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Managing Performance of a Highway System in the 21st Century

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Synopsis

Before deciding on the direction of road management in the 21st Century, the role of roads in the land use context needs to be determined. Based on the changing technology of vehicle propulsion and the use of new technology to manage the safety of vehicles on the road, a whole new era in improved travel is about to unfold.

Roads as a Utility

Before deciding how roads should be managed, it is essential to ask the question: should roads be treated as a private good like most other utilities, or should they be treated as a public good?

This is a very fundamental question, as it is likely to have a profound bearing on how roads are managed, and hence what role technology will play. For instance, if roads are treated as a public good, it is likely politicians will want to continue to have a significant management role. Also, if roads are to be treated as a public good, it is likely that an integrated transport model for deciding on investments will emerge as centralistic planners continue to push their Awe know best@ ideology.

In my own experience I have found that integrated transport modelling results in efforts to pick winners for future investment. Trying to find evaluation tools which can fairly evaluate investment options across all transport modes is fraught with considerable difficulty. Even if an evaluation tool can be developed and validated, the funding source for these investment decisions can be controversial. For example, funds from road users are normally regarded as Afair game@ for use by other land transport modes, especially public transport and rail freight.

The arguments for this transfer of funding from roads to passenger transport or rail is normally justified on the basis that road users do not pay their full externality costs. The question I would pose is: Why should road users not be charged the full costs in the first place, to eliminate the need for intermodal cross subsidy? This would enable roads to be managed as a utility, using normal commercial principles.

The Future of Roads

It is not uncommon especially for anti-car propagandists to predict the demise of roads. However, looking back in history, as soon as civilisation needed to be mobile to survive, some form of corridor rapidly developed.

The width, geometry and surfacing of these corridors may have improved over the last 10,000 years, but the need for communication corridors has not diminished, and hence it is hard to see the redundancy of such corridors.

Also, you might wish to restrict passenger cars, but preventing the free flow of commercial vehicles will have a detrimental effect on the country's economy.

Role of Roads Connecting Urban Areas

Like rail development in the 19th century, roads in the 20th century have been a major driver for the development of countries and their respective economies. The more extensive the road network, the better the country's prosperity, eg. USA. These roads are more likely to be seen as a utility.

Roads in Urban Areas

When looking at managing roads within an urban area, many diverse views surface in respect to public/private good roles, including the role of other transport modes. Roads in urban areas serve as:

- corridors for utility services
- access to adjoining property
- space for amenities
- view shafts
- open space
- wind corridors
- barriers between activities on either side of the road
- vehicle corridors
- influence on adjoining land use
- public space

Within urban areas, local roads serve a major role in providing access, while many of the national highways provide through routes. However these through routes can, at the same time, be an intrusion into the surrounding environment.

In my view, there must be a balance between road building and land use. Appropriate urban planning will enable urban areas to develop quiet residential areas separate from major arterial highways. Good land use planning of commercial, industrial and residential areas can go a long way to minimising both unnecessary travel and conflict between vehicle travel and adjoining land use activities.

Most of the friction between road development and communities is a result of poor land use planning in the past, when inadequate provision was made for limited access arterial highway corridors. Many politicians attempt to convince urban communities that public transport will solve all their transport problems, when in fact the previous land use developer has already prejudiced the viability of many passenger transport options such as rail.

Environmentalists add to the anti-road lobby but, given that today=s society is so reliant on mobility, they offer no real viable solutions. It is important to note that good road access is essential for commerce, which in turn is the life blood of a city. Barring vehicles and road building in one city will leave the economic growth opportunities to other cities or countries, who will see the development potential.

Managing Road Networks in the Future

Road management ranges across the spectrum from the traditional public service politically-driven road provision to the other end of the scale, where a road is treated as just another utility, and provision is made by the private sector as with telecommunications (see Figure 1).

Many countries realise that managing, maintaining and constructing roads using only government owned resources is a very inefficient way to operate a road network, and they have moved to some extent along the reform continuum described in Figure 1.

One way of determining the best management structure for a road network is to look at the outputs required by the road users, as in the end they are the ultimate purchasers of the service, despite what politicians say.

