strategies are more suitable for emerging market areas with good existing transport service that can support redevelopment at higher densities; these areas are prime locations for catalytic TOD to push the market and provide affordable housing. Transformation station planning strategies apply to major hubs, which already support high job and population densities. In these stations, the focus of TOD can be on creating a high level of place value through major investments in local amenities and the public realm and other innovations such as building retrofitting and lower parking ratios.

### **TOD and Value-Generating Strategies**

Value-generating strategies are related directly to accessibility gains and other local neighborhood amenities that have the potential to capitalize these benefits into land property values. Among the most common strategies that local practitioners use to reap the benefits of urban rail project investments is to encourage development around stations through zoning policies, allocation of street space, and other traditional planning instruments

#### *Create Compact and Mixed-Use Communities*

Zoning policy should increase compactness and diversity of land uses around rail stations. One way to increase compactness is by increasing floor area ratios to

encourage higher, denser development. FARs are usually set at different levels depending on land uses and accessibility gains.<sup>3</sup> Good practice also entails allowing private developers to adjust the use and intensity of development based on dynamic market needs or conditions. By offering bonus FAR and other regulatory incentives, practitioners can require developers to provide affordable housing, day care centers, and space for other public amenities in their new facilities (London and New York have used these mechanisms).

Compactness at the neighborhood scale also involves spatial integration by good walking and cycling connectivity and orientation toward urban rail stations, in turn providing opportunities for social interaction and a feeling of safety. Diverse and complementary land uses within the same or adjacent blocks, also brought by changes in zoning regulation, reduce trip lengths and support the clustering of economic activity. Mixed-use development that concentrates commercial, cultural, recreational, and educational amenities helps to create vibrant, sustainable neighborhoods.

### *Prioritize Walkability*

The creation of a vibrant and active pedestrian public realm facilitates walking (see image 16.5). Walking can be highly attractive when sidewalks are lively and lined with useful ground-floor activities and services, such as storefronts and restaurants. Pedestrians and cyclists increase the exposure and vitality of local retail shops, creating an environment that fosters local economic growth. This nonmotorized transport-oriented environment ensures that people do not find congestion and density oppressive, making streets places for people and creating a “sense of place” and human-scale development (Salat and Ollivier 2017). Safe, connected, and convenient pedestrian and bicycle access helps to ensure the realization of TOD benefits in the rail station’s surrounding area, even beyond the traditional TOD buffer area.

### *Reduce Parking*

The land surrounding urban rail stations is highly valuable. Nonetheless, some project-implementing agencies choose to dedicate some of this land for parking. A recent study of select U.S. cities found that even in TOD rail stations that built less parking than recommended by design standards, parking was not used to capacity, with an oversupply between 58 and 84 percent (Smart Growth America 2016). Park-and-ride facilities at suburban rail stations are usually justified because these stations are used by commuters who have to arrive by car. This is not the case for central-hub stations in consolidated urban areas or for urban rail stations in developing cities where most of the transit users do not own a personal vehicle. If local practitioners plan for cars, they will get cars;

**IMAGE 16.5. Compact, Mixed-Use Development with Street-Level Commercial Spaces that Prioritize Pedestrians: Morningside Heights, New York City, United States**



Source: Luc Nadal. Reproduced with permission under CC license by ITDP.

whereas, if they plan for people, with pedestrian and bicycle access and transfer facilities, they will get people and considerably higher ridership at rail stations.

Recommendations from the ITDP's TOD Standard are critical regarding this aspect. In high-value TOD places, personal motor vehicles become largely unnecessary in day-to-day life, making it possible to reduce the roadway area. Scarce and valuable urban space can be reclaimed from unnecessary roads and parking space and reallocated to more socially and economically productive uses (ITDP 2017). To support the design of TOD neighborhoods, walking and cycling should be given street space previously allocated for cars. Walking and cycling are the most natural, affordable, healthy, and clean modes of travel for short distances—and a necessary component of the vast majority of transit trips (Salat and Ollivier 2017). Therefore, they are critical components of any TOD strategy.



### *Foster Community-Driven Development*

Creating vibrant, inclusive, and sustainable communities involves much more than increasing FAR, increasing compactness, diversifying land uses, and promoting walking and cycling through good urban design (see box 16.7). It also requires broader policies for community-driven development and local economic development. TOD investments are intended to stimulate a market response, but many other critical investments and incentives are needed in the form of human capital, neighborhood services, and business development programs that help to realize the full range of TOD benefits (Salat and Ollivier 2017). The optimal mix of land uses and urban design at each station relates to economic (commercial), social, cultural, educational, recreational, and transport opportunities that are clustered for the needs of people. People should be the focus of the local planning process, not land use and urban design characteristics. High-quality TOD and opportunities for value generation will be manifested through street-life patterns that enable people to move about easily and confidently, to linger, and to get together with other people.

### *Embrace Place Making*

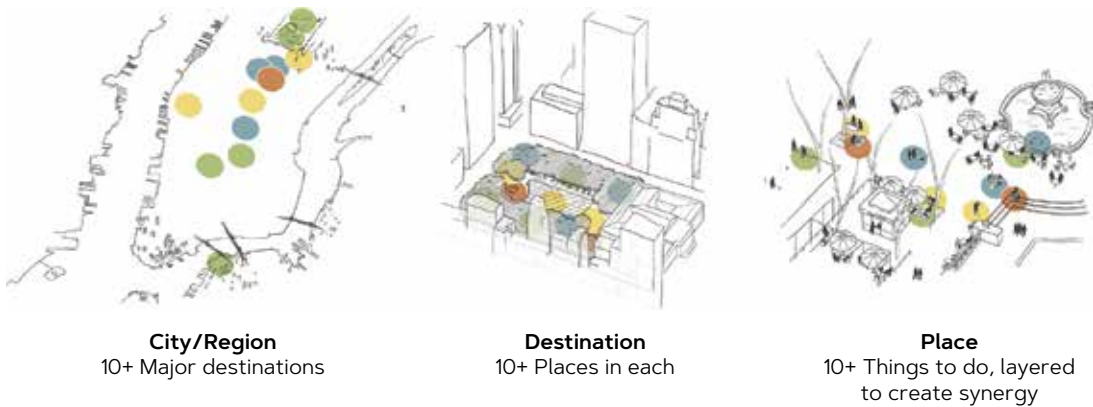
A complementary approach in devising strategies to develop and revitalize cities and neighborhoods through TOD is the Power of 10+, a methodology that focuses squarely on the concept of place making (figure 16.1). Its central tenet is that “cities succeed or fail at the human scale (the place scale) and [that] this

#### **BOX 16.7.**

### **The Eight Principles for Inclusive and Resilient Transit-Oriented Development**

1. Maximize accessibility by aligning human and economic densities, rapid transit capacity, and network characteristics.
2. Create compact regions with short commutes.
3. Ensure resilience of areas connected by rapid transit.
4. Plan and zone for mixed-use and mixed-income neighborhoods at the corridor level.
5. Create vibrant, people-centric public spaces around stations.
6. Develop neighborhoods that promote walking and biking.
7. Develop good-quality, accessible, and integrated public transport.
8. Manage demand for private vehicles.

Source: Ollivier 2018.

**FIGURE 16.1. The Power of 10+ Methodology for Transforming Cities through Place Making**

Source: © Project for Public Spaces. Reproduced with permission; further permission required for reuse.

scale is often overlooked. The Power of 10+ shows how paying attention to the human experience when building a city's destinations and districts can have immediate and widespread impacts" (Project for Public Spaces 2017).

The argument is that places, including TOD neighborhoods, succeed when people have several reasons (ideally 10 or more) to be there. These reasons may vary and appeal in different ways to different people—ranging from something as simple as offering a comfortable place to sit and read or a piece of art to contemplate, to having an interesting shop or a good restaurant at which to eat and drink with friends. Ideally, some of these elements will reflect the local character of the area and define a sense of uniqueness relative to other areas of the city. These elements should be layered thoughtfully to deliver a sense of synergy. Further place making is thus built from these elements at the human or place scale, up to the neighborhood or destination scale, and, finally, up to the city scale. A destination is more likely to thrive if it brings together 10 or more places that people want to visit. In turn, a city is more likely to generate enthusiasm among local residents and tourists alike when it has at least 10 of these destinations or districts for everyone to enjoy (Project for Public Spaces 1997).

### Overcoming Barriers to TOD Implementation

Although TOD typologies and principles are well documented, TOD implementation often faces barriers in practice. Institutional challenges and financial restrictions can impede the process, and concerns about gentrification and the

long-term impacts on low-income residents of communities need to be addressed. Land value capture (with some of the revenue reinvested in affordable housing provision) is one way to help recoup the cost of TOD improvements around rail stations.

### **Barriers to TOD Implementation**

Conceptually, the case for integrated transport, economic, and land use planning is straightforward and irrefutable. The true barriers to its realization lie in implementing the concepts and strategies described above within long-standing institutional structures, in overcoming entrenched interests and other political economy issues, and in addressing the ever-present challenge of resource scarcity. This subsection lists common barriers and suggests potential solutions to address them.<sup>4</sup>

#### *Long-Term Processes in the Face of Political Urgency*

Achieving a strategic transformation in the transport, economic, and land use development of a city is a lengthy process that typically takes between 10 and 20 years. It is a process that requires a long-term commitment in contexts where the city's political leadership may be changing as often as every three to five years. The relative ease with which master plans and even projects as costly as new urban rail lines may be changed by new administrations in developing cities makes this type of transformation more difficult to achieve.

Solutions to this challenge include strengthening long-term planning institutions and processes and allowing more flexibility to change one station area at a time without derailing the entire urban rail project. Practitioners may pick a strategic station where opportunities and potential impact are well aligned with one another using the TOD typology guidelines and value-generating strategies presented in this chapter. From a successful case, practitioners can then deliver TOD concepts throughout the length of the new urban rail line.

#### *Metropolitan Fragmentation*

The natural geography for integrated transport, economic, and land use planning is the metropolitan level (the functional agglomeration of people, industries, housing, and infrastructure). In some cases (for example, China), a city's political boundaries extend beyond the functional metropolitan area. In other cases (for example, in the United States and many countries in Latin America), the functional metropolitan area spans the political boundaries of many cities. As such, urban rail projects and TOD interventions require coordination among various city governments. The development of a new urban rail line is typically achieved with the financial support of higher levels of government (state-province

level or national-federal level). In order to secure such financial support, the various cities making up a metropolitan area have to put in place arrangements to work together throughout the planning, implementation, and operations of the urban rail infrastructure and other urban improvements. Local practitioners should use this type of ad hoc arrangement as a stepping-stone for more thorough transport, economic, and land use planning at the metropolitan scale, perhaps culminating in the eventual establishment of metropolitan transport and land use authorities (see chapter 12).

### *Silo Behavior*

City departments and agencies have long-established missions, objectives, governance structures, and personnel profiles that are often at odds with efforts to deliver TOD through integrated transport, economic, and land use planning. For instance, in many countries, transport departments have little knowledge of land use issues, may disregard urban design for functionality, and commonly focus on improving mobility rather than accessibility. In turn, separate urban planning agencies often struggle to understand transport dynamics and the urban development opportunities they represent. Finally, management and staff from both sides have restricted budgets and limited incentives to take up the additional effort needed to deliver integrated environments.

In the absence of institutions and regulations promoting integrated and multi-sector planning practices, the urban rail project itself may be the catalyst for institutional reorganization, new development practices, and a process of change moving forward. Although urban rail projects are more likely to be led by the city's transport agencies, key staff from urban planning agencies should be brought on board to participate in meetings and strategic committees and freely provide their input throughout the project's planning. In time, transport and planning agencies should also develop an integrated transport, local economic, and land use plan for the urban rail corridor (800-meter to 1-kilometer buffers), with subsequent detailed station area and neighborhood plans to follow.

### *Financial Restrictions*

Urban rail projects are incredibly costly, particularly when additional investments are required to achieve better land use integration and TOD. Accordingly, even if national governments assume the majority of the project's cost, city governments still face an uphill battle to provide the funding and financing needed to generate the most urban and economic benefits from TOD interventions at the local scale. Unfortunately, when faced with this challenge, cities often cut corners—for example, alignments stray from strategic locations due to land acquisition costs; subways are replaced by at-grade and elevated solutions even

in areas of strategic value; and urban design components that facilitate integration with feeder buses, nonmotorized transport, and the public realm are dismissed. Practitioners should explore different options, including TOD-progressive options such as adapting land use plans and zoning strategies to increase property tax and sales tax revenues for the city. These and other LVC strategies are discussed in detail later in this chapter.

### *The Retrofitting Challenge*

The first urban rail lines in any city will be developed in areas of high demand that, for the most part, have already consolidated densities, land uses, and urban design patterns. Accordingly, retrofitting these areas around TOD principles in response to the development of a new urban rail line is more complex than developing an unoccupied greenfield. A key challenge to retrofitting built-up areas is that private businesses or households own most of the properties within the station's area of influence, leaving the government with little control over them. Another challenge is the implicit need to demolish existing physical assets (buildings, housing, or infrastructure), which always comes at high economic and social costs, including the need to resettle displaced residents (see chapter 14).

The first principle to consider when looking at existing properties is that their value is bound to improve considerably with development of the urban rail line as well as local investments in public spaces and other facilities, especially close to station entrances. Cities can benefit from acquiring strategically located properties as early as possible, even if they have to pay more than the current market rate. Conversely, sometimes the best approach is simply to allow regulations and markets to deliver the desired transformation. By increasing FARs and shifting the composition of land use through new zoning policies to attract more people and economic activity around new urban rail stations, the market itself can put enough pressure on holdout property owners.

However, it is also important to balance market dynamics to ensure that neighborhoods conserve their local sense of place and community and, more broadly, that the benefits of the new urban rail line and TOD are enjoyed in more equitable ways. This balance is often achieved by using a share of the revenues from joint developments or higher tax inflows to fund affordable housing projects and programs to protect local business owners.

### **TOD and Gentrification**

TOD implementation that leverages improved accessibility with the appetite of developers and the real estate market for delivering dense, mixed-use, livable communities can be at odds with affordability. Almost by definition, TOD increases the price of land around the station and attracts not only new

riders to the urban rail system, but also new residents to the areas around stations (even those in currently developed areas). This increase in land prices does not necessarily mean that housing prices rise, since better use of available land with higher-density development that adds more housing units could theoretically decrease the value per square meter. However, in most cases, housing prices do increase with the introduction of urban rail infrastructure and TOD because new supply does not keep pace with rising land prices. In such cases, local residents may find themselves priced out of their homes (see image 16.6).

**IMAGE 16.6. Brownstown Building Owner in Upper Manhattan Responds to Gentrification Pressure with a Sign on the Door: New York City, United States**



Source: Luc Nadal. Reproduced with permission under CC license by ITDP.

To mitigate such a social impact, city governments may combine TOD zoning and planning initiatives with inclusionary housing or a guaranteed minimum number of affordable housing units per development. Furthermore, higher land values can be captured by the city and reinvested in affordable housing development at well-connected stations within the urban rail network. The need for affordable housing has to be considered at a network level and balanced to mitigate the displacement of local residents without discouraging developers from providing new, higher-density housing supply.

Although areas around stations are likely to see higher land prices, other areas adjacent to at-grade or elevated right-of-way or close to maintenance garages or storage yards may see their value decrease or may accrue significant negative externalities. The design and implementation of these facilities should minimize the impact on adjacent buildings, and neighborhoods near these areas may need mitigations and improvements in exchange for supporting the urban rail infrastructure (see chapters 14 and 15).

