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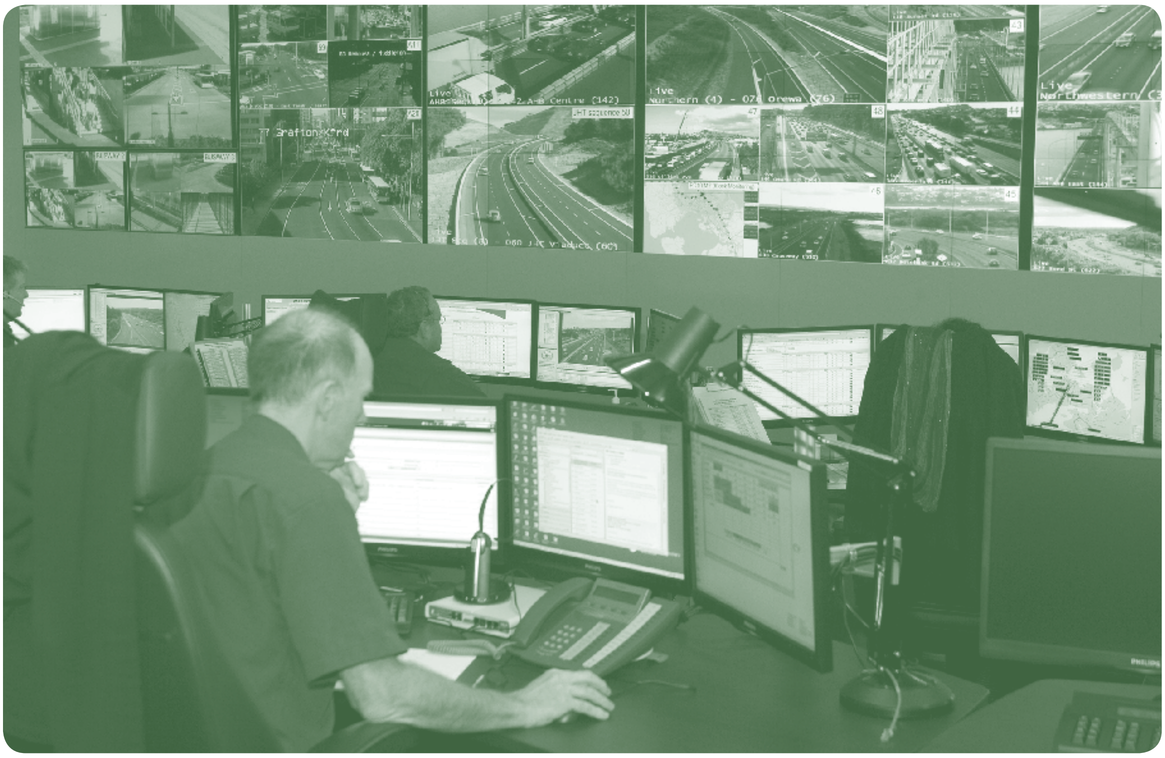

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Intelligent transport systems in the frame

Harnessing the potential of intelligent transport systems (ITS) to improve services for users was a driving force behind research on developing a first step toward a national ITS architecture.

The research report, prepared by Rod James, James Date and Cormac McBride of Traffic Design Group (was Hyder Consulting) between 2007 and 2010, acts as a framework for developing a future architecture, by building a shared understanding of what ITS architecture involves and aligning the efforts of the various stakeholders involved.

Back to basics: what is ITS?

ITS has been defined by the International Standards Organisation as:

> The application of information technology, communications technology and sensor technology, including the internet (both wired and wireless), to the general challenges and opportunities of surface transportation.

There are already many ITS at work on and around New Zealand's transport network. These include systems for traffic signal control, traffic management, electronic vehicle safety (such as anti-lock braking systems), engine management, public transport, electronic surface transport and information sharing between different transport modes.

Cormac McBride says, 'Taken together, these systems have enormous potential for increasing transport efficiency, enhancing safety and providing better services for customers.

'New ITS technologies are being invented and adopted all the time, but because New Zealand lacks any form of overarching architecture, all this work is happening discretely, without new projects and systems informing or drawing on each other. The challenge for transport practitioners becomes how to harness and integrate the data in these systems so we can make best use of it. There are many hurdles facing the full integration of ITS, including political, social, institutional and regulatory ones. In our report, we explain how having in place an ITS architecture can help stakeholders resolve these.'

Next steps: what is ITS architecture?

ITS architecture refers to a technology-neutral map of the services that currently incorporate ITS, plus a 'big picture' of how these services might interlink and develop in the future.