The five key outputs required by road users are (reference[1] "State Highway Satisfaction Survey", 1998):

- a safe system
- known reliability of journey times (service availability)
- comfortable low-stress driving conditions
- an efficiently run service
- an understanding of the price for given levels of service

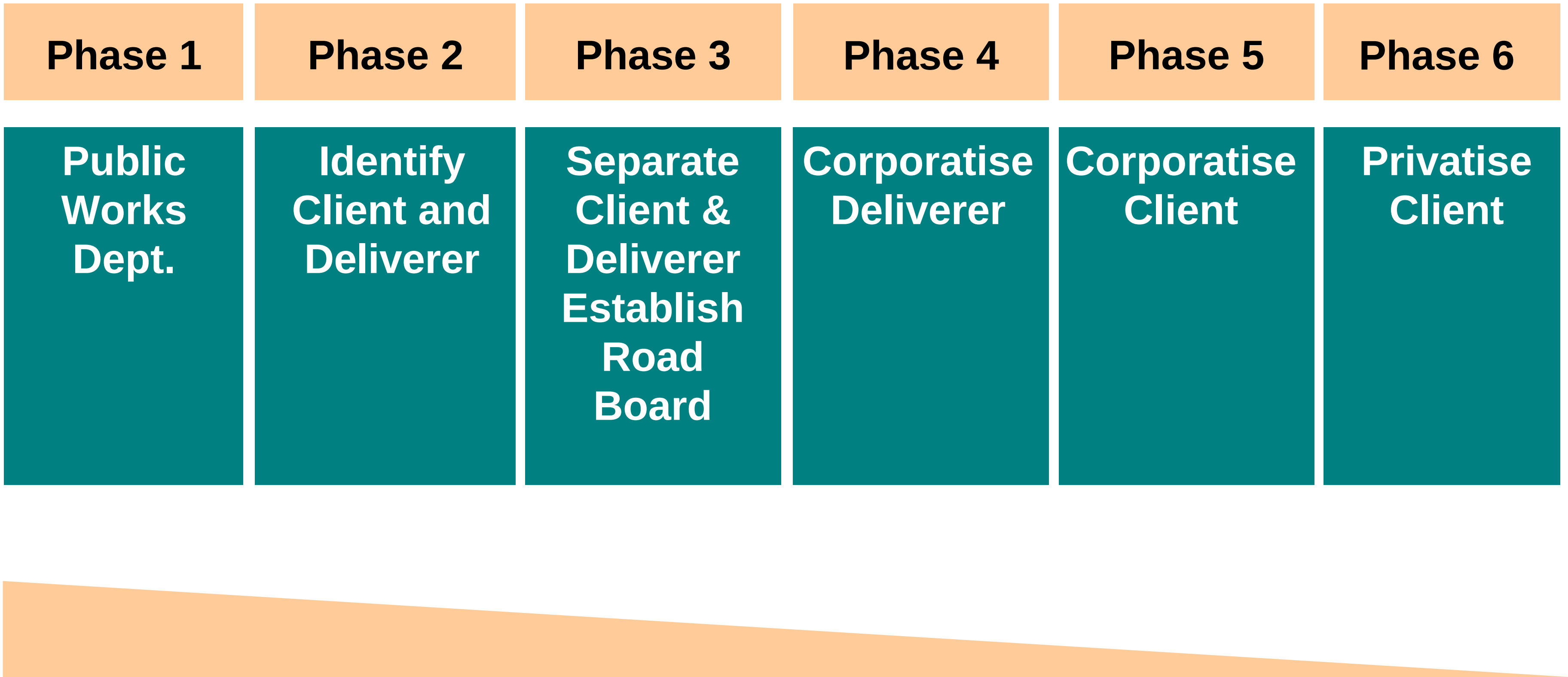

Figure 1

Footnote: ***Client*** *is defined as the organisation responsible for safe and efficient management of a network of roads.* ***Deliverer*** *is defined as a person or organisation that provides services eg design, or that carries out maintenance and construction of behalf of the client.* ***Corporatise*** *means to place the business into a publicly owned company.*

Theoretically a politically-driven, publicly-managed road system should be able to deliver the above. However from my experience the appropriate incentives do not exist to deliver a safe, reliable and efficient system. In fact, the more obscure the funding of a highway network, the more road users will demand from politicians, with no regard for price versus levels of service tradeoffs. If a country is rich enough to adequately fund their road network, then the politically-driven, publicly-controlled roads will deliver acceptable levels of service. Unfortunately very few countries have the luxury of having adequate funding to satisfy demand for road space.

In addition, if roads are not correctly priced, over heated demand for road use will result, with requests for infrastructure investment above the desired optimum efficiency. Hence, the inevitable under-utilisation of other transport modes, or inappropriate land use decisions. Likewise, environmental degradation is likely to be higher if pricing does not reflect the actual costs of the services being offered.

The question that has prompted many discussions in recent times is: Can the private sector provide a road network which will achieve the above five key outputs in a more efficient manner? The answer to this question will depend on the environment which prevails in any particular country. Simply handing over a road network to the private sector poses many risks, not the least of which may be inappropriate charging for what is predominantly a monopoly service.