### **Using Land Value Capture to Deliver TOD**

Rather than representing an additional financial burden, optimizing transport, economic, and land use integration along the urban rail's alignment and promoting (re)development following TOD concepts provide an opportunity for the government to add further value to the city and, in turn, to realize additional funding alternatives from the urban rail investment itself. Even with this potential, many cities in low- and middle-income countries underfund urban rail construction and service provision. In these cities, the up-front investments are large compared with their fiscal capacity and revenue from tax sources. Taking on additional expenditures to acquire new plots of land, improve public spaces, provide transfer facilities for buses and bicycles, or engage in joint development opportunities may impose an even more onerous burden on government in the short term. However, urban rail projects that are conceived to improve accessibility and catalyze TOD can have a significant impact on property values in the area of influence of the urban rail system, so the additional investment around station areas has great potential to realize financial and economic returns. The challenge lies in the government's ability to recuperate part of its investments by capturing a portion of those property value increases.

Suzuki et al. (2015) describe how cities can use LVC to finance and encourage more inclusive urban growth. Ensuring that governments can capture a portion of the value they generate through their urban rail investments and complementary actions can be critical to their ability to finance strategic TOD projects and, over time, to achieve broader improvements in urban development patterns. By

investing some of the captured value in parks, sidewalks, street lights, and cycle lanes, city governments can work with transport agencies, developers, and communities to develop efficient, attractive, and safe public places, thereby increasing property values.

The two major LVC categories are (1) tax- or fee-based LVC and (2) development-based LVC. This subsection discusses the most common LVC instruments in each of these categories. However, many other instruments have been developed, depending on local legal, jurisdictional, and regulatory frameworks (for example, impact fees in the United States and the transfer of construction rights or issuance of securities for greater “buildability” in Argentina, Brazil, and Colombia) (see chapter 10).

#### *Tax- or Fee-Based LVC Instruments*

There are three types of tax- or fee-based instruments: land and property taxes, betterment taxes, and tax increment financing.

Many cities levy some form of tax on property owners based on the estimated value of their land (and, in some cases, the structures built on it). Accordingly, an increase in the market value of any property due to improvements in accessibility or new potential development opportunities should translate into an increase in property tax revenues.

However, implementing a property tax presents some challenges. For starters, although many high-income countries have a long tradition of property taxation, in low- and middle-income countries where property rights often are not clearly defined, the notion of paying a property tax can be problematic. Additionally, efficient property tax systems can be very costly to implement for city governments strapped for cash—they require a very detailed and up-to-date cadastral system as well as thoroughly staffed teams of experts in tax assessment and enforcement.

Betterment taxes are a more direct form of LVC than property taxes. They charge property owners who benefit directly from public investments for a portion of the investment cost, either prior to construction or once it is completed. The benefit refers to the specific increase in property value realized from construction of the new urban rail line, complementary facilities, and so forth. Betterment taxes have been used to capture as much as 30–60 percent of property value increases due to public expenditures.

However, estimating an isolated increase in property value for each property with precision requires sophisticated cadastral monitoring and analysis and can be challenging.<sup>5</sup> Additionally, charging betterment taxes on top of property taxes can be unpopular and generate public resistance.



Tax increment financing is used primarily in the United States, but it is slowly gaining momentum in other countries. The idea is to earmark the future increase in property tax revenues in areas targeted for redevelopment in order to finance directly the strategic investments that would catalyze that redevelopment process. In the context of this chapter, those investments would include building an urban rail line or specific rail stations, as well as improvements to building public space and the provision of amenities around these stations. The area targeted for redevelopment is deemed a tax increment financing district, which effectively freezes all property valuations in the district and thus their contribution to the general property tax fund. Instead, the tax increase in the district goes directly to servicing and repaying municipal debt issued against the expected increases in tax revenue.

### *Development-Based LVC*

There are four types of development-based LVC: land sale or leasing, joint developments, air rights sale, and land readjustment.

With land sale or leasing, the government or transit agency owns or acquires plots of land prior to building the new urban rail line, servicing the area, and enacting strategic changes in FAR and land use designation. Once the area is properly equipped and ready for TOD implementation, the public lands are sold or leased to private developers, with the government capturing all of the land value increment realized through its efforts. The challenge is to acquire upfront properties located in high-demand areas of the city that very likely will be of significant cost even prior to the urban construction. An alternative is to target more peripheral areas on the urban rail line that might be less costly, but then redevelopment needs to be supported clearly in the city's integrated transport and land use plan for the property values to increase appreciably.

Joint developments refer to instances in which the transit agency partners with private sector actors in a real estate project, often sharing revenue streams and ownership. Joint developments are commonly located near stations in land previously owned or acquired by the transport agency and may go as far as including the adjacent urban station itself and other public space facilities typically built by the government alone. In this case, the LVC is achieved in the form of significant cost savings in the development of key infrastructure needed to catalyze TOD, the creation of new revenue streams for the transport agency from real estate operations, or both (see chapter 10). Many transport agencies around the world—including the Washington Metropolitan Area Transport Authority in Washington, DC, the MTRC in Hong Kong SAR, China, and Crossrail in London (see image 16.7)—collect significant revenues on an annual basis from joint development deals.

**IMAGE 16.7. Aerial View of Woolwich Station with Berkeley Homes Oversight Developments: London, United Kingdom**



Source: © Crossrail, Ltd. Reproduced with permission; further permission required for reuse.

With the sale of air rights, governments charge for strategic changes in land use regulations for specific plots, such as increasing the allowed FAR or modifying the land use designation, rather than granting them for free. This new revenue stream can be used to finance investments in urban development and neighborhood upgrades. Municipal governments are still empowered to choose where they want to allow air rights sales (for example, near urban stations to promote TOD) and where they do not. For instance, in São Paulo, Brazil, air rights sales are implemented through certificates of additional construction potential (CEPACs), which are only applicable in preselected areas of the city; the revenue generated is earmarked for financing predetermined urban infrastructure investments. CEPACs are a hybrid between development-based and tax-based LVC, as their price consists of both the price of air rights and future increases in land value from infrastructure investments funded by the CEPAC.

Land readjustment is commonly used in peripheral areas of the city where the existing land distribution is somewhat irregular for TOD and urban services may be lacking. Once the area has been selected for urban expansion, the government consolidates all parcels of interest and then restructures them in more efficient shapes that better serve TOD. Landowners eventually receive a smaller plot of land, but one that is better serviced with public utilities and has a higher development potential. The government, in turn, sells the extra land or remnant parcels to private actors to develop, generating new revenues for the public sector that can be used to finance the urban station or other key public amenities in the area.

These and other LVC instruments can be used to leverage TOD and the increase in land prices associated with urban rail development as a funding source or financing tool for the infrastructure investment. Despite concerns about gentrification, LVC instruments do not affect market prices so long as the supply of real estate in the station area is sufficient. However, when demand outstrips supply, the city or regional government may want to consider other initiatives to ensure a minimum level of affordable housing within the area.

### **Toward TOD Implementation: Building a Support Coalition**

Transforming the urban development patterns of any city is a long-term process that only begins to deliver tangible outcomes in the long term. Although a long-term and integrated vision of urban form and transport development of the city is needed, the most meaningful transformations start one project or neighborhood at a time. Focus ought to be placed on implementing that first project to demonstrate the government's vision and the possibilities moving forward, thus encouraging the development of new projects elsewhere.

According to the "3V" approach, balanced nodes offer the most promising opportunities to intervene and consolidate TOD (Salat and Ollivier 2017). Balanced nodes are areas where the new urban rail line intersects with other key transit lines, and, although there is a good amount of density and mixed uses, there is still room and market demand for additional development. As such, very early in planning the new urban rail line's alignment, balanced nodes and other areas of strategic value need to be identified and planning of that area's transformation needs to begin.

Plans are bound to become empty documents if they fail to bring together a broad support coalition committed to their implementation. Particularly in the case of urban rail stations and TOD, where the aim is to change the very fabric of cities and neighborhoods, obstacles down the road can only be overcome by

the sheer willpower of those committed to see such changes materialize. Support coalitions do not come together overnight; they need to be developed gradually from the early stages of the planning process. It is critical to build up the requisite trust among project stakeholders to enable difficult compromises down the road and push through the many challenges of implementation.

Planners within the key transport and urban development agencies will have to bring together the support coalition and drive it decisively until project completion. To this extent, planners' social and political skills to operate within different levels of influence and to sell people on the importance of TOD are just as crucial as their command of all the technical tenets of integrated transport and land use planning.

In the early stages, planners have to map out all key stakeholders in the city and begin the process of reaching out to them and gathering feedback on the feasibility of pursuing TOD (see table 16.1). These first inquiries should explore all potential aspects of TOD implementation, from what locations in the city have the highest potential for TOD, to what strategic partners need to be approached, or what might be the main barriers to successful TOD delivery. Allies often become evident through this process. Planners should build on those allies' strengths to devise a broader strategy to assemble a support coalition.

A strong support coalition is built on both bottom-up and top-down support for the project. As such, planners need to build trust and excitement for the project within the local community and to identify a political project champion.

### Local Community Engagement

Certainly, any type of significant neighborhood redevelopment effort should take place with input and support from the local community. The best practice for gaining that support is to engage the local community as early as possible

**TABLE 16.1. Key Stakeholders in TOD Implementation**

ELECTED OFFICIALS	GOVERNMENT AGENCIES	PRIVATE SECTOR	LOCAL COMMUNITY
<ul style="list-style-type: none"> <li>• Mayors</li> <li>• City council</li> </ul>	<ul style="list-style-type: none"> <li>• Public transport authority and urban rail project-implementing agency: decision makers, planners</li> <li>• Department of transportation</li> <li>• Department of housing or economic planning and development</li> </ul>	<ul style="list-style-type: none"> <li>• Real estate developers</li> <li>• Business associations</li> <li>• Large employers</li> </ul>	<ul style="list-style-type: none"> <li>• Local leaders</li> <li>• Local interest and advocacy groups: people with disabilities, women, affordable housing</li> <li>• Public at large</li> </ul>

Note: TOD = transit-oriented development.

and to grant multiple opportunities for members to provide input on the type of redevelopment they want to see take place (see chapter 14). Design competitions and other participatory planning activities have proven to be very fruitful in bringing planners and community members together. When the community starts to see their ideas and concerns manifested in plans and proposals, the trust that planners are looking out for their best interests is consolidated. Participatory planning efforts are also the best space for planners to identify local leaders who have a nuanced understanding of the community and may be better positioned than government representatives to bring people together around shared ideas, shared goals, and necessary compromises.

### **Political Champion(s)**

On the other side of this spectrum, the project's political champion needs to hold enough political power to help the project to overcome key obstacles throughout planning and implementation—for instance, assembling budgets, pushing critical regulations through, or doing anything else that might be necessary to close a deal. Typically, a new urban rail line is a project of the highest priority and is championed by the city's mayor. However, the urgency to see a new urban rail line completed within a mayor's term in office often means that complementary projects such as TOD fall by the wayside. Therefore, this political champion should be supported by technical staff that embrace TOD as an essential component of urban rail projects.

Although the most successful projects are motivated by the needs of the city independent of political terms, planners need to understand these political-economy dynamics and prepare themselves for the window of opportunity to prioritize TOD implementation. Planners need to identify political allies in heads of government agencies and city council representatives and to mobilize them to advance the project through the drafting of plans and the completion of bureaucratic procedures. These allies are crucial to establishing a broader sense of institutional ownership of the project, which can help the project to prevail over changes in government leadership. To this end, building bottom-up support from the local community can help to shield the project from changes in government priority. Ballots or referenda and other forms of advocacy can additionally incentivize political leaders to align themselves with the project.

### **Private Sector Involvement**

Planners also need to reach out to the private sector to strengthen the support coalition. For instance, the collaboration of real estate developers will be fundamental to achieving redevelopment and (re)densification through TOD—from their investment in strategic projects to their insights in the design of innovative

business models. If carefully structured, such relationships can provide reasonable profits to the private partner, while stimulating new investment that brings jobs, infrastructure, and other amenities to the neighborhood. Different business associations, from retail and commercial associations to restaurant and other hospitality associations, will also be decisive in bringing to life thriving mixed-use areas that attract people and create job opportunities. Large employers within the city might also be interested in relocating near the new urban rail lines and could work with the city to catalyze TOD.

### **Social Inclusivity**

Finally, planners need to extend the support coalition to include nongovernmental organizations, special interest groups, and local associations to ensure that TOD plans and regulations are inclusive and egalitarian. For example, delivering universal accessibility has to become a priority in TOD design. Accordingly, planners need to seek out the guidance of advocates for people with disabilities regarding design and to budget for infrastructure and transport services that better address their needs. The same holds true for women's groups, whose guidance can help to ensure that the special transport needs of women are addressed (see chapter 2). Yet, transport is not the only space in which to deliver inclusiveness. New job opportunities created by TOD also need to be more egalitarian; thus, planners need to bring together business associations and groups supporting people with disabilities and women to discuss how to open up better jobs for everyone. Finally, it is crucial that TOD does not become a driver for displacement and gentrification. Planners need to work with the local community, affordable housing advocates, and real estate developers to devise ways to ensure that new housing opportunities are affordable for long-standing residents in the community.

### **Conclusions and Recommendations**

*To harness the true potential of urban rail investment to unlock urban development, it is important to think about accessibility, not mobility.* Typically, the principal objective of any new urban rail project is to improve urban mobility by enhancing public transport services between different areas of the city. The most visionary, impactful urban rail projects are conceived with the aim of not only improving mobility and transport-related performance indicators, but also transforming urban development patterns and thus improving accessibility, sustainability, social inclusion, economic vibrancy, and livability. Therefore, they require an integrated transport, economic, and land use perspective that balances accessibility at three levels—regional, local, and universal.

***Considering urban development along with infrastructure investment unlocks the full potential benefits of urban rail.*** Improvements in regional accessibility from urban rail investments typically manifest themselves as premiums in property values within the new rail line's area of influence, especially around stations. These regional gains in accessibility are multiplied by other complementary factors, such as regional and local economic growth dynamics, policies incentivizing development, and the unique local accessibility and TOD characteristics of each station. In order to capitalize on the full potential of urban rail systems, it is important to consider the development of land adjacent to tracks and stations and to put in place the proper tools to shape and harness this new development. Value-generating TOD should (1) create compact and mixed-use communities, (2) prioritize walkability, (3) reduce parking, (4) foster community-driven development, and (5) embrace place making.

***By using LVC instruments, TOD should be seen as a way to realize additional funding for urban rail investment rather than an additional cost.*** Rather than representing an additional financial burden, optimizing transport, economic, and land use integration along the urban rail's alignment and promoting (re)development following TOD concepts provide an opportunity for government to add further value to the city and, in turn, to gain additional funding from the urban rail investment itself. Cities can use tax-based or development-based LVC to finance and encourage more inclusive urban growth and to promote the vibrancy of rail station areas and the long-term financial sustainability of the urban rail investment.

***A strong, multistakeholder support coalition is necessary for successful TOD implementation.*** The project-implementing agency will have to work with other urban development agencies within the city government to bring together the support coalition necessary to implement TOD. Such a support coalition should have the backing of the project's political champions and engage local communities in the redevelopment of their own neighborhoods. Private sector stakeholders, including real estate developers and business and commercial associations, can strengthen the business model of TOD. Nongovernmental organizations and advocacy groups should also be consulted to ensure that TOD plans are inclusive and egalitarian.