Further development of ITS architecture will enable stakeholders to identify both the services that end-users need and the potential sources of data for the services. The architecture describes how to coordinate, structure and share the data sources and information services.

An ITS architecture is not a system design, nor is it a design concept. Instead it's a framework around which multiple design approaches can be adapted and developed. Each design approach will still be tailored to the needs of the user, but will benefit from sharing data as part of a larger common plan. Architectures are often layered with higher layers describing the big picture and lower layers addressing physical subsystems.

Cormac says, 'ITS architecture is intended to simplify the process of developing ITS applications. By sharing data, services and information, the cost of providing each part of the system, and the overall costs, are kept down. For new ITS, it will be cheaper to share data already available from existing systems than to build new systems to collect the same data. There are potential efficiency gains for all stakeholders, and it is this type of coordinated approach that ITS architecture enables.'

Approach

The research was a first step towards building an ITS architecture in New Zealand, setting out a framework for how that development might occur. International examples of ITS architecture were examined and some of the common ITS components that are already being used (or are likely to be used in the next decade) were described. After consultation with experts in the field, a core set of ITS services and sub-services tailored to the New Zealand transport environment was proposed.

Cormac explains, 'The framework architecture we've set out in our report is intended to raise awareness of the best-practice basis from which to develop a full ITS architecture for New Zealand. Our hope is that it will enable the public and private sectors and individual end-users to start aligning how they design, develop and implement their ITS strategies, products and services.'

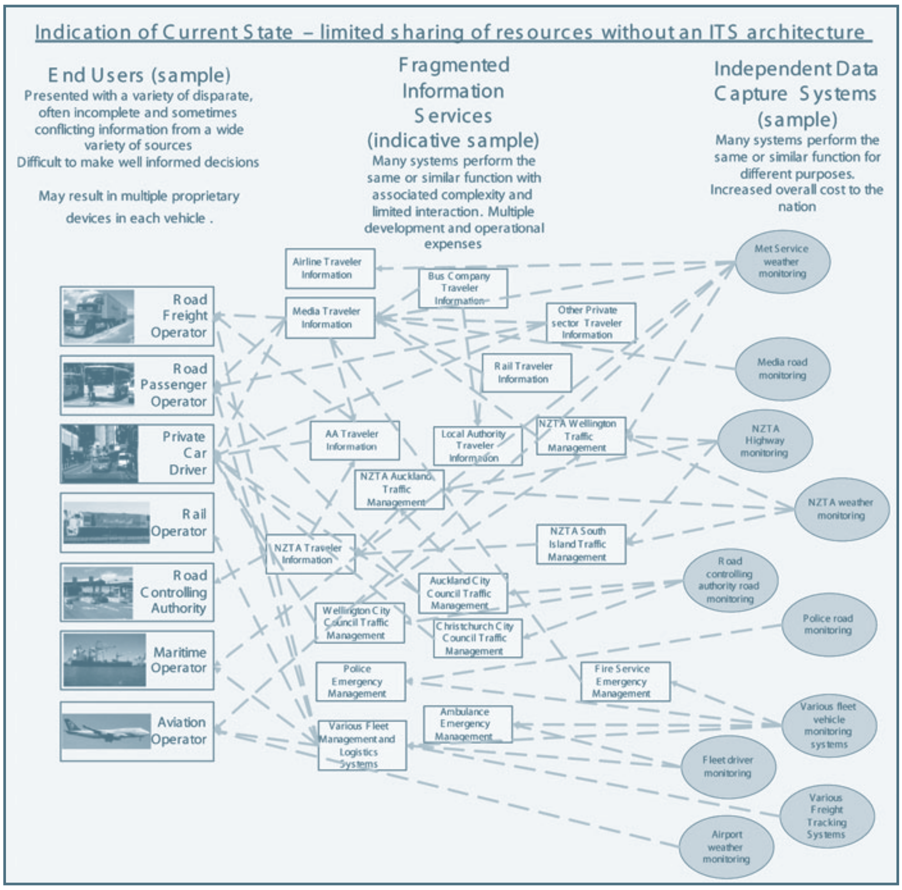

Figure 2.1 Without an ITS architecture, multiple components perform the same task