For the private sector to provide an efficient road network, the existence of an appropriate regulatory regime and competition of supply needs to be present. While regulations can be implemented to control the way in which a road company performs, it is difficult to develop true competition between suppliers except for the provision of, for example, a short length of road construction. While ways around this problem may eventually be found, my personal opinion is that the bulk of the road network should be retained in public ownership, with management being conducted in a commercial environment, and bearing in mind the five key outputs described previously in this section.

To some extent, the retention of a road network in public ownership provides communities with protection of the many wider roles which highways play in the fabric of a country.

The Future Management Model

Any road management structure should be designed to meet the key outputs that road users consider essential, and at the same time gain the efficiencies that can be inherent in private sector provision. This is more likely to be achieved using public sector-owned company structures, where the main focus is on the achievement of the five key road user outputs, and not on retaining resources to collect revenue or maintain and construct roads. In other words, I would suggest development of smart buyer organisations which own the road network, and maximise the utilisation of private sector technology and innovation via competition and strategic partnerships.

This means that the smart buyer organisations must concentrate their efforts on determining road users' willingness to pay for services, rather than making these decisions in isolation of users. Clearly, regulatory and statutory responsibilities also need to be met and factored into any pricing for levels of service.

How the publicly-owned smart buyer organisations obtain the input from road users is open to discussion and experimentation. One way is to introduce a reseller into the equation, with their role focused on negotiating on behalf of road users the levels of service required, at the best prices. This is the option currently proposed in the New Zealand Government reform.

Another alternative is to require road network owners to negotiate directly with road user groups. In some cases, such as heavy vehicle users, these negotiations could be arranged reasonably easily, but this will not be the case for many diverse owners of light vehicles. This issue will no doubt receive considerable attention in the future.

A third alternative is the use of market research techniques such as customer satisfaction surveys and willingness-to-pay surveys.

Use of New Technology to Aid Road Management

In order to achieve the key outputs for road users, the smart buyer road network operator will have to embrace new technology if it is to achieve these outputs. While one can continue to improve road safety and traffic flows using conventional technology, the real quantum leap in road management efficiency is achieved when new technology enables much better road pricing and management of traffic on the road network.

An examination of each of the key outputs expected by road users should shed some light on the future application of technology.

Safety

There are a number of approaches to road safety. For instance, Sweden has adopted the ethical approach, ie. Vision zero for accidents. The Netherlands have adopted an environmental approach which separates different types of users in order to minimise accidents. On the other hand, New Zealand has adopted the efficiency approach, where any investment must achieve safety benefits greater than the cost.

The best way to ensure that a network of roads is managed in a safe manner is to develop a safety system which enables all the activities to be co-ordinated. Transit New Zealand has developed components of a safety system over the last eight years, but it has only recently completed the first full draft plan.

The main components of Transit's safety management system are:

(a) Management
(b) Identifying hazards
(c) Road, pavement and bridge design and maintenance
(d) Traffic control devices
(e) The roadside
(f) Vulnerable road users

In particular, the main thrust of our state highway design and management is:

- fitness for purpose
- no surprises to the driver
- balance between mobility and safety.

Safety will be a real winner if new technology is used in road use management. For instance, in-vehicle guidance systems can detect whether a vehicle is straying from its vehicle lane and then correct its movement by overriding the driver. Likewise, the problem of following too close can be eliminated if vehicle drivers were to accept the use of technology to govern the safe space between two vehicles.

Visibility at night and around blind corners makes driving difficult, but with built-in passive infra-red sensors, safe driving will be greatly improved.

In the future, we are likely to see some form of automated highway which should be safer and certainly will allow a greater throughput of vehicles per hour, which will greatly increase the utilisation of the existing road network.

Likewise, improved vehicle design has enabled many safety features to be incorporated which have greatly improved the chances of surviving a crash.

Road System Reliability

Every year, road users are becoming more demanding in respect of delays and road closures. Technology in the future will enable real time information on road works, accidents, closures from natural events, and congestion to be relayed directly into the vehicle, or made available by a number of communication media forums, including the Internet.

In particular, road information systems such as VICS in Japan enable subscribers to access information on the shortest route to a destination, the approximate time it will take to complete the journey, and even directions for the driver. This type of information exchange is not an option but essential, in order to satisfy this required key output.

Delays in themselves are not totally unacceptable. However having little or no information on delay times and alternative routes is unacceptable in the 21st century.