## Notes

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1. The case of Ballston in Arlington County, Virginia, is well documented. Once a neighborhood in transition, with an odd mix of low-density apartments, fast-food outlets, automobile repair shops, and other marginal land uses, development of the Orange Line to Vienna, Virginia, was embraced as an opportunity to revitalize the area. Today, Ballston is one of Northern Virginia's most prestigious addresses for offices, restaurants, and hotels (TCRP 2004, 11).
2. Further research on TOD has yielded alternative approaches to understand the attributes that increase accessibility and generate value. Yet, in one way or another, the "5Ds" remain a reasonable instrumentation of variables that characterize the dimensions of accessibility and value-generating attributes. The Institute for Transport and Development Policy's TOD Standard suggests eight related principles for TOD: (1) walk, (2) cycle, (3) connect, (4) transit, (5) mix, (6) densify, (7) compact, and (8) shift (ITDP 2017).
3. In Manhattan, for example, the FAR is 24.0 for highly accessible areas around Grand Central Terminal, 21.6 along Park Avenue, and 14.0–18.0 in other areas to the east and west (New York City Planning Commission 2013). Seoul and Singapore also use FARs based on proximity to stations.
4. For a more comprehensive analysis of these barriers and potential solutions, see Suzuki, Cervero, and Iuchi (2013).
5. For example, estimates of land value created by the extension of the London Underground's Jubilee Line ranged from £300 million (US\$484 million) to £2.7 billion (US\$4.4 billion) (Buck 2017).

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## CLIMATE AND NATURAL HAZARD RESILIENCE IN URBAN RAIL PROJECTS

Juliet Mian, Matthew Free, Áine Ní Bhreasail, and Savina Carluccio

Resilient infrastructure is essential for the safety, well-being, sustainability, and economic prosperity of cities (World Bank 2012). This chapter presents high-level practical guidance for the consideration of climate and natural hazard resilience in urban rail projects, covering both the implementation of new urban rail infrastructure and the management of existing urban rail systems. Resilience should be integrated across all types of hazards and all steps of the project development process. Therefore, this chapter should not be read in isolation from the rest of the handbook; resilience is inherently related to all aspects of urban rail project development.

Thinking about resilience should extend beyond specific climate-related and other natural hazards. It should encompass the ability of urban rail systems and the cities within which they operate to prepare and plan for, absorb, recover from, or adapt to any adverse events—the manifestation of a hazard with the potential to cause losses (societal, economic or physical)—during the system’s operational life (National Academy of Sciences 2012). In many cases, measures to enhance resilience are applicable across multiple hazard events, both foreseen and unexpected.<sup>1</sup> For example, although many natural and man-made causes could lead to significant service disruption, the physical and

*Photo:* Workers clear snow off the tracks in Brooklyn, New York, after a blizzard, 2016.  
*Source:* Metropolitan Transportation Authority via Flickr (CC BY 2.0).

organizational measures to reduce the severity of impacts are not always specific to the initial hazard.

This chapter emphasizes fully understanding climate and natural hazards and infrastructure system performance and putting in place measures to prevent incidents from cascading into disasters. This understanding requires recognizing that urban rail systems are only one component of a larger transport system within an urban system-of-systems that involves interdependencies between all infrastructure systems and the society they support.

Repairing and recovering damaged infrastructure after an event has occurred (a *reactive* approach) has a high opportunity cost—the value that is lost once a particular course of action is chosen—compared with investing proactively in resilience (for example, through maintenance, response planning, or physical enhancement measures).<sup>2</sup> This opportunity cost is even greater in low- and middle-income countries where repair costs after an event can decrease the amount of funds available for other urgently needed infrastructure. Furthermore, losses due to large climate and natural hazard events have a proportionally higher impact, both on national economic prosperity and on affected communities, in low- and middle-income countries than in high-income countries (Schweikert et al. 2014). For this reason, investing in infrastructure resilience should be a higher priority in low- and middle-income countries.

This guidance is relevant to decision makers and practitioners from a variety of disciplines, including local and international engineers, urban planners, and public and private transport operators. It is intended to support decision making during project conceptualization through operation and maintenance (O&M) that will enhance the resilience of the system. The chapter follows the project development process described in chapter 1 (see table 17.1). Many, but not all, of the best-practice examples and proposed measures are taken from high-income countries such as Japan and the United States, but they are relevant in low- and middle-income countries as well.

### **How Climate and Natural Hazards Affect Urban Rail Systems**

Natural hazards are naturally occurring physical phenomena caused by either rapid- or slow-onset events<sup>3</sup> that can be categorized broadly as geophysical, hydrological, climatological, and meteorological (see table 17.2).<sup>4</sup> The hazards arising in each of these categories and their impact on urban rail are described in more detail in tables 17A.1–17A.4 in the annex to this chapter. In particular, it is useful to distinguish geophysical hazards from other hazards. Other hazards are and will be attributed increasingly to

**TABLE 17.1. Key Actions to Ensure Climate and Natural Hazard Resilience throughout the Project Development Process**

System and corridor planning	Preliminary and detailed design	Procurement and financing	Construction	Operation and maintenance
<ul style="list-style-type: none"> <li>• Adopt systems approach to urban planning (including site selection and economic evaluation)</li> <li>• Select a resilience strategy and appropriate measures</li> <li>• Assess climate and natural hazards</li> <li>• Complete vulnerability and criticality assessments</li> </ul>	<ul style="list-style-type: none"> <li>• Set urban rail system performance requirements and design standards</li> <li>• Develop resilience strategy</li> <li>• Design physical resilience measures</li> <li>• Exploit and embed new technologies while being mindful of introducing vulnerabilities</li> </ul>	<ul style="list-style-type: none"> <li>• Appropriately account for long-term and wider benefits of resilience</li> <li>• Select the most suitable method for valuing resilience to be proportionate to project complexity</li> <li>• Allocate resilience risks and responsibilities through performance-based contracts</li> </ul>	<ul style="list-style-type: none"> <li>• Construct technically resilient systems</li> <li>• Use resistant materials</li> <li>• Consider preparedness for events that could occur during construction</li> </ul>	<ul style="list-style-type: none"> <li>• Implement robust asset management and timely maintenance</li> <li>• Activate early warning systems</li> <li>• Ensure operational preparedness and emergency response and recovery</li> </ul>
Institutional capacity building and coordination				

**TABLE 17.2. Types of Climate and Natural Hazards Affecting Urban Rail Systems and Their Secondary Hazards**

HAZARD CATEGORY	PRIMARY HAZARD	SECONDARY HAZARDS
Geophysical	Earthquakes	Ground shaking, landslide, liquefaction, surface fault rupture
	Landslides	Mass movement
	Volcanoes	Ash fall, lava and pyroclastic flows, hazardous gas
	Tsunamis	Coastal inundation, erosion and scour, impact forces of water and debris
	Sinkholes	Opening up of voids
Hydrological	Sea-level rise	Coastal inundation
	(Flash) floods	Standing water, surface runoff, river (fluvial) flooding, rising groundwater
Climatological	Droughts	Soil moisture reduction, loss of vegetation
	Wildfires	Flames, smoke, debris on track, loss of vegetation

(table continues next page)

**TABLE 17.2. Types of Climate and Natural Hazards Affecting Urban Rail Systems and Their Secondary Hazards (Continued)**

HAZARD CATEGORY	PRIMARY HAZARD	SECONDARY HAZARDS
Meteorological	Storm surges	Wave action, coastal inundation
	Heavy rainfall	Rain, surface runoff, rising groundwater, high river flows, flooding
	Thunderstorms	Lightning
	Windstorms	Strong wind
	Snow, ice, low temperature	Snow and ice, freeze-thaw action
	High temperature	Higher temperature and more heat waves, thermal expansion of rails
	Space weather, solar storms	Strong magnetic fields leading to power surges, radio interference

climate change; therefore, they have a temporal component and are influenced by human activity.

A natural hazard will become a disaster if its occurrence seriously disrupts the functioning of a community or society and causes human, material, economic, or environmental losses that exceed the community's or society's ability to cope using its own resources.

### **Impact of Climate and Natural Hazards on Physical Rail Infrastructure**

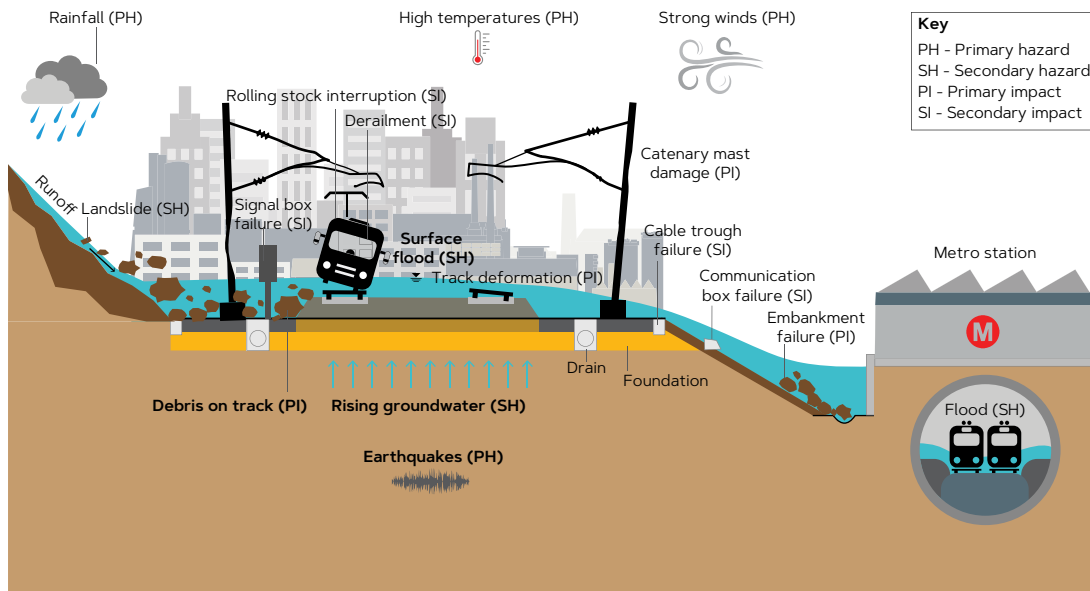
Primary hazards of any type can either directly affect urban rail systems or trigger secondary hazards that can cause harm (see figure 17.1). This complexity is increased by the fact that even single hazards can affect multiple components of a complex rail system—infrastructure, rolling stock, and systems—at the same time.

Direct, physical impacts need to be considered in terms of their effects on the functionality of an urban rail system and the wider city system (see box 17.1). These impacts can be classified as follows (Xia et al. 2013):

1. *Safety impacts.* Physical harm to system components (ranging from minor damage to destruction) that could lead to train accidents or damage to buildings and infrastructure
2. *Service impacts.* Short-term service disruptions (speed restrictions, short-term cancellations, longer-term track closures) due to the presence of snow, wind, heavy rain, or standing floodwaters, for example, when functionality can be restored quickly once the hazard has passed



**FIGURE 17.1.** How Primary Hazards Can Either Directly Affect Urban Rail Systems or Trigger Secondary Hazards



Source: Created by Arup, London, United Kingdom for the World Bank.

### BOX 17.1.

#### Response to Superstorm Sandy: New York City, New York, United States

In 2012, Superstorm Sandy caused extensive damage to urban rail systems across New Jersey and New York, inundating several railway stations and causing major damage to several tunnels, locomotive engines, rail cars, and signaling systems. Adaptations<sup>a</sup> for climate change had been

undertaken by elevating infrastructure and developing marshes along the coast to limit the impacts of flooding. However, these measures were not sufficient in the changing climate. Recognizing that future adaptation and mitigation plans cannot rely only on past climate records, New York's

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**BOX 17.1.****Response to Superstorm Sandy: New York City, New York, United States**  
(Continued)

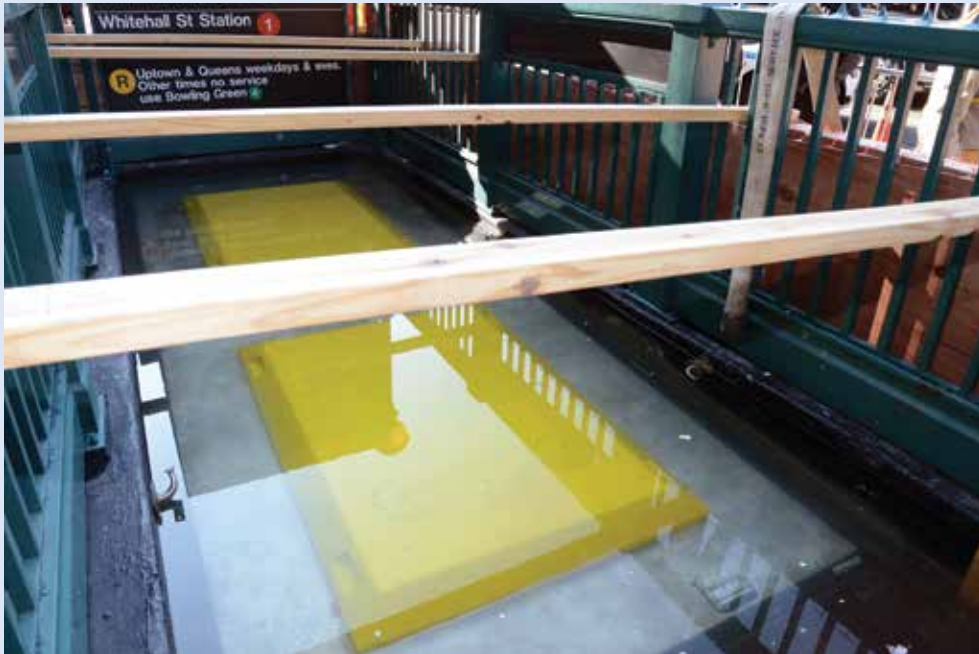
public institutions are rethinking standards for future investments. The Metropolitan Transportation Authority (MTA) created a Climate Adaptation Task Force that builds resilience through interventions, including

repairing and sealing tunnels, sealing vents and station doors during a storm, and sealing signal communication rooms and equipment at vulnerable stations (MTA 2017) (see images B17.1.1 and B17.1.2).

**IMAGE B17.1.1. Temporary Flood Mitigation Measures at a New York Subway Station during Superstorm Sandy in 2012**

Source: © Yaacov Dagan, Alamy. Reproduced with permission; further permission required for reuse.

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**BOX 17.1.****Response to Superstorm Sandy: New York City, New York, United States**  
(Continued)**IMAGE B17.1.2. Removable Flood Control Cover for Subway Stairs at the Whitehall St. Station in New York in 2013**

Sources: Ríos et al. 2017; Metropolitan Transportation Authority of the state of New York via Wikimedia Commons.

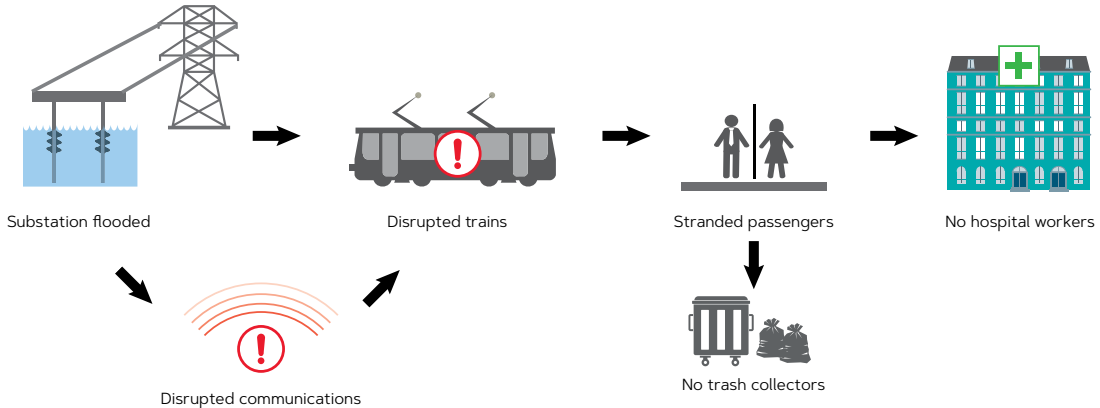
a. Climate change adaptation refers to actions undertaken to reduce the adverse consequences of climate change (for example, higher temperatures leading to increased frequency of rail buckling), as well as to harness any beneficial opportunities. This is as opposed to “mitigation,” which refers to taking steps to prevent further climate change and its impacts from taking place.