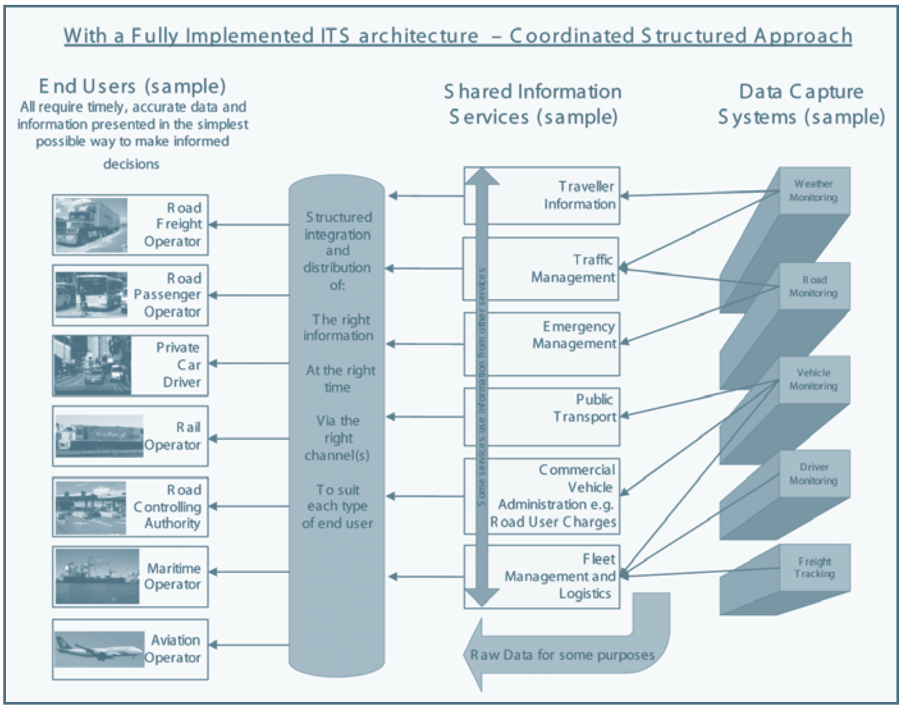

Figure 2.2 The ITS architecture enables a coordinated and effective information structure

What are the benefits?

Having ITS architecture in place helps identify synergies between separate ITS and encourages the development of systems that work together and share data. This creates opportunities for users to access better-quality, more timely data, and to deliver a greater range of information and other services than if each system were operating alone. Access to better data improves business intelligence, enhances the evidence base for decision-making and results in more cost-effective transport management.

Properly implemented ITS are a means of reducing crashes and congestion, improving compliance, improving performance monitoring, improving transport modelling, and enabling more productive use of vehicles and roads. They also enable existing assets to be better managed, postponing the need for investments in infrastructure upgrades. The net results are safer roads, improved customer service and improved productivity, enabling economic growth.

Cormac says, 'The key issue is to identify which ITS services will work together. This is what further development of an ITS architecture will do, providing a technical big picture of the feasible, practical and logical linkages.'

A good example of where ITS architecture would be valuable is with respect to integrating data from commercial fleet tracking systems. New Zealand currently has 23 of these systems in operation, all performing similar tasks, but using different methods and technologies. The systems have no inter-operability and provide different data outputs. The NZ Transport Agency relies on data from many of them to support road user charges off-road claims. This year, one of them has been approved to measure on-road distance and collect charges. Application of the concepts contained in the ITS architecture might offer a range of other safety, productivity and planning benefits from the same technology.

Another example is electronic ticketing. A project is underway to converge the different electronic ticketing systems that are operating nationwide. These systems tend to have been devised and implemented company by company, even for companies operating within the same cities. Bringing them together retrospectively involves substantial political and financial costs. Had there been an ITS architecture in place up front, these costs might have been avoided by ensuring that the systems were compatible at the design stage.

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Framework for a national intelligent transport systems architecture
Research report 397

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What's in the framework?

The framework for a national ITS architecture developed by the research lists user services and sub-services that make use of ITS. The framework is based on architectures overseas, what technologies were (or might soon be) available and feedback from consultation with industry specialists.

Cormac says, 'The framework indicates relatively accurately what a future New Zealand reference ITS architecture might look like. Our intention is that it should be used as a starting point for further discussion between stakeholders. From there we can fine-tune and add services to obtain a working national architecture that benefits all groups in the transport sector.'

The full report contains explanations of what each technology involves, including more specific systems within each category, the data each system generates, its current inter-operability and potential or planned future enhancements.