Comfort and Low Stress

Comfort results from a smooth road surface and no sudden curves. Low stress comes from good traffic flow, no hold ups behind slower traffic, and wide lanes requiring less concentration and minimisation of conflicting traffic movements. Technology will assist by:

(a) Using details of accidents, congestion and other natural events, change traffic messages either on the road or in the vehicle to minimise travel time

(b) Using automated highways which will increase throughput of vehicles per hour lane, and hence reduce the need to expand the road network capacity.

(c) Embracing new technology such as ice or air flowing vehicles, which will provide a smoother ride.

Efficiency

In effect, road users expect an efficient road system which includes the management of traffic, maintenance of highway, innovative construction techniques, and the most effective utilisation of the current road asset.

Technology will play a major role in improving the efficiency of a road network by:

(a) Charging for actual road user rather than average pricing.

(b) Enabling road construction parameters such as compaction density to be monitored away from the site.

(c) Being informed in a central office location of damage to the road furniture, eg an embedded chip in a road sign will advise the road manager the sign has been damaged.

(d) Better monitoring of the actual weight of vehicles using the road system.

(e) Using global positioning systems to control access by extra heavy vehicles to selected upgraded super routes.

(f) Increasing traffic throughput by automating existing highway throughput, and reducing the need to expand the road network capacity.

Also, vehicles are becoming more fuel efficient eg. hyper vehicles, which reduces emission levels and enables more travel for the dollar.

Price and Levels of Service

Currently, road agencies or politicians decide the levels of service normally based on standards or funding availability. In the future, technology will enable lengths of road to be priced for different levels of service, which would mean that road users can decide which options they want. However a certain minimum level of safety would be required regardless of what road users want to pay. Perhaps the road users should also have the opportunity to trade off safety with mobility.

Hand in hand with this ability to trade off different features, road users are likely to want to know what levels of service actually mean on the road. For instance, in the case of a new road they are likely to want to know the design speed value, how the road will fit into the landscape, and what environmental effects it would produce.

The use of visual graphics to present the built environment for the road will greatly assist road user understanding of what they are purchasing.

Environmental Benefits

With the rapidly changing fuel efficiency of modern vehicles including hydrogen-powered and combined electric / combustion hyper engines, the level of emissions will greatly reduce over the next 15 years. This will also help to reduce the particles which are deposited from exhaust pipes directly on to the road surface and then run off into the surrounding countryside.

Technology which helps to provide free flowing traffic combined with congestion pricing will greatly reduce the stop-start nature of congested networks.

Intelligent Roads

Research is currently underway in North America, UK and Finland to develop the intelligent road concept. This entails developing inexpensive instrumentation and data acquisition systems to monitor road conditions.

The type of instrumentation would include stress, strain and moisture measurement.

The stress and strain sensors could be installed in the pavement and the subgrade and would indicate the effect of any particular vehicle on the pavement structure. This would assist with the more accurate estimation of road user costs since the stress and strain is directly related to the damage. This system will also indicate when rehabilitation is required and in which layer.

These intelligent roads would make the weigh in motion (WIM) systems redundant since the WIMs provide a measure of the vehicle axle load which is then translated into a pavement damage effect using the load equivalency concept. This will not be required when the road itself is used to measure the effect of the load passing over it.

The moisture sensors will yield early warning to one of the most destructive influences on pavements, namely water. The typical level of service/life of a pavement curve for unbound granular pavements tends to remain flat until the pavement surfacing cracks and moisture enters the pavement structure. There is then a dramatic loss in the level of service in a short period of time. Moisture sensors would detect an increase in the water levels in the pavement which may provide the time for remedial treatment prior to the onset of major damage.

Surface Conditions

Substantial progress has been made in developing new technology to monitor road surface conditions and relay the information to a central processor. For instance in Finland they are trialing a monitoring system which uses heavy vehicles fitted with under-floor monitoring equipment which picks up temperature, presence of ice, flushing or skid resistance. This sort of information will not only assist pavement managers but will be able to be relayed to other road users so that they can be informed about a particular highway's condition, either by in-vehicle processes or by on-road variable message signs.

Future Pavement Design

Similar to the design of a steel beam in the future the repeated load strength properties of materials used in pavements will be well understood through the development of advanced in situ and laboratory testing techniques. This will enable a designer to engineer a pavement.

A proposed pavement could be modelled as finite elements or multiple layers of known material properties in an appropriate computer program. The design traffic loading will be simulated over the pavement and the permanent deformation (rutting) determined. If the level of permanent deformation is unacceptable the pavement materials are changed and/or pavement depth increased and the pavement reanalysed.