Examples of these direct impacts for many primary hazards facing urban rail systems are presented in tables 17A.1–17A.4 in the annex to this chapter.

**Recognizing the Potential for Cascading Failures**

Urban infrastructure systems are complex and highly interdependent and cannot be considered in isolation from one another. Urban rail operations, in particular, depend on other urban systems, such as electricity and telecommunications. Accordingly, damage to these other systems can affect urban rail operations (see figure 17.2). For example, during Superstorm Sandy in 2012, widespread

**FIGURE 17.2. Examples of Interdependent Urban Infrastructure Systems Causing Cascading Failures**



Source: Created by Arup, London, United Kingdom for the World Bank.

damage to the power network in the greater New York City area affected the computer system that controlled the movement of trains, affecting dispatching, routing, and operations.

Given the reliance of urban rail systems on other urban infrastructure systems, integrated plans need to be developed that enhance the connectivity of utilities, improve communications between utility and other systems across agencies and sector boundaries, reduce the risk of cascading failures that could interrupt essential services, and therefore improve infrastructure resilience.

Besides affecting the physical and organizational components of rail systems, long-term climate change may also affect both local and national demographics (for example, changing working patterns) and hence the demand for transport (Leichenko et al. 2010). The interdependencies between technical systems and the people who operate and use them (often referred to as a sociotechnical system) are highly relevant to decisions regarding system resilience.

### Predicting or Forecasting Climate and Natural Hazard Events

The resilience of an urban rail system is underpinned by the ability to predict and hence prepare for different natural hazard events. Prediction methods, where available, can provide a degree of advance warning as to when a hazard is expected to occur at a certain time and location, alongside its expected magnitude. Not all hazards can be forecast with any reliability. Those responsible for planning and decision making for urban rail projects should be clear on the

difference between hazards that can be forecast and, therefore, prepared for through operational planning in the short term (for example, windstorms) and those for which there is no reliable means of forecasting (for example, earthquakes and flash floods).

Methods for assessing or predicting natural and climate hazards are not specific to urban rail systems; they would be the same for any distributed urban infrastructure system that face similar hazards (see tables A17.1–A17.4 in the chapter annex). The following aspects are particularly relevant for urban rail:

- Urban rail operators should establish and use customized weather forecasting services at a granularity (both spatially and temporally) that meets their specific requirements. This is discussed further in the section on embedding resilience into O&M in this chapter.
- Complex tools exist to undertake hydrological and hydraulic modeling of flood events, and such modeling (by experienced practitioners) is essential during detailed design of an urban rail project. Planning and design should consider not only the potential impact of floods but also the possible impact of the project (for example, raised embankments and increased impermeable “gray” infrastructure) on local flood patterns. These models should incorporate allowances for regional or national climate change.
- Regional seismic hazard maps should be supported by site- or route-specific probabilistic seismic hazard assessments (PSHAs), including consideration of the potential for liquefaction of the ground, earthquake-induced landslides, and permanent ground deformation, all of which are important factors to consider in system design. Such detailed PSHAs may not be common practice for project-implementing agencies in low- and middle-income countries, but lack of internal capacity can be complemented with external experts.
- For the purpose of urban rail systems, the assessment of landslide hazards should account for the site-specific geometry, ground and groundwater conditions, geotechnical parameters, and associated design loads. The correlation between landslide hazards and extreme rainfall events should be understood in order to implement operational response measures (Railway Technical Research Institute 2015).

The World Bank Think Hazard tool provides a resource of natural hazard and risk information.<sup>5</sup>

### **Dealing with Uncertainty**

Uncertainty is often categorized as either “epistemic uncertainty,” due to lack of knowledge, which can be reduced by gathering more information,<sup>6</sup> and “aleatory

uncertainty,” which is associated with inherent variability or randomness that cannot be reduced. The risks associated with these uncertainties can be managed in different ways. One such approach is decision making under “deep uncertainty” (defined as a situation on which analysts cannot agree or simply do not know) (World Bank 2012). Another robust method for dealing with climate change and other uncertainties for any infrastructure system is to take an adaptive approach toward achieving long-term resilience, which entails making decisions over time that will allow for adaptability to change (Lyons and Davidson 2016).

Design criteria for urban rail systems are often based on a “nominal return period of event”—the average time interval between events of similar size and intensity. However, this concept can be difficult for nontechnical stakeholders to understand, so the meaning of all metrics should be communicated adequately with all stakeholders, including end users. For end users, who want to understand the level of service to expect from their chosen mode and route, the (annual) probability of occurrence of an event may be a more appropriate descriptor than the nominal return period of an event. Return periods or probabilities of occurrence for natural hazards are often estimated based on statistical modeling of observed records. However, in the context of a changing climate, time dynamics pose a challenge to achieving resilience. As the frequency of future climatic events increases, hazards cannot be estimated reliably based on observed or historical records alone. Therefore, robustness of design decisions against risk and uncertainty need to be balanced carefully with the cost of resilience and mitigation measures (see box 17.2).

### **Learning from Historical Events**

Although past climate is not necessarily representative of future climate, urban rail project-implementing agencies and operators can learn from past events about the potential impacts of climate and natural hazards on rail systems. Observed weather records, for example, can be analyzed in combination with historical asset failure records or flooding distribution to identify correlations. For cities in low- and middle-income countries, formal records of climate and natural hazards in the region may not be available; however, news reports and other informal sources can be used to build a more comprehensive picture of historical events. For example, the Geological Institute in São Paulo, Brazil, completed such an activity, compiling 21 years worth of disaster information from nontraditional sources (UNISDR 2014).

A review of historical events can help to develop an understanding of the relationship between hazards and the performance of infrastructure, especially legacy infrastructure,<sup>7</sup> which may not have been designed for either current or future loads (World Bank 2012). Careful review of the performance of

**BOX 17.2.****Flood Mitigation Measures: Bangkok, Thailand**

In 2011, Thailand experienced severe monsoons affecting 14 million people and resulting in more than 800 deaths. Despite flooding, Bangkok's urban subway and aboveground Skytrain services remained operational throughout the monsoons (see image B17.2.1). This resilience of Bangkok's subway is attributed to aspects of the system's design, which included

locating station entrances 1.2 meters above street level.

However, the impact of the 2011 flooding—including loss of life, an estimated US\$45 billion in direct losses, and the interruption of economic activity in the region—is an important reminder that resilience has to be considered within the wider urban context (UNISDR 2012).

**IMAGE B17.2.1. Skytrain Track Elevated above Monsoon Flood Levels, Bangkok, Thailand**

Source: © Shutterstock. Reproduced with permission; further permission required for reuse.

infrastructure systems during hazard events can offer lessons that can be incorporated into the design and asset management and maintenance requirements for infrastructure. For metropolitan regions implementing their first urban rail line, regional and international experience (particularly that of urban rail operators) regarding the impact of different types of hazards can be reviewed and modified as appropriate for the local context.

### **Risk Assessment**

Chapter 7 of this handbook discusses management of risks on urban rail projects and offers key terminology and guidance. The robust assessment of risk is crucial to managing urban rail systems effectively in the context of uncertainty. Knowledge of the risks presented by known climate and natural hazards can serve as the basis for prioritizing efforts and funds to the most critical parts of the system, which will enhance the resilience of the overall system while recognizing uncertainties and limited resources.

Resilience assessment and planning, while relying on assessment and mitigation of risks for known hazards, should also consider the potential for unforeseen events (“black swans”) and move toward measures that can accommodate residual risks and facilitate rapid recovery from unforeseen events. Considering the criticality of components within a system, both physical and organizational, can help to identify measures that will enhance resilience to all hazards.

### **Valuing Resilience**

The uncertainty involved in assessing natural hazards and climate change and the range of resilience measures available (and their different degrees of effectiveness) mean that demonstrating the value of resilience to decision makers is not straightforward. Many of the benefits are far in the future, accrue to a wide range of individuals, are nonfinancial, and are in the form of avoided losses (rather than profits or other tangible benefits). The performance of an urban rail system has a role to play in other sectors of the economy and in wider society by connecting people to work, education, health care, and other societal opportunities, particularly immediately following an event.

For any infrastructure asset or system, the value of improved resilience is more than just avoiding the costs to replace damaged assets and reducing the income lost for the period during which the asset is out of use. It also includes the following:

- The impact of more reliable services on local workplaces and schools (for example, the avoidance of lost work hours and the benefits of allowing individuals to access educational opportunities)



- Lower health and safety risks, including, for example, the loss of well-being suffered by individuals and families as a result of long-term loss of income
- Reduced impacts on neighboring property and assets
- Avoided impacts on the local environment, including ecosystems

Of course, these gains need to be set against the costs of adaptation, which can be substantial. Leichenko et al. (2010) found that the transport sector had the highest climate change impacts among the infrastructure sectors that they studied in the state of New York and also the highest adaptation costs. U.K. Rail Safety and Standards Board (RSSB) (2016) also found that the societal benefits of improved flood defenses of a rail line under threat from climate change significantly outweighed the rebuild cost and that the financial benefits to the rail operator represented only a small part of the overall benefits to society (see box 17.3). Economic evaluations need to consider these factors.

### **BOX 17.3.**

#### **Valuing Resilience: Cowley Bridge Junction, United Kingdom**

Cowley Bridge Junction is a busy intersection of rail lines in western England. Its location is adjacent to the River Exe and historic culverts, which are prone to floods under sustained heavy rainfall. When floods occur, water can breach the rail embankment, encountering switch gear and electrical cabinets and resulting in electrical system failures. The water also washes out the ballast, often leading to a line closure for several days after the floodwater has subsided. These events have associated costs of replacement, renewal, compensation, and disruption to passengers and freight. Given the long-term cost of these events, new investments in resilience were proposed, including enlarging the flood relief culvert, installing slab track, and constructing a protective wall (see image B17.3.1).

In 2016, the U.K. Rail Safety and Standards Board (RSSB) undertook a case study of the overall value of these proposed modifications as part of its Tomorrow's Railway and Climate Change Adaptation (TRaCCA) program. The RSSB study indicated that, because of climate change, the flooding that occurred 1 in every 10 years at Cowley Bridge Junction in the mid-2010s would likely occur 1 in every 7.6 years by the mid-2080s. Simply by looking forward rather than backward and accounting for the increased frequency of hazard events, the analysis indicated that the net benefits of investing in resilience can increase by 20 percent. Furthermore, the societal impacts of improved resilience on user journey times together with the wider economic impacts were found to outweigh

*(box continues next page)*

**BOX 17.3.****Valuing Resilience: Cowley Bridge Junction, United Kingdom** *(Continued)***IMAGE B17.3.1. Railway Engineers and Fire and Rescue Service Personnel Watch Over Inflatable Dams Protecting the Tracks at Cowley Bridge Junction**

Source: © Ben Birchall/PA Archive/PA Images. Reproduced with permission; further permission required for reuse.

significantly the up-front financial costs to the infrastructure operator. By including these wider benefits, the benefit-to-cost ratio increased from 1.6:1 to 6:1, and the pay-back period declined from 13 to 5 years.

The overall implication is that appropriately accounting for the long-term, myriad benefits of resilience is likely to lead to many more positive investment cases and a

Source: Adapted from RSSB 2016.

more efficient allocation of scarce (public) resources. As resilience is better valued in project appraisal and development, there may be other implications as well—for example, projects that receive funding from a given budget may change from those offering the highest financial return to those having a greater economic impact on the wider community.

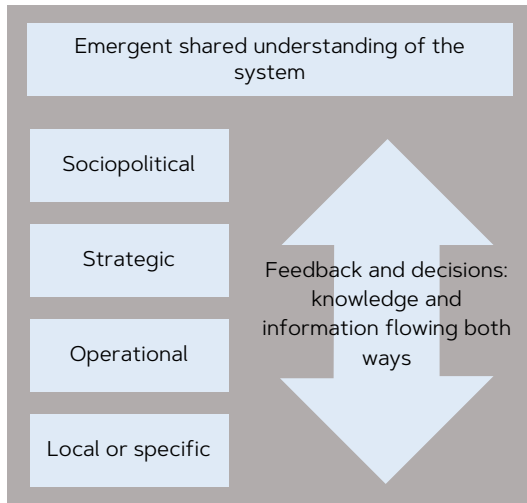
Governments and organizations may estimate the value of improved resilience in different ways and rank their investment choices accordingly. Although economic evaluation methods in general are discussed in chapter 3 of this handbook, one special variation of benefit-cost analysis (BCA) may be warranted in justifying investment in resilience measures: real options analysis (ROA). ROA allows the valuation of options (or flexibility) created by a specific course of action (HM Treasury 2013). The value of the real options created is assessed by assigning a probability to each scenario, based on the best possible information at the time, and carrying out a series of BCAs. The BCA of the investment strategy over time is weighted according to the possible futures. In climate change adaptation, this can be particularly useful, because it can promote staged investment over several years as more is known about the impacts (see also chapter 6). By flexing the investment plan in ROA, the worthwhileness of early preventative investment can be compared with a “wait and see” approach, which can promote the standing of “no or low regrets” options.

Decision makers needing to understand the value that resilience measures will add to an urban rail project should consider the use of simpler techniques such as multicriteria analysis for lower-cost, lower-impact initiatives. Armstrong, Hood, and Preston (2017) present one framework for assessing the risks to railways associated with climate change and prioritizing remedial actions based on benefits and costs. For complex, costly, and staged multigenerational megaprojects that seek to improve resilience, such as the large-scale development of urban rail systems, a full BCA and ROA should be undertaken. These considerations should be included as part of the overall economic evaluation described in chapter 3.

### **Embedding Climate and Natural Hazard Resilience in Urban Rail Institutions**

Embedding resilience in urban railway systems first requires evaluating the existing capacity of urban rail institutions in terms of climate and hazard resilience. This evaluation can be done through a maturity assessment, which enables the identification of priority areas for capacity building. Using the International Organization for Standardization (ISO) 55000 process,<sup>8</sup> maturity is assessed on a six-point scale of maturity states: 1 (innocent) to 6 (excellent). The Climate Capacity Diagnosis and Development (CaDD) method, which is widely used in infrastructure and climate change risk assessments, uses screening and “deep-dive” methods to analyze gaps and prioritize actions.

**FIGURE 17.3. Organizational Hierarchy for Rail Institutions**



Source: Adapted from RSSB 2016.