Framework ITS architecture for New Zealand

- Traffic management systems
  - Traffic network flow monitoring and management
  - Vehicle-based sensing supporting traffic management systems
  - Parking management
  - Pedestrian and cycle management
  - Traffic control
  - Environmental conditions management
  - Operations and maintenance
  - Automated dynamic warning and enforcement
- Driver monitoring systems
  - Fatigue monitoring systems
  - Driver behaviour monitoring
  - Electronic driving hours logbook system
- Vehicle monitoring systems
  - Real-time monitoring system
  - Engine management
- Vehicle safety and control systems
  - Vehicle-based collision avoidance
  - Infrastructure-based collision avoidance
- Commercial transport operator and fleet services
  - Commercial vehicle administrative processes
  - Electronic road user charging
  - Automated overdimension and overweight permit system
  - Online hazardous materials register
  - Operator Rating System
  - Weigh in motion
  - Electronic clearance
  - Roadside check facility (weighstation)
  - Roadside inspection system
  - Commercial freight management
- Public transport services
  - Near real-time timetabling
  - Fixed route passenger operations
  - Multi-modal coordination
  - Multi-modal connection protection
  - Demand responsive passenger transport
- Emergency management and enforcement services
  - Personal and public transport security
  - Public security
  - Automated emergency notification
  - Remote power down
  - Emergency response management
  - Emergency vehicle priority
  - Emergency response chain
  - Hazardous material planning and incident response
  - Coordinated incident management system emergency support system
- Electronic offence detection systems
  - Digital speed cameras
  - Intersection cameras
  - Automated number plate recognition
  - Roadside inspection
  - Electronic crash reporting
  - Electronic offence subsystem
- Electronic payment services
  - Toll collection
  - Parking payment
  - Fuel payment
  - Passenger transport services payment
- Traveller information services
  - Real-time ridesharing information
  - Traveller business directory
  - Parking facility management
  - Autonomous route guidance
  - Dynamic route guidance
- Information storage and retrieval
  - Data warehousing

Rising to the cycle safety challenge

As cycling becomes more popular, understanding the benefits of various cycle safety measures becomes more important. A recent study helps engineers and other transport professionals make this assessment, drawing on data from home and overseas, to clarify what factors contribute to making cycling safe.

Government transport strategies have encouraged transport authorities to develop cycling and walking plans, and to improve infrastructure to encourage people to cycle or walk. Although cycling is sustainable, and better for the environment than equivalent trips taken by car, a key barrier to getting people to cycle is the fear of traffic and concerns about safety while cycling.

The risk of being injured in a crash when cycling is higher than when driving or being driven in a car. But the benefits gained by cycling often outweigh the disadvantages, and there is a 'safety in numbers' effect that reduces the crash risk as more people cycle.

Many of the safety problems for cycling are caused by factors that cannot be influenced by transport authorities, eg driver behaviour and the experience of the cyclist. The element that transport authorities can influence is the infrastructure designed for cyclists. This is an area where evaluating the appropriateness and design of cycle facilities can aim to create a safer environment.

Popular measures to date have included on-road cycle lanes, cyclist storage bays and approach lanes at intersections, off-road cycle paths, and strategies to reduce traffic volumes and speeds. The effectiveness of these measures had not, until recently, been quantified in New Zealand. An NZTA funded research project has sought to fill (at least partially) the gap by looking at the crash rates for both on-road and off-road cycling facilities, and developing prediction models for crashes. Such models will provide a valuable tool for the design and implementation of new cycle routes.

Perceived and actual safety are two different concepts and this study focuses on the actual safety of cycle facilities based on available New Zealand crash data and cycle injury records from local hospitals.

Evaluating the measures

Shane Turner of Beca Infrastructure, who led the research, says that the challenge for transport practitioners is to create a cycling environment that is as safe as possible.

'While the relationship between cycle crash risks and traffic and cycling volumes has already been established,' says Shane, 'the engineering interventions that are popularly used to improve cycle safety had not been quantified. Through the project we were seeking to explore what additional reductions in crash numbers could be achieved through reducing traffic speeds and installing cycle lanes, paths and intersection facilities.'

Some of the findings from the research were unexpected and, Shane says, warrant further research. For example, findings (from modelling) that flush (or painted) medians along roads can reduce cycle crash risk. This may be due to motor vehicles having extra space to take evasive action if they encounter a cyclist in their travel path but this is not known for certain.

The differing needs of different types of cyclists also need to be taken into account in improving cycle safety, with young and novice cyclists more likely to favour off-road facilities and quiet roads. However, often these off-road routes can be some of the most dangerous parts of the cycle network.

On the other hand, more confident cyclists may elect to ride on busy roads in order to use more direct routes. This means that, even if off-road and local road routes are provided, many cyclists will still choose to use the main road, and on-road facilities are often still warranted to reduce crash risk.

Shane says that the research will be useful for engineers and other transport planners in providing them with some data about the effectiveness of the various cycling safety measures.