Engineering pavements would negate the need for a subgrade strain criterion converting all traffic to Equivalent Standard Axles. The whole traffic spectrum would be simulated over the pavement rather than as one standard axle repeated millions of times. In addition, the damage (permanent deformation) caused by individual vehicle types could be calculated for determining an appropriate level of road user charges. This could be linked to the Intelligent Road concept to complete the loop.

The effects of construction variability on pavement life could be assessed. Variations in constructed pavement depth, aggregate strength (due to variations in compaction and materials), subgrade strength etc. could be inputted into the computer program in terms of confidence limits and assumed distribution plotted showing the traffic vs. percentage of pavement area that will fail prior to design life. This system would be capable of determining the design life when eg. 5%, 10% or 15% of the pavement has failed.

One of the positive aspects of this is it will allow the pavement designer to be less conservative for designing a low volume road as perhaps the design life can be extended to when 10% of the road has failed rather than 5%.

In addition, this tool can be used to analyse the affects of tighter quality control in road construction.

Monitoring Pavement Construction

Using technology, it is now possible to monitor actual pavement layer construction remotely using sensors laid within each layer. This will enable considerably more attention to be paid to the quality of construction of the pavement layers at a low cost, in that you do not have to have a team of experts on site to carry out the testing.

This technology advancement, combined with the design methods described above will enable more cost efficient pavements to be constructed.

Collecting Data on Pavement Condition at High Speed

Many countries are already collecting continuous data on rutting, profile and surface texture using a high speed multi-laser profilometer over the entire state highway roading network. This information, although useful does not give the full picture. Ground

Penetrating Radar (GPR) surveys or test pits are needed to determine the pavement depth; Sideway Force Coefficient Routine Investigatory Machine (SCRIM) surveys are conducted to measure the level of skid resistance; the Falling Weight Deflectometer (FWD) is used to measure the strength of the pavement; a visual assessment of chip loss and cracking is still required.

Future advancements will see the development of a machine that is capable of measuring all the information on pavement condition in one pass at highway speed. The machine will incorporate: all the functions of the already existing multi-laser profilometer; a SCRIM to measure skid resistance; a GPR to measure pavement depth; a laser profile beam placed longitudinally to measure the deflection bowl caused by a standard wheel load for determining the pavement strength; and a device to measure the extent of cracking and chip loss.

Skills Required

Very different resource skills are going to be required to manage a highway network on a commercial basis and fully utilise technology, than those traditionally required in a normal public sector management structure. In particular, skills will be required in pricing road use, negotiating these charges with user representatives, and marketing the benefits being offered with the costs imposed, and interfacing with road users as direct paying customers.

Also with the considerable use of technology, a high level of application skills will be required. However what is absolutely essential is that such a commercial highway infrastructure provider does not end up with technocrats who know how to produce numbers but do not have the skill to do the reliability checks to ensure the results are logical. Therefore there is still a place for the knowledgeable practitioner.

Conclusion

Intelligent transport systems offer real opportunities to improve the efficiency and safety of highway networks. However, many institutional structures now in place for management of publicly owned highway networks do not provide the right incentives to ensure that the full potential of intelligent transport systems is exploited.

This technology development, combined with far more demanding road users, means it is essential that network managers break away from conventional thinking and look at how all the components of these highway networks will combine to produce the most cost efficient and affordable infrastructure consistent with customer needs and willingness to pay. Those of us who do not pick up this challenge and move with the opportunities being opened up will not survive the next decade in the highway management field.

Many writers conclude that the present transportation system is not sustainable due to the finite availability of fossil fuels, the environmental damage caused by emissions, the consumption of land for roads, the effects or costs of crashes on communities, and the cost of congestion.

What they fail to do is project their thinking into the future where technology developments are likely to radically change these current conditions.

Hyper or green vehicles could greatly reduce the dependence on fossil fuels and the effect of emissions on the atmosphere. Safety will dramatically improve with the introduction of technology which will hold a vehicle in its lane on the road at an appropriate distance behind a vehicle in front.

Better road management, and possibly automated highways, will greatly improve traffic throughput, and hence the need for widening highways.

As proper road pricing is introduced, transport decisions will start being made, based on actual costs. Passenger transport will then be more viable, and congestion will reduce. Also, proper pricing will raise the funds to carry out essential capacity improvements. It is anticipated that the most difficult environmental effects of roads to overcome will be the severance of communities. This is where land use planning allows for such corridors, and they are planned into developments.

Disclaimer: Any views expressed in this paper are those of the author and do not necessarily reflect the views of either Transit New Zealand or the Government of New Zealand

References

1 State Highway Satisfaction Survey, September 1998, Transit New Zealand