Organizations can use CaDD assessment to identify where to build their institutional capacity. The World Bank also highlights the importance of capacity building across all sectors and provides a range of resources related to capacity development.<sup>9</sup>

Figure 17.3 shows the TRaCCA organizational hierarchy for rail institutions (RSSB 2016). Higher parts of the institutional setup give lower parts permission to act; lower parts provide information upward. Within an institutional setup for urban rail, strategy needs political direction, operations cannot perform without a strategy, and local responses work within an operational framework that permits action (see also chapter 12). Each level, therefore, requires an appropriate degree of capability—competence, skills, and knowledge of resilience requirements—relevant to its level. At a political or strategic level, organiza-

tions should consider city-scale perspectives over 30-year time horizons or longer; at operational and local levels, daily or weekly time horizons at smaller-than-kilometer scales are more relevant. As a concrete example, a strategic manager does not need to know the detail of an earthquake monitoring system, whereas the local maintainer should.

Systems thinking may be used as a way to identify and scope capacity-building activities. A rail system-of-systems map may be created to show critical interdependencies among the rail institutions and external organizations (for example, energy and communications providers) and to identify a wide range of stakeholders, which can then be prioritized. Mapping of institutional stakeholders includes ministries, emergency response authorities, police, and fire departments. Other national or subnational institutions such as hydrometeorological agencies, consultancies, and weather service providers may also feature.

Institutional capacity can be hampered by the inability of the supply chain to deliver replacement components, rebuild damaged infrastructure, or provide reliable communications services. Rail institutions should make sure that supplier contracts are fit-for-purpose in terms of resilience. For new-build projects, assuring resilience of suppliers is relatively easy; for legacy systems and even fleet renewal, this assurance would require a comprehensive review and

fact-finding exercise throughout multiple supply chains, likely based on climate and natural hazard scenarios.

Institutions need monitoring and evaluation processes that take learning from the capacity assessment process, planning activities, and real events and embed that knowledge in the corporate “system.” This process may involve altering policies, strategies, and standards; retraining staff; offering awareness briefings; and introducing organizational changes or other measures (see also chapter 4 on project management planning).

Communication is key at all stages of resilience and capacity building. Internally, accurate feedback upward from lower institutional levels is needed so that upper levels are kept informed and decisions are made with accurate information. Metrics need to be meaningful to the resilient operation of an urban rail network, such as the time to reach a certain percentage of full service, and be related to performance and outcomes. Externally, stakeholders should be consulted on relevant communications.

Rail institutions should have business continuity plans to identify and respond to all of the shocks and stresses (not only climate and natural hazards) that can potentially affect their business.

## **Embedding Climate and Natural Hazard Resilience in Urban Rail Projects during Planning**

The resilience of an urban rail system and how it will enhance the resilience of the city that it serves should be considered from the earliest step of project development in order to achieve the greatest benefits. From a resilience perspective, decision makers should seek to answer the question, “Is this an appropriate solution given uncertainties?” Resilience should be embedded in the urban mobility and land use strategy that plays an important role in identifying the need for and location of an urban rail project (see chapter 3). However, the answer should consider more than climate and natural hazard resilience.

### **Selecting a Resilience Strategy**

Various approaches to designing resilience strategies are possible:

- “No-regret” options create beneficial effects regardless of whether the natural hazard event occurs or not. For example, Transport for London, United Kingdom, is currently improving cooling systems on the London Underground trains, which will improve passenger comfort as well as the system’s resilience to future climate events.

- *“Low-regret” options* may incur some additional cost, specifically in relation to resilience enhancement, but these costs are small compared with future benefits.
- *Managed adaptation* includes flexible, reversible options that can be changed as understanding of the hazard or the response of the urban environment to the hazard increases. It requires regular monitoring and review.
- *A resistance approach* adds safety margins and physical resistance for potential natural hazard risks.
- *Institutional measures* deal effectively with the response to hazard events through improved institutional structures and response plans.

Preparation for resilience consists of two mutually reinforcing aspects: institutional resilience and technical resilience, achieved through robust design and construction that performs well under physical stresses caused by natural hazards. The former on its own is principally reactive, whereas the latter is principally precautionary (see figure 17.4).

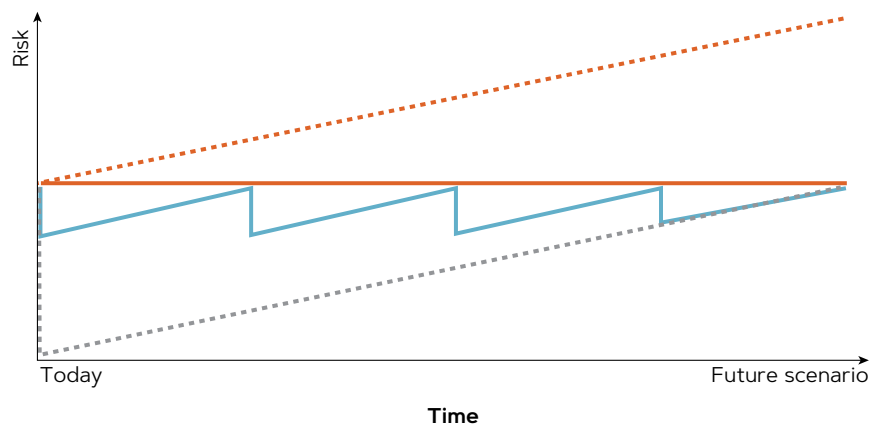
New and legacy urban rail systems should consider a mix of resilience strategies depending on life span, criticality, and type of facility. Bridges and structures, for example, should perform acceptably under a specified strength of earthquake-induced ground shaking equal to the maximum quake with a defined likelihood of occurrence during their design lives. Where future interventions would be costly and time-consuming—for example, requiring a large bridge span to accommodate extreme flood levels—these measures may be built in at the beginning of a project. However, where options exist to use “softer” measures such as blue-green infrastructure solutions<sup>10</sup>—for example, artificial wetlands to absorb floodwaters—combined with the potential, for example, to raise flood barriers in the future, there may be value and wider benefits in adopting an adaptive approach.

### **Resilience Measures**

Resilience measures can be categorized under the following broad headings:

- *The ability to anticipate adverse events.* The ability to anticipate draws on prediction methods to understand hazard events and climate risks and to avoid the hazards where feasible (for example, locating depots on higher ground), using appropriate parameters in design and having robust response plans in place if they do occur.
- *The ability to absorb adverse events.* The ability to absorb has two main elements: (a) physical resistance (achieved through an appropriate level of

**FIGURE 17.4. Illustrative Framework for Adaptive Management of Any Infrastructure System (Compared with a Precautionary Approach or a Do-Nothing or Reactive Approach)**



#### Key

- ..... Precautionary approach: single intervention point at start, to manage risk over the whole life
- Managed adaptive approach: several interventions over time to manage risk
- Hazard-specific risk: managed so it does not exceed this level (set by “policy” and or objectives)
- ..... Hazard-specific risk: increases with time if not managed by active interventions

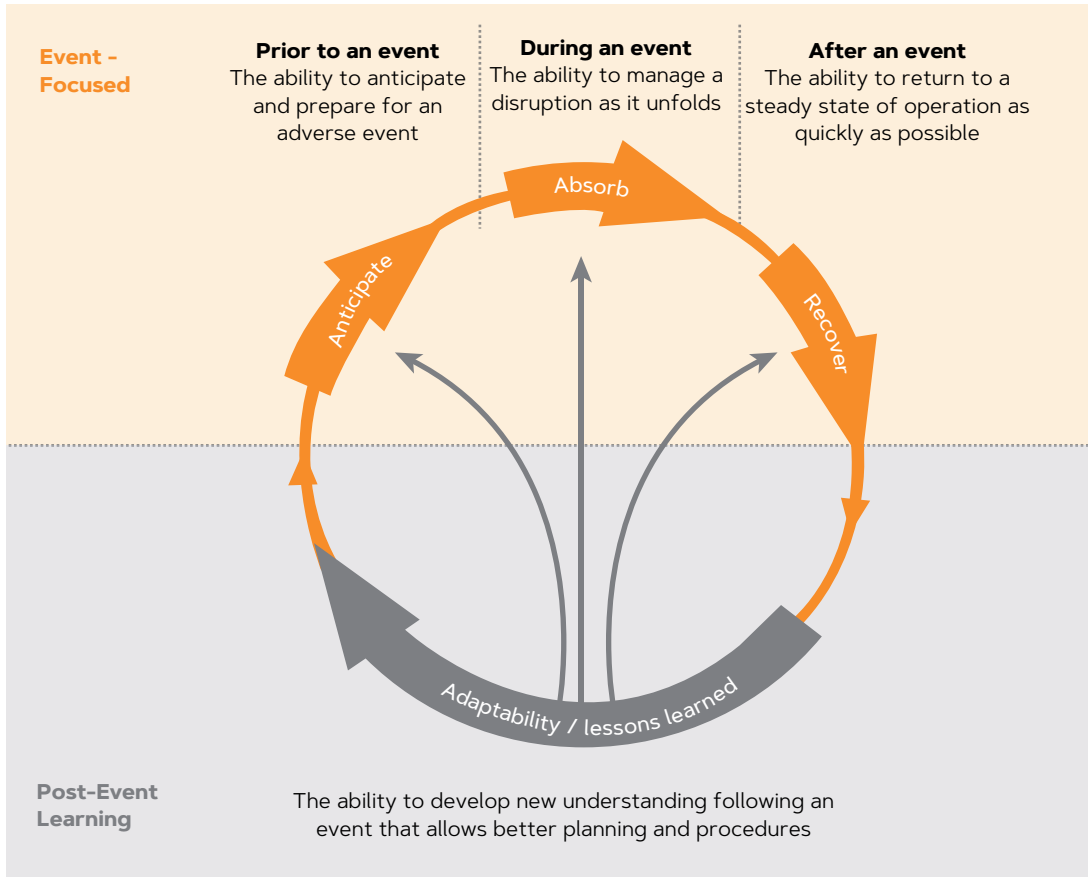
Source: Adapted from U.K. Environment Agency 2011.

Note: The orange line indicates the current risk level. Above this point is increased risk; below it is decreased risk.

robustness in design) and (b) redundancy (achieved, for example, through alternative routes, alternative modes of transport, alternative power sources, or alternative means of communication). The ability to absorb shocks can also be achieved through the provision of blue-green infrastructure such as artificial wetlands or storm tanks inside the city that temporarily absorb excess floodwaters.

- *The ability to recover rapidly from adverse events.* Response and recovery rely on good advance planning and communication across all stakeholders as well as an understanding of the potential impacts, the expected performance levels, and the most vulnerable and critical locations of the rail system.
- *The ability to adapt to adverse events.* Adaptability requires lessons to be learned and acted on following an event (see figure 17.5). The ability to adapt

**FIGURE 17.5. Four Components of an Event-Focused Resilience Construct, Showing Different Categories of Resilience Measures**



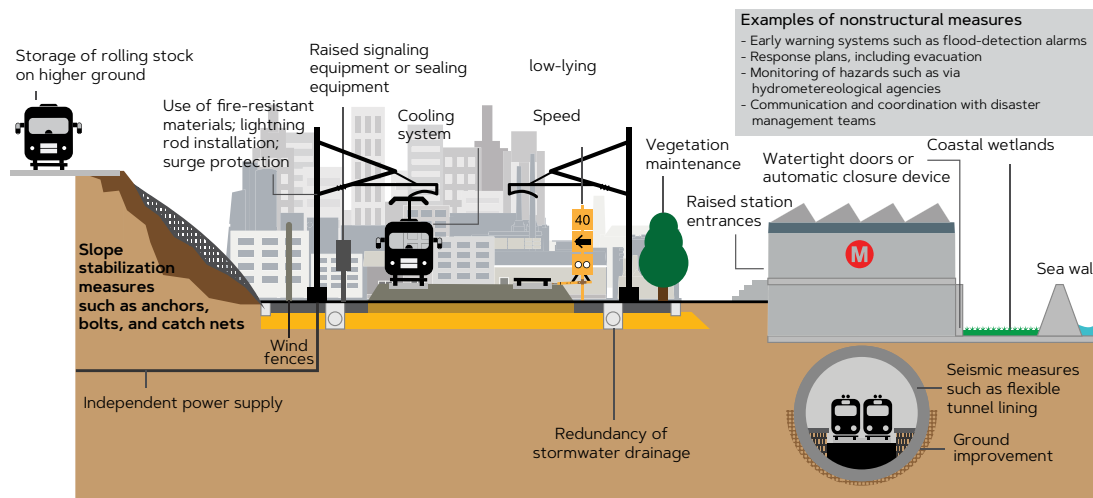
Source: Adapted from NIAC 2010.

could include long-term retreat from a hazardous area, for example. Planned or managed adaptation could include allowance for increased frequency of ballast tamping following heavy rainfall and flooding (in contrast to the use of slab track, which can resist heavy rainfall with less maintenance).

Figure 17.6 presents specific examples of resilience measures appropriate to the various types of hazards for urban rail systems, which are expanded in tables A17.1–A17.4 in the chapter annex (see also boxes 17.1 and 17.2). An important concept in selecting appropriate resilience measures for an urban rail system is to recognize that physical measures to reduce the impact of hazards through



**FIGURE 17.6. Example of Resilience Measures That Can Be Applied to an Urban Rail Development**



Source: Created by Arup, London, United Kingdom for the World Bank.

resistance or avoidance are highly effective for the specific hazard for which they are designed. Institutional measures to reduce risk and enhance recovery are often common to any known and potentially unknown hazard events, provided they are implemented effectively. However, such nonstructural measures will not prevent physical damage from occurring; they can only reduce the impact of damage.

Communications plans and delivery themselves need to be resilient to the hazard impacts or an alternative needs to be available. For example, reliance on Internet-based communications needs confidence that those involved will have access to power and the Internet. If this is not the case, an alternative means of communication has to be available.

### A Systems Approach to Urban Railway Planning

Urban railways are complex sociotechnical systems (where the people who run and use the system are a fundamental part of it) and highly dependent on other transport and urban systems. In particular, urban rail systems are typically heavily dependent on electric power and communications systems. Other less obvious dependencies may exist, for example, railway staff need to travel to get to work, which makes the system potentially reliant on other forms of transportation (for example, roads) (Booth 2012). These inherent and often unavoidable interconnections or interdependencies can result from physical, digital, geographical,

and institutional interactions (Frontier Economics 2012; ICIF 2014). Historically, urban infrastructure planning has taken place in separate sectors, but there is an increasing need to plan infrastructure considering the overall system-of-systems. A multisectoral approach that involves early engagement with stakeholders will help project decision makers to understand these dependencies.

Considering the following factors would help to ensure that resilience is embedded in the planning of project development:

- How will the project enhance societal or community resilience? A resilient community will contribute to rapid recovery of a city affected by a hazard event.
- Have climate and natural hazards relevant to the project geography been identified, and what are their potential impacts throughout the life cycle of the rail system? This information will avoid large, unanticipated increases in project cost estimates during detailed design, construction, and operations and maintenance.
- Which parts of the proposed system, or of other systems where a dependency exists, are the most critical?
- Where and when should resources be committed to address these concerns?

During planning, cost-effective resilience measures should be identified by undertaking structured vulnerability assessments and identifying where redundancy in the overall urban transportation network is necessary to reduce the impact of critical locations. For example, flooding that affects urban rail systems also affects roadways at or below the same grade level. Therefore, it is important to consider redundancy and to model impacts over the entire transport network of the metropolitan region. Spatial planning tools can be effective for this process (see World Bank 2017a).

### **Urban Rail System Performance Requirements**

Table 17.3 illustrates a framework for setting levels of tolerability in terms of the consequence that a climate or natural hazard event may have on an urban rail system's function, including operations, infrastructure, financial position, or reputation. Defining these consequence ratings will enable urban rail institutions to make appropriate and consistent decisions regarding resilience measures.

Acceptable performance may depend on the type of component or its location in the network. For example, "major delays" may be tolerable on a part of the system that has adequate redundancy in terms of alternative modes of

**TABLE 17.3. Indicative Consequence Ratings for Climate or Natural Hazard Events**

CONSEQUENCE RATING	SAFETY	COST OF DAMAGE AND DISRUPTION (US\$, MILLIONS)	JOURNEY TIMES	PUBLIC PERCEPTION
Very low	Minor harm or near miss	< 5	Minor delays	Short-term adverse local stakeholder reaction
Low	Lost time, injury or medical treatment required, short-term impact on persons affected	5–25	Significant delays	Adverse local media reports over sustained period; localized stakeholder concern
Medium	Long-term injury or illness, prolonged hospitalization or inability to work	25–100	Major delays and cancellations < 1 day	Significant local or regional reports, including social media; national media interest creating public concern
High	Single fatality or multiple long-term injuries	100–250	Major cancellations 1–14 days	Extensive prolonged adverse national reporting and public disputes with key stakeholders, utility companies, or government agencies
Very high	Multiple fatalities	> 250	Severe cancellations > 2 weeks	Extensive and prolonged negative reporting nationally or public disputes with key stakeholders

transport (low importance), but the same major delays may be unacceptable for a critical section with no redundancy. At a more granular level, tolerable performance levels may be set for different system components subjected to different levels of hazard, particularly for floods, windstorms, and earthquakes.

Acceptable performance is also dependent on the frequency or probability of hazard occurrence, where, for a frequent event, no or very minor consequences would be expected, both by the rail operator and by customers, whereas, for a very rare event, a higher level of impact may be tolerable. Tolerable performance levels, including the time to return to normal service for all hazards, should be defined at the outset of a project and communicated to all stakeholders. Typical performance metrics for rail operations are based

on availability, safety, reliability, quality, quantity, and effectiveness and are calculated on a rolling basis (see chapter 13). However, special metrics may need to be defined for response to and recovery from adverse events. Ensuring life safety is the minimum acceptable level of performance; it should be provided by designing to the relevant codes and standards. Brabhaharan (2006) presents a useful review of performance measures due to extreme events for roads, bridges, and water systems that can serve as a useful starting point for urban rail systems.

Deloukas and Apostolopoulou (2017) suggest that another critical key performance indicator for the restoration of urban transport systems is the recovery time required to achieve 90 percent operability. Acceptable recovery time objectives should be developed in discussions with the stakeholders of other urban transport systems and agreed at a metropolitan regional level, recognizing that passengers are interested in their end-to-end journeys rather than any one form of transport.

### **Vulnerability Assessments**

Most elements of an urban rail system are vulnerable to some extent to climate and natural hazards. Identifying the greatest vulnerabilities—that is, those elements with the greatest potential to be harmed should a hazard occur—will assist in prioritizing physical measures to enhance resilience and also inform response and recovery plans. Vulnerable assets should be identified by location and by railway subsystem and critical interdependencies should be studied. A database of assets could be compiled, including buildings, which are vulnerable to either excess rainfall, drought, fluvial flooding, or coastal flooding (RSSB 2016).

Spatial tools can be used to overlay enhanced weather data and asset information (such as type, condition, age, location, and function) with long-term hazard assessments in order to identify existing vulnerabilities. For example, merging flood hazard maps with the types and locations of bridges can identify railway bridges that are potentially vulnerable to flooding. Asset vulnerabilities data can be viewed with safety events and service disruptions in order to prioritize investment. Vulnerability mapping should inform operational preparedness and response to forecast extreme events. ARISCC (2011) presents vulnerability rankings for railway infrastructure assets and guidance for vulnerability mapping in geographic information systems (GISs).

### **Criticality Assessment**

During early planning of new urban rail systems or adaptation projects for existing systems, there is value in undertaking a high-level criticality assessment to

identify critical components of the system, potential “choke points” where congestion or blockage may occur, and critical interdependencies.

Four parameters are most often considered during a criticality assessment (Fekete 2011; Theoharidou, Kotzanikolaou, and Gritzalis 2009):

- *Spatial distribution.* The geographic impact of disruption should the piece of infrastructure be unavailable
- *Severity, intensity, magnitude.* Consequences of disruption or destruction of a certain piece of infrastructure (for example, number of users affected)
- *Effects of time or temporal disruption.* The point at which the loss of an element could have a serious impact (for example, immediate, one to two days, one week)
- *Diversity and redundancy.* Capabilities needed to prevent, mitigate, or compensate for failures

Criticality, in terms of resilience, may also be influenced by the extent to which a system is tightly coupled or complex. For example, a tightly coupled system will allow failure to cascade rapidly as the specific part of the system cannot be isolated quickly from the rest. A complex system is one where the many interconnected components may interact in unexpected ways. Network modeling can be used to understand what happens to a transport system when one node or link is removed (World Bank 2017b).

## **Embedding Climate and Natural Hazard Resilience in the Design and Construction of Urban Rail**

Appropriate resilience measures should be considered when designing new infrastructure for major urban rail projects or upgrading legacy systems. These measures can be built into the design through the use of modern rail design standards that take into account climate and natural hazards relevant to a particular geography. The adaptation of prescribed standards should be considered to allow partial service to resume after an emergency event when restoring full service is infeasible (Royal Academy of Engineering 2011).

Earthquake, wind, and flood engineering is well understood, and many countries have robust design standards for these hazards. Designers of projects in countries without robust local codes should consider adopting best international practice, such as the EN 1990 to EN 1999 suite of Eurocodes (Comité Européen de Normalisation 2007), the design standards of the American Association of

State Highway and Transportation Officials (AASHTO), and the Standard Specifications by the Japan Society of Civil Engineers (2007) (see box 17.4).

However, codes and standards to future-proof designs against long-term climate change effects are still being developed. Changing weather and climate mean that railway standards, particularly the specifications regarding drainage

#### **BOX 17.4.**

### **Japan's Performance Requirements**

In 1995, Kobe was struck by the Great Hanshin earthquake, ranked as one of Japan's deadliest and costliest earthquakes. It resulted in more than 6,000 deaths, destroyed 150,000 buildings, and caused US\$100 billion worth of

damage. Many railway, train, and metro stations either collapsed or were seriously damaged, leaving only 30 percent of railway tracks in the area operational (see image B17.4.1). Structures built according to the earthquake

**IMAGE B17.4.1. Trains Parked at the Shinzaike Depot on the Hanshin Dentetsu Line Thrown to One Side Following the Great Hanshin Earthquake: Japan, 1995**



Source: © Roy Garner, Alamy. Reproduced with permission; further permission required for reuse.

*(box continues next page)*

**BOX 17.4.****Japan's Performance Requirements (Continued)**

building codes at the time were deemed sufficient to withstand earthquakes of such magnitude but nonetheless failed.

In response to this earthquake and the damage it caused, Japanese design codes were upgraded with the introduction of performance-based codes. The first code to be revised was the Building Standard Law in 1998, which states that, for seismic design of buildings, two levels of performance are required, depending on the earthquake

experienced. These levels are (1) life safety and (2) damage limitation. For a maximum earthquake (as indicated by earthquake records and seismic and geological assessment), life safety has to be ensured. For a once-in-a-lifetime event (30- to 50-year return period), no structural damage that could threaten the structural safety of the building shall take place. Since 1999, rail structures and earthworks also have adopted a performance-based design code.

*Source:* Adapted from the Japan Society of Civil Engineers 2007.

systems, maintenance, flood protection, and extreme heat, have been identified as critical for future performance. Taking into account future conditions is particularly relevant because of the long lifespan of rail assets. Rather than specifying design inputs, given the uncertain nature of the changing climate, a move toward standards based on performance (outputs) is recommended by research such as *Adaptation of Railway Infrastructure to Climate Change* and TRaCCA. Urban rail project-implementing agencies need to understand what a code-based design actually means for the expected performance of the system and to determine whether the project design is compatible with the performance requirements.

The following list highlights some systemwide design considerations that may be influenced by the requirement for resilience to climate and natural hazards (see also tables 17A.1–17A.4):

- *Fundamental design choices.* Linear infrastructure resilience can be improved by enforcing different design criteria for different infrastructure elements based on the assessed risk profile. Underground segments must be appropriately designed and supported based on the seismic risk and local geological conditions (see box 17.5). Elevated structures may be more vulnerable to seismic hazards and wind than railway at-grade, but less vulnerable to flood hazards.
- *Design life of components.* The design life of each individual component should be considered in the context of climate change and other hazards.

Many track systems or electronics and communications technology have design lives of less than 30 years, and climate projections have a reasonable level of confidence over this time period. However, stations and other assets may have much longer design lives with appropriate renewal (see chapter 13).

- *Innovative technologies.* Digital communications or “smart” infrastructure monitoring systems can provide increased availability of information on, for example, the location of vehicles within the system, wear of materials, and state of repair of assets. This information is critical for more efficient operations and provides opportunities for smarter maintenance approaches, all of which will enhance the ability to prepare for, respond to, and recover from hazard events. Conversely, technology-based solutions can increase the complexity of an already complex urban rail system, creating potential “emergent properties,”<sup>11</sup> which designers need to recognize, understand, and communicate.
- *Power supply redundancy.* Rail systems are difficult to decouple from their electricity supply. Therefore, for resilient rail systems, a backup supply should always be available. For example, the New Jersey TransitGrid program is constructing an electrical microgrid specifically for supplying power to rail infrastructure during storms or other shock events. Energy-efficient measures, such as designing low-energy stations and depots, optimizing heating and cooling systems, and recovering braking energy, bring multiple benefits, including lower operating costs, enhanced sustainability, and less environmental impact.<sup>12</sup> In addition, lower energy consumption reduces the reliance of an urban rail system on external electricity networks and can enhance resilience.
- *System design.* Urban rail network design should include considerations of redundancy for critical sections of the route. Dynamic and flexible signaling and timetabling can increase the availability of a railway system during and immediately after an event and minimize the cascading effects that can arise from the loss of one part of the system. Automatic “driverless” trains make it possible to optimize acceleration and braking efficiency and provide greater service flexibility in response to events without having to mobilize crews.

Detailed design of an urban rail system should be supported by specialists in hydrological and hydraulic modeling both to understand the vulnerability of the project to flooding and to ensure that the physical presence of a new railway will not adversely affect wider flooding patterns. Drainage capacity should be designed with consideration of the effects of climate change. Traditional “gray” infrastructure, such as drains and culverts, is difficult to adapt during the design



**BOX 17.5.****Design of Marmaray Tunnel: Istanbul, Turkey**

Turkey is subject to devastating earthquakes. On August 17, 1999, the region of Izmit east of Istanbul was struck by a magnitude 7.6 earthquake that killed 17,000 people and caused up to US\$8.5 billion in damages. The Istanbul Metropolitan Municipality subsequently introduced stringent requirements for seismic design of urban rail facilities.

The Marmaray Tunnel, carrying the Istanbul Metro, is only 16 kilometers from

the active North Anatolian Fault. The design of the tunnel includes several measures to enhance resilience to a large earthquake, including grout injections to minimize liquefaction effects, a flexible tunnel that will not fracture under powerful ground shaking, and flood wall gates to seal water out in the event of a breach (see image B17.5.1).

**IMAGE B17.5.1. Workers in the Earthquake-Resilient Marmaray Tunnel: Istanbul, Turkey**

Source: © ymphotos/Shutterstock. Reproduced with permission; further permission required for reuse.

life of a project; therefore, taking a precautionary approach to designing the capacity of drains and culverts that is mindful of climate change effects is recommended. For underground systems, urban rail tunnels can be inundated with water and act as pipes if the water and sewage systems in the city are unable to handle flooding. In addition, flood models should be checked to evaluate the implications of a design exceedance flood—if the consequences of design exceedance are significant and a slight increase in capacity could accommodate this, it may be better to take this information into account up-front on a precautionary basis.

Chapter 11 of this handbook describes construction methods for urban rail projects in detail. Typically, the selection of construction methods and choice of construction materials are dominated by factors other than resilience, including design specifications, cost, safety, and availability of materials. Nonetheless, in common with the recommendations made throughout this chapter, considerations of resilience to climate and natural hazards should be included in the selection of the construction method. Simple measures should be incorporated, such as the use of heat-resistant paint to reduce the vulnerability of rails to extreme heat.

The potential for extreme weather events or other natural hazards to occur during construction should be recognized and managed contractually. Consideration should be given, for example, to monitoring weather and other warnings and taking appropriate steps to ensure that such events do not lead to catastrophic safety or environmental impacts (for example, through the release of stockpiled material during a storm event) (see chapter 15). The use of performance-based contracting, whereby procurement decisions are based on the intended purpose of the product or service, will make both designers and contractors think about the long-term implications and performance of the infrastructure systems they design and construct.

### **Embedding Climate and Natural Hazard Resilience into Operation and Maintenance**

O&M considerations apply equally to the planning and execution of new projects and the operation of existing rail systems. Legacy systems are likely to present significantly greater challenges since it is unlikely that they were designed to resist natural hazards in the same way that a new system would be. Furthermore, legacy systems present additional complexities of aging and deterioration of assets and components, and the understanding of

time-based deterioration may not incorporate the impacts of climate change—for example, increased frequency of high temperatures on rails. Chapter 13 presents operational, asset management, and maintenance considerations for urban rail. This section focuses on issues specific to climate and natural hazard resilience.

### **Asset Management and Maintenance**

Maintaining assets is an essential component of resilience to ensure that assets perform as required during an extreme event. Keeping drains clear of debris is a key example of this, as is managing vegetation on and around urban rail systems. Blocked drains can, for example, lead to inundation of tracks and signaling equipment. Failing to maintain assets or postponing maintenance activities to save costs can escalate vulnerability and exacerbate damage, even during “normal” operating conditions.

Robust asset management systems<sup>13</sup> based on infrastructure life-cycle analysis can be highly effective in supporting the planning for and response to extreme events (World Bank 2017a). Spatial data defining asset type, condition, and also vulnerability and criticality can be overlaid with hazard data such as seismic or other geophysical hazards and also real-time weather forecasts. Customized weather forecasting services should be procured at an appropriate level of spatial and temporal granularity for the requirements of the system, combined with thresholds.

Key asset management decisions (discussed more fully in chapter 13) include the optimum timing for replacement of aging assets balanced against the potential to extend asset life, where appropriate. Such decisions need to consider resilience to climate and natural hazards, including the potential increase in hazards during the extended design life, and new vulnerabilities created by aging. For existing rail systems, incorporating adaptation measures to provide enhanced resilience to climate and natural hazards in planned asset management activities such as renewals is the most cost-effective approach. Such interventions can be prioritized based on the vulnerability and criticality assessments.

Implementing modern train control and signaling systems are other operational measures that not only improve routine performance and reliability but also reduce vulnerability to climate hazards. Adaptive measures can be relatively simple, such as replacing exposed cabling with fiber-optic or more resistant materials. As discussed earlier in this chapter, providing alternative sources of electricity is important. Ensuring that such backup systems are operational, given their infrequent use, should be part of the maintenance regime.

Examination and inspection data are an essential component of an asset management system, and data describing defects and changes in condition will provide asset managers with a valid model of asset condition. “Smart” monitoring solutions such as embedded sensors and remote survey data are increasingly valuable in the quality and accuracy of the data they provide and the additional benefits realized, such as removing workers from an unsafe track environment. Technological advances even allow remote self-diagnosis and repair.

### **Operational Preparedness and Response**

Time is precious when disasters occur. Emergency response plans, policies, and procedures that set out operational responses to different types and severity of hazards should be developed as part of the overall O&M manual for a rail system. The human factors within these plans have to be taken into account, for example, whether key personnel are likely to have access to communications and power, whether they will be able to reach a common location, and how they will respond during a period of crisis. Such human factors are fundamental to an effective response plan.

Simulations, either within an operations team or at a larger regional or multi-sector scale are a highly effective means of ensuring that those responsible for acting during an emergency understand their responsibilities and interfaces. Simulations will also reveal the potential for unforeseen or unexpected consequences and enable institutions to be better prepared for them. The New York MTA regularly conducts emergency planning training and drills. Effective communications and the resilience of these communications themselves should be part of the response planning. Social media have frequently been found to be an effective means of communication during a crisis.

Urban rail operators should have adverse weather plans, recognizing the vulnerability of different assets to different weather events and making effective use of the spatial planning capabilities of the asset management system to plan risk-targeted actions prior to and during adverse events. Known vulnerabilities should also inform visual or remote inspections—for example, structures known to be vulnerable to high winds should be prioritized for inspections following storm events. The MTA Climate Adaptation Task Force (2017) describes its countdown from approximately five days prior to a forecast storm to “zero hours,” where bridges and tunnels may be closed. These plans are developed with other city authorities in order to facilitate evacuation, for example.

Decisions have to be made to balance the need to keep trains running during adverse weather conditions with the potential safety impacts of doing so.

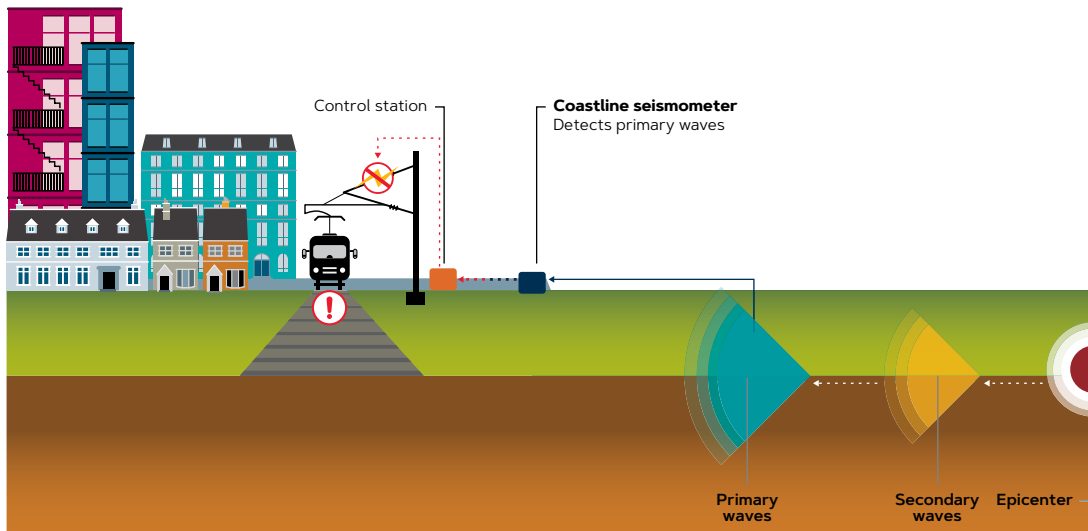
During heavy snowfall, operational decisions need to be made about whether to keep trains running, which reduces the potential for snow settling on tracks, or whether to suspend services due to the severity of the event, which leads to a longer recovery period due to a buildup of snow. Weather thresholds and actions should be defined on a project-specific (and potentially even location-specific or asset-specific) basis to ensure appropriateness and to avoid “false alerts.”

### *Monitoring and Warning Systems*

Monitoring and warning systems are cost-effective options to enhance resilience. Such systems could include sensors to detect landslides, rain gauge stations, or the regular measurement of water levels to monitor flooding events. They can be installed after construction when hazards are identified, but it is frequently more effective to include smart monitoring solutions during design and construction. Successful monitoring can prevent loss of life during an extreme event, but it does not physically prevent damage to the rail infrastructure.

Monitoring systems require specialist advice to develop appropriate thresholds for action (for example, strength of ground shaking, amount of rainfall, or amount of ground deformation), which are specific to both the performance requirements and the vulnerability of the asset being monitored. For example, the Railway Technical Research Institute (2015) describes how rainfall trigger values (that is, rainfall thresholds that trigger operational response) are defined for railway earthworks, which are dependent on the nature of the slope and its geotechnical properties. Having defined trigger values, appropriate operational responses should be set, such as limiting train speed or suspending operations. These trigger values will be very specific to the context of the rail system.

These trigger values can feed into early warning systems that enable the generation and dissemination of timely and meaningful warning information to enable a response to a hazard occurrence in sufficient time to reduce the possibility of harm or loss. Japanese early warning systems for earthquakes, landslides, severe weather, and other hazards (see figure 17.7) trigger preparedness measures across multiple stakeholders, including transport operators, law enforcement, and local governments in charge of disaster management, but they also alert members of the public to be vigilant of their surroundings and to heed communications from emergency services, while taking necessary steps to protect life. Japan’s earthquake early warning system successfully cut power and applied emergency brakes to Shinkansen trains in the first seconds of ground shaking during the 2011 Great East Japan Earthquake, avoiding derailment.

**FIGURE 17.7.** Japan's Earthquake Early Warning System

Source: Created by Arup, London, United Kingdom for the World Bank.

### *Emergency Response and Recovery*

Selected systemwide measures for responding to foreseen and unforeseen events include the following:

- *Coordination with other transportation and infrastructure sectors as well as law enforcement and emergency responders.* The East Japan Railway Company, for example, offers the use of its facilities as temporary emergency shelter (see image 17.1). Emergency plans need to include “what-if” scenarios for the loss of other infrastructure services. For urban rail systems, close collaboration with other surface transportation, particularly buses, is important to ensure functionality of the overall transport system.
- *Procurement and budgeting arrangements that allow responsiveness to incidents without compromising public finances.* Urban rail operators should consider insuring their operational revenue against the potential impacts of climate and natural hazards in order to minimize economic and financial losses in an event.
- *Protocols for inspections and assessments for safety and functionality after an event, prioritizing known vulnerable locations and critical infrastructure.* Recovery should be planned and phased. Temporary bus services and partial operation of the network are often the first response, followed by implementation of short- and longer-term structural measures.

**IMAGE 17.1.** Participants in a Drill Testing the Emergency Shelter Capabilities of Train Stations Following an Earthquake: Tokyo, Japan



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- Arrangements for access to pumps, mobile cranes, and specialist inspection personnel, among others. Such arrangements should be in place prior to an event to expedite recovery.

### Coordination with Stakeholders for Resilient Rail Development and Operations

Stakeholders at every step of project development have an important role to play in the selection, implementation, and success of resilience measures (see table 17.4). International good practice in resilience planning highlights engaging in and arranging multisector simulations and workshop exercises based on

**TABLE 17.4. Summary of the Stakeholders Involved in the Various Steps of an Urban Rail Project Development Process**

	System and corridor planning	Preliminary and detailed design	Procurement and financing	Construction	Operation and maintenance
Decision maker (government authority)	✓	✓			
Rail authority		✓	✓	✓	✓
Urban planner or designer	✓	✓	✓		
Contractor		✓	✓	✓	
Rail operator					✓
Forecast and monitoring (for example, hydro-meteorological agencies)		✓			✓
Investor		✓	✓	✓	✓
Insurance	✓	✓	✓	✓	✓
Emergency response teams				✓	✓
Passengers					✓
Media outlets					✓
Civil society		✓			✓



plausible hazard scenarios. Scenario planning can tackle funding, prioritization, and budgetary issues at a strategic level. Operational and local staff will need to know that they have adequate funding to respond to events in their jurisdiction. Simulations and trials should include all stakeholders who would be involved in event planning, response, and recovery, not only those directly employed by a rail organization. Local, regional, or national first responders, emergency response agencies, hydrometeorological agencies, and other private sector businesses all have a role to play.

### **Roles of the Public Sector**

The role of government, at both the national and local level, is important for coordinating the multiple public and private organizations, including emergency services prior to, during, and after an event. Depending on the scale of the event, public funds are likely to be ring-fenced specifically for the wider societal response and recovery processes. However, appropriate financial planning by urban rail operators should be in place to ensure that transport systems can recover without diverting essential funds away from other areas. Governments set and enforce minimum acceptable standards for resilience.

A rail operator controls train operations such as speed limits by integrating data and forecasts (for example, rain, snow, storms, and wind) from hydrometeorological agencies (which are often public sector organizations) as well as their own monitoring stations along the railways. Therefore, coordination is necessary between the operator and these agencies, which also are responsible for directly issuing warnings for severe events.

### **Roles of the Private Sector**

The private sector has a role to play across all steps of urban rail project development, from developing new and innovative technologies that have the potential to transform infrastructure systems to providing services and equipment in the aftermath of an event. Chapter 9 sets out guidance for private participation in the implementation of urban rail projects. Investors, both private and public, need to recognize the economic imperatives of investing in resilience measures by demonstrating the value over the project's life cycle. Governments have a role to play in incentivizing private sector investment in resilience and disincentivizing nonresilient investment, reducing the potential to benefit from short-term cost savings to the detriment of long-term resilience. The private sector needs to recognize the importance of collaboration with the public sector to ensure business continuity and resilience, as businesses are unable to function without the city's infrastructure systems, including urban rail. Many media outlets, including social media, are private sector businesses. They play a vital role in informing,

alerting, and educating communities during and after events and in counteracting false and inaccurate information.

Rail owners and operators should consider entering into “prior support agreements” with civil, mechanical, and electrical engineering companies to aid recovery. For example, leasing flood relief equipment, including mobile barriers and pumps, may be more efficient and cost-effective than owning and stockpiling this equipment for infrequent use. Recovery can be slowed down due to foreseeable issues such as shortages of mobile cranes, but this shortage can be mitigated through agreements with the private sector.

Rail operators can also obtain insurance against natural hazards and catastrophes as well as other risks facing their businesses. The MTA in New York has specific insurance to help to pay for recovery from storm surges and earthquakes, following lessons learned from Superstorm Sandy. This transfer of low-frequency, high-impact risk to the private sector significantly enhances the ability of the MTA to manage its recovery from events. Insurance against unforeseen events during construction can also enhance the resilience of a construction project to open on time.

### **Role of Academia**

Urban rail resilience and all of the topics touched on in this chapter are emerging topics, where knowledge and understanding are still growing and changing. Research institutions are at the forefront of this thinking, ensuring that research is transformed into tools and approaches that can be used by practitioners.

### **Communication with the Public**

Finally, people and communities, especially the passengers of urban rail systems, need to be aware of and educated on the response and recovery measures before, during, and after an event. Stakeholders should agree on appropriate performance levels dependent on the criticality of the system and the severity of the hazard. These decisions need to be communicated with end users, who have to be prepared for a period of time without service. Advanced network modeling can be used to simulate the potential disruption affecting passengers.

### **Tools for Addressing Climate and Natural Hazard Resilience**

Many tools can assist with addressing climate and natural hazard resilience, including hazard prediction and assessment, design tools, maturity assessment, interdependencies assessment, and asset management tools tailored for resilience.

This section aims to capture other relevant tools that can assist with the embedding of resilience in urban rail projects.<sup>14</sup>

- *City resilience assessments* can provide a holistic view of the resilience of a city in which an urban rail system operates or will operate and can provide valuable information to inform planning and decision making. The United Nations Office for Disaster Risk Reduction has published a set of recommendations and indicators for cities to monitor and review progress in implementing resilience measures (UNISDR 2017). Another example is the City Resilience Index developed for the Rockefeller Foundation (Arup 2014).
- *Asset management systems* can be adapted for use to address resilience. The ability to present and overlay data in a spatial environment such as GIS is particularly valuable to compare hazard, vulnerability, and criticality (SmartRail World 2016). Such management systems enable rail operators to turn data into valuable knowledge to support their decisions.
- *Vulnerability assessments* can be undertaken by overlaying hazard data with asset data in a GIS environment, supported by technical understanding of the characteristics of an asset (for example, type, condition, and age) that will contribute to vulnerability. Typically, such assessments are customized for a specific infrastructure system; they are not commercial or open-source, off-the-shelf tools. Criticality assessments are also typically customized spreadsheet or GIS assessments that reflect the specific objectives of the system being assessed.
- *Network assessment* of criticality and redundancy can help to identify critical components of the system that must be protected, such as potential “choke points” where congestion or blockage may occur, critical interdependencies with other modes and urban service systems (that may lead to cascading failures), and areas with insufficient redundancy in the transport network. This assessment may lead to the establishment of a lifeline system to enhance connections across modes in the metropolitan region.
- *Quantitative risk assessments* can be undertaken by specialists to determine the potential losses (for example, damage and its costs, potential casualties, or service interruption) in the event of a known hazard and its likelihood of occurrence. Such a quantitative risk assessment can help to prioritize interventions in the face of budget constraints. These assessments require detailed inputs, including explicit treatment of hazards, exposure, and vulnerability, as well as modeling the response of infrastructure elements to different hazard levels.

- *Business continuity planning* requirements are defined in ISO 22301, which sets out the requirements of a management system to protect against, reduce the likelihood of, and ensure recovery from any disruptive incident. These principles are as relevant to rail organizations as they are to any other sector facing natural hazards or other potential threats.

## Conclusions and Recommendations

International climate change agreements have recognized that the transport sector needs to focus on adaptation measures as well as mitigation of climate change (PPMC 2016). Adaptation and mitigation can be achieved through many of the principles presented in this chapter, which reflect the need for resilience to all natural hazards, including geophysical hazards and short-term meteorological hazards, not just the longer-term impacts of climate change. This chapter introduces many different types of climate and natural hazards faced by urban rail systems and discusses tools for assessing and mitigating them (with details provided in tables A17.1–A17.4 in the annex). This final section synthesizes key takeaways.

***Resilience has to be considered early in project development and be a continuous focus through operations.*** A key message of the chapter is the importance of embedding resilience-related decisions alongside every consideration presented throughout the handbook. Resilience should not be an afterthought, and resilience measures should not be placed in a silo separate from other key decisions. Adaptation to climate change and other natural hazards is most efficient when incorporated into asset renewal for existing projects (see chapter 13) or designed for new projects at the outset (see chapter 5). Conversely, postponing maintenance and renewal activities will lead to a proportionate increase in asset and system vulnerability, so a short-term approach that only thinks about today's problems will create future problems.

***Cross-sector collaboration is key for urban rail resilience as part of a city's interconnected infrastructure system-of-systems.*** While focusing on urban rail systems, this chapter draws on lessons and approaches used across infrastructure sectors. It is essential to recognize that a resilient rail system exists within a wider infrastructure system-of-systems, which is intended to enable society to function. Therefore, owners and operators of urban rail systems need to recognize the importance of cross-sector collaboration to enhance resilience, both in planning for and in responding to unexpected events. For passengers, the end-to-end journey and the functionality of the citywide system are what matter.

*International experience suggests that investment in measures that enhance the resilience of urban rail systems pays off in the face of hazards and can enhance efficiency and safety of the rail system during normal operations.*

There is a hierarchy of measures to enhance resilience of urban rail systems, the simplest of which is avoiding the hazard, followed by minimizing or preventing any impact should the hazard occur, and, finally, mitigating the impact where it cannot be avoided or prevented. Many of the measures presented in this chapter—such as early warning systems or innovative flood-resistant technologies—represent best practice in high-income countries. Project-implementing agencies in low- and middle-income countries, particularly those implementing new urban rail systems, should seek to learn from and add to such examples of emerging best practice. Furthermore, many measures that enhance climate and natural hazard resilience also enhance efficiency and safety of the rail system during normal operations. Modern train control systems, for example, enable smarter, quicker, and more effective response to asset failures. They also provide cost, safety, and reliability benefits in a business-as-usual situation.

*The resilience of rail systems depends as much on institutional and stakeholder coordination as on the resilience of the physical infrastructure.* This chapter mainly considers the technical and institutional measures that can enhance resilience of the rail system itself. However, the sociotechnical nature of an urban rail system has to remain at the forefront. Urban rail systems can support enhanced prosperity by being accessible, affordable, available, and acceptable (see chapter 2). A resilient rail system that can remain functional following a hazard event will enhance the resilience of the society it serves, and a more resilient society will be able to absorb and adapt to some level of disruption while functionality is restored. Thus, it is the resilience of the sociotechnical system that prevents an event from becoming a disaster.

## Annex 17A. Geophysical, Hydrological, Meteorological, and Climatological Hazards and Their Impacts on Urban Rail

TABLE 17A.1. Geophysical Hazards and Their Impact on Urban Rail System Infrastructure

PRIMARY HAZARD	EFFECT	ASSESSMENT OR PREDICTION	EXAMPLE IMPACTS ON INFRASTRUCTURE	EXAMPLE RESILIENCE MEASURES
Earthquake	Ground shaking	Historical data plus modeling—regional seismic hazard maps, site- or route-specific probabilistic seismic hazard assessments (for example, Global Earthquake Model; <sup>a</sup> very short-term warning (seconds) before seismic waves reach a receptor; no short-term prediction or forecast	Rolling stock shaken and potential derailment; structural damage to buildings (for example, stations and depots) and infrastructure	Anticipate via early warning systems; response plans, including evacuation; resist through use of appropriate parameters in design
	Landslide	As for nonearthquake-triggered landslides	As for nonearthquake-triggered landslides	As for nonearthquake-triggered landslides
	Liquefaction	Geotechnical assessment using geological maps, historical evidence, and in-situ investigations; assessment and prediction links to ground shaking; triggered by ground shaking so no advance warning	Ground settlement beneath track or buildings causing damage; track displacement, obstruction, and potential derailment; deterioration in quality of ride	Resist through use of appropriate design measures such as ground improvement
	Surface fault rupture	Specialist geological and seismological studies of the characteristics of mapped geological faults; no advance warning	Ground deformation, track displacement, obstruction, and potential derailment; damage to buildings and infrastructure	Avoid (for point locations); resist or absorb through design
Landslides	Mass movement	Monitoring plus modeling using geological maps, historical evidence, and in-situ investigations; short-term prediction may be possible depending on rate of failure	Debris on track; undermining of track; potential derailment; maintenance costs	Avoid; resist through use of appropriate parameters in design; monitor (including hydrometeorological and weather); and respond

(table continues next page)

**TABLE 17A.1. Geophysical Hazards and Their Impact on Urban Rail System Infrastructure (Continued)**

PRIMARY HAZARD	EFFECT	ASSESSMENT OR PREDICTION	EXAMPLE IMPACTS ON INFRASTRUCTURE	EXAMPLE RESILIENCE MEASURES
Volcanoes	Ash fall; lava flow; pyroclastic hazardous gas	Assessment using historic data, for example, the Global Volcanism Program and the Volcanoes of the World Database <sup>a</sup> and specialist studies on a volcano-specific basis; advance warning possible through monitoring	Structural damage; reduced visibility	Resist through appropriate design measures; anticipate via early warning systems; absorb by putting in place speed restrictions
Tsunami	Coastal inundation; erosion and scour; water and debris impact forces	Short-term advance warning (0–60+ minutes in advance) once fault rupture has occurred offshore <sup>c</sup>	Structural damage to coastal buildings and infrastructure; train obstruction or derailment; flood inundation of track, buildings, infrastructure, and systems; scour or debris impact	Avoid (elevated ground); anticipate via early warning systems; response plans, including evacuation
Sinkholes	Opening up of voids	Geological assessment using geological maps, historical evidence, and in-situ investigations; no short-term prediction, but triggers can be monitored	Track deformation, ground movement impacts on buildings and infrastructure	Anticipate through assessment of monitoring; resist through design

a. See [www.globalquakemodel.org](http://www.globalquakemodel.org).

b. See <http://volcano.si.edu>.

c. See <https://maps.ngdc.noaa.gov/viewers/hazards/>.

TABLE 17A.2. Hydrological Hazards and Their Impact on Urban Rail System Infrastructure

PRIMARY HAZARD	EFFECT	ASSESSMENT OR PREDICTION	EXAMPLE IMPACTS ON INFRASTRUCTURE	EXAMPLE RESILIENCE MEASURES
Sea-level rise	Coastal inundation	Climate models such as the General Circulation Model applied in combination with regional climate models to provide an understanding of potential climate changes in a given region; predictions can be benchmarked against observation over time <sup>a</sup>	Inundation of track, buildings, infrastructure (including tunnels) and systems; corrosion	Avoid low-lying coastal areas; resist through appropriate design measures such as flood barriers, raising signaling equipment, elevating structures, drainage, and pumping; absorb, through redundancy; adapt, including long-term retreat from affected areas
			Coastal erosion and damage to sea walls	Resist through appropriate design measures such as new or upgraded sea walls; absorb through use of blue-green infrastructure such as coastal wetlands as buffers
Floods	Standing water; surface runoff; river (fluvial) flooding; rising groundwater	Flood hazard assessment for long-term magnitude and frequency and short-term prediction possible when combined with meteorological forecasting; statistical analysis of past flood events incorporating regional or national climate change allowances can also be used <sup>b</sup> ; also, hydrometeorological and weather monitoring, since heavy rain can trigger such events	Damage to connected infrastructure, for example, substations Inundation of track, depots, tunnels, stations, signaling equipment; damage to electrical systems; debris impact requiring removal	Avoid, resist, absorb, and respond; consider independent power supply Avoid flood risk zones; resist through appropriate design measures, such as installing flood barriers, automatic closure devices, watertight doors; raising signaling equipment; elevating structures; adding drainage and pumping; and sealing vulnerable equipment; absorb through temporary speed restrictions or redundancy; respond through flood-detection alarms, mobile flood barriers; recover through storing equipment and rolling stock on higher ground; adapt by including long-term retreat from affected areas; relocate equipment in low-lying areas; raise station entrances; reduce the extent of impermeable "gray" infrastructure

(table continues next page)



**TABLE 17A.2. Hydrological Hazards and Their Impact on Urban Rail System Infrastructure (Continued)**

PRIMARY HAZARD	EFFECT	ASSESSMENT OR PREDICTION	EXAMPLE IMPACTS ON INFRASTRUCTURE	EXAMPLE RESILIENCE MEASURES
Floods (continued)			Scour failure of embankments; loss of support to track	Anticipate by appropriate maintenance; recover through enhanced condition monitoring of earthworks after an event
			Scour failure of bridge piers or abutments	Resist through design (for example, using more durable materials); respond and recover through inspection and monitoring plans
			Drainage problems (blocked or unable to cope)	Anticipate by maintaining drains appropriately; absorb by pumping; design new drainage to accommodate expected future flooding
Flash floods	As for floods	Occur very quickly, short-term prediction not reliable	As for floods	As for floods

a. See, for example, <http://slr-cities.clmsystems.com/>.

b. See, for example, <http://documents.worldbank.org/curated/en/928051469466398905/pdf/WPS7765.pdf>.

TABLE 17A.3. Climatological Hazards and Their Impact on Urban Rail System Infrastructure

PRIMARY HAZARD	EFFECT	ASSESSMENT OR PREDICTION	EXAMPLE IMPACTS ON INFRASTRUCTURE	EXAMPLE RESILIENCE MEASURES
Drought	Soil moisture reduction; vegetation loss	Historical data plus modeling incorporating regional or national climate change allowances, which may indicate increased frequency; short- to medium-term prediction	Earthworks failure due to desiccation; movement of overhead line equipment due to soil shrinkage around foundations; trees on line; embankment shrinkage	Resist through appropriate design measures such as choice of earthworks fill, ground improvement of embankment, and installation of sensors on line; prepare by regularly maintaining vegetation
Wildfire	Flames and smoke	Conditions representing increased hazard can be identified; trigger event is not predictable	Direct damage to buildings and infrastructure	Resist through appropriate design such as using fire-resistant material; absorb by putting in place response plans, including evacuation; respond through emergency response planning, recognizing that local fire services may be overloaded
	Debris on track	As for drought	Service disruption	Absorb by putting in place speed restrictions
	Vegetation loss	As for flames and smoke	Embankment shrinkage	As for drought

**TABLE 17A.4. Meteorological Hazards and Their Impact on Urban Rail System Infrastructure**

PRIMARY HAZARD	EFFECT	ASSESSMENT OR PREDICTION <sup>a</sup>	EXAMPLE IMPACTS ON INFRASTRUCTURE	EXAMPLE RESILIENCE MEASURES
Storm surge	Wave action and coastal inundation	Flood hazard assessment for long-term magnitude and frequency; short-term prediction possible when combined with meteorological forecasting	Damage and flooding	Resist through appropriate design measures such as sea walls, protection of coastal wetlands, flood barriers, automatic closure devices, watertight doors, raised signaling equipment; response plans; see also tsunami, sea-level rise, and flood
Heavy rainfall	Rain; surface runoff; rising groundwater; high river flows; flooding	Short-term prediction via meteorological forecasting; long-term trends from climate models such as the General Circulation Model applied in combination with regional climate models to provide an understanding of potential rainfall changes	Reduced visibility; washout failure of embankment; earthworks scour; bridge scour; see also flood	Absorb through, for example, temporary speed restrictions; resist through appropriate design parameters and measures such as improved drainage capacity; see also flood
Thunderstorm	Lightning	Short-term prediction via meteorological forecasting	Damage to infrastructure, track, and vegetation; electrical equipment damage and interference	Resist through appropriate design measures such as installation of lightning rods and surge protection for electrical equipment; prepare by regularly maintaining vegetation; response plans
Windstorm	Strong wind	Short-term prediction via meteorological forecasting; long-term trends from climate models such as the General Circulation Model applied in combination with regional climate models to provide an understanding of potential changes in a given region	Damage to overhead line equipment caused by falling trees; obstructions on tracks; increased autumn leaf fall; damage to buildings and infrastructure	Resist through appropriate design parameters such as wind fences and circuit breaker protection for overhead line equipment; prepare by regularly maintaining vegetation; response plans, including evacuation plans

*(table continues next page)*

**TABLE 17A.4. Meteorological Hazards and Their Impact on Urban Rail System Infrastructure (Continued)**

PRIMARY HAZARD	EFFECT	ASSESSMENT OR PREDICTION <sup>a</sup>	EXAMPLE IMPACTS ON INFRASTRUCTURE	EXAMPLE RESILIENCE MEASURES
Snow, ice, low temperature	Snow, ice; freeze-thaw action	Short-term prediction via meteorological forecasting; long-term trends from climate models such as the General Circulation Model applied in combination with regional climate models to provide an understanding of potential temperature changes in a given region	Traction motor failures due to snow ingress; points failures; reduced employee and passenger access (see also flood due to snow melt); rock slope failures	Resist through upgrading traction motors with models less likely to be affected by snow ingress; anticipate by monitoring points or installing protective covers; run trains through the night to keep tracks free; absorb through response plan, including communications of alternative routes to stations, use of salt or grit, deicer, snow ploughs for access; resist through appropriate design measures such as installation of catch nets, anchors, or bolts; response plans
High temperature	Higher temperature and more heat waves; thermal expansion of rails	Short-term prediction via meteorological forecasting; long-term trends from climate models such as the General Circulation Model applied in combination with regional climate models to provide an understanding of potential rainfall changes in a given region	Passenger discomfort; heat stress on workers; overheating of electrical equipment; overhead line sag; increase in number of days where track maintenance cannot be carried out; buckling of rails and track movement	Resist through design of better cooling systems for rolling stock, underground networks, and working environments; prepare by improving systems to communicate warnings to dispatch centers, crews, and stations; response plans, including hot weather contingencies; absorb and recover through earlier planning of maintenance activities; resist through design: welded track or slab track; paint rails white; anticipate through maintenance such as rail stressing; absorb; impose speed restrictions
Space weather, solar storms	Strong magnetic fields leading to power surges; radio interference	Short- and medium-term prediction (30 minutes up to 1 month) via forecasting; <sup>b</sup> long-term trends based on the 11-year solar cycle also available	Damage to electronic equipment; reduction in accuracy of Global Positioning System, particularly at high latitudes; disruption to signaling equipment; unforeseen impacts	Resist: for example, transformers resilient to geomagnetic-induced currents, shorter transmission lines; prepare by putting in place plans to shut down electrical equipment if large event is predicted and also by increasing the number of spare parts stockpiled; response plans

a. The severity, frequency, duration, and spatial distribution of all meteorological hazards are influenced by climate change.

b. From, for example, [www.swpc.noaa.gov](http://www.swpc.noaa.gov).

## Notes

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1. Although malicious threats and security are not covered in this chapter, the impacts of such threats and the means of enabling rapid recovery are often similar to what is discussed here with regard to climate and natural hazards.
2. Choosing not to invest in resilience measures would mean that the potential future benefits (of continued operation during and after an extreme weather event, for example) have been lost.
3. A distinction should be made between sudden events, often referred to as *shocks*, and longer-term changes, or *stresses*. Climate change, in particular, can present a *stress*, for example, longer and hotter summers, as well as shocks such as major storms.
4. Meteorological or weather hazards are hazards related to atmospheric conditions over a short period of time, while climatological hazards are related to how the atmosphere behaves over the course of decades. For more information, see the definitions of the International Federation of Red Cross and Red Crescent Societies in “Types of Disasters: Definition of Hazard” (<http://www.ifrc.org/en/what-we-do/disaster-management/about-disasters/definition-of-hazard/>) and “What Is a Disaster” (<http://www.ifrc.org/en/what-we-do/disaster-management/about-disasters/definition-of-hazard/>).
5. For information on the Think Hazard tool, see <http://thinkhazard.org>.
6. Ideally, citywide hazard information will be available for this analysis; however in low- and middle-income countries, it may be necessary to undertake specific hazard assessments during project planning. In low- and middle-income countries, epistemic uncertainty may also be reduced through improved knowledge and capacity.
7. The term “legacy infrastructure” is often used to define existing infrastructure systems, which typically have been in place for some time, such as the London Underground, parts of which date to the mid-1800s.
8. The ISO 55000 series provides a 28-point requirement specification for establishing whole-life management systems for all types of physical assets. Guidance is also available from the United Kingdom’s Institute of Asset Management.
9. For CaDD, see <https://www.cadd.global>; for capacity-building resources, see [www.worldbank.org/capacity](http://www.worldbank.org/capacity).
10. While *gray* infrastructure refers to traditional engineered structures, including drains and culverts, *blue* infrastructure refers to landscape elements linked to water, such as rivers and canals, and *green* infrastructure refers to landscape elements linked to vegetation, such as ground cover or trees to avoid erosion.
11. Emergent properties arise when several simple elements are combined, leading to a system that has properties that the elements on their own do not.
12. For guidance on energy efficiency, see UITP (2014).
13. The ISO 55000 series provides a 28-point specification of requirements for establishing whole-life management systems for all types of physical assets.
14. Decision-making tools and guidelines available to assist in determining adaptation needs and options for urban rail are summarized in Eichhorst (2009), which presents a seven-step framework for climate change transport and a practical checklist for decision makers.

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