'Overall, we've found that we can achieve significant safety improvements for cyclists by adopting one or more of the measures we looked at,' says Shane. 'Combining this evidence of effectiveness with considerations about implementation costs will help transport practitioners select cycling safety measures that are appropriate for their localities'.

Understanding the on-road variables

Most of the effort in the research project went into quantifying the effect that various on-road features had on cycle safety and crash rates. Features such as cycle lanes, flush medians, and whether or not there was provision for vehicle parking on the route, were all subject to crash prediction modelling to examine their impact on safety.

In all the models, the volume of traffic using

The five-step hierarchy of measures

The UK Institution of Highways and Transportation has proposed a five-step hierarchy of cycle improvements. Measures at the top of the hierarchy are typically applied first (depending on the type of site being treated). The five steps are:

1. reducing motor vehicle traffic volumes
2. reducing motor vehicle traffic speeds
3. installing intersection treatments and traffic management
4. reallocating road or corridor space (eg through on-road cycle lanes)
5. separating cycle facilities (eg through off-road cycle tracks).

The cycle safety measures looked at in the current study fitted within this hierarchy. Two methods (before and after studies, and crash prediction modelling) were used to assess the effectiveness of on-road cycle facilities, intersection cycle facilities and flush medians, and to understand the impact that traffic volumes and parking had on on-road cycling. Other measures, such as off-road cycle facilities and vehicle speeds, were assessed from international literature.

the route was found to be an important variable (backing up findings from earlier studies that had found that reducing traffic volumes along cycle routes had a substantial impact on cyclist safety). The number of cyclists using the route was also an important variable, as was the distance between major intersections (the longer the distance, the greater the safety).

Having a flush or painted median between cyclists and vehicles reduced crashes by up to 37 percent in some situations, a fact that Shane attributes to the extra space that medians provide for motor vehicles. 'The availability of space is a key issue for cyclists,' says Shane. 'But giving cyclists more space can be difficult to achieve on busy arterial roads. In these situations it's a matter of balancing the need for space against the needs of other road users.'

Parking (or its absence) is another major factor that emerged through modelling, with crashes reducing by up to 50 percent in some situations where there was no provision for parking made. Conversely, routes where there was provision for parking, but it was seldom used, were much less safe than routes where parking spaces were well patronised. 'This could be because cyclists are using the parking hard shoulder to get along,' explains Shane, 'but every now and then they have to pull out to avoid a parked car, taking drivers by surprise.'

Interestingly, the presence of a cycle lane did not emerge in the research as a strong factor affecting safety, with parking and flush medians much more likely to influence crash rates. In fact, models developed as part of the research suggested that routes with cycle lanes experienced higher crash rates than those without. However, further analysis using before and after crash comparisons indicated a small reduction in crashes of around 10 percent at those sites where cycle lanes were installed.

Shane says, 'The level of crash reduction found was not as high as that calculated in several overseas studies, where research shows that cycle lanes can improve safety by over 20 percent.

'This could be because, in New Zealand, cycle lanes have often been installed on routes that already have high crash rates and because of the poor standard of some of the older cycle lanes we looked at in the study. Either way, this disparity in findings needs to be investigated further, so that we can get a more accurate picture of the impact that cycle lanes have on safety.'

The dangers of footpaths

Dedicated paths for cyclists can be either adjacent to or completely independent from roadways. The latter option is more common in New Zealand, with most of these paths also being shared with pedestrians. This approach differs from many overseas countries, where paths frequently run alongside roads and are often cycle-only.

Overseas research on cycle paths follows this trend, with most of it focusing on cyclist-only paths alongside roads. This makes the research not particularly relevant in New Zealand. With limited crash data being available about segregated cycle paths, eg along railway lines or in public parks, it is difficult to assess the safety of such paths, particularly where pedestrians are in the mix and where the greatest danger is often at road crossing locations.

However, what the studies do show is that crash rates for shared cycle and pedestrian footpaths along roads are much higher than for either on-road or fully segregated off-road options. Cycling on a footpath (alongside a road) is 1.8 to 2.5 times more dangerous than cycling on the road. Cyclist casualties rose 48 percent following the introduction of off-roadway cycle paths, with vehicle, moped and pedestrian crashes (and casualties) also rising.

The reason for these alarming statistics is the increased potential for conflict that shared footpaths introduce between cyclist and pedestrians, vehicles and other cyclists. Factors that can reduce the conflict include minimising the number of motor vehicle crossings over the path and clarifying who has priority at each crossing, improving visibility and pavement markings at crossings and underpasses, and increasing the width of the path.

Shane says, 'We still need more New Zealand research on how best to design off-road paths, especially shared-use footpaths, for cyclists. Dedicated bike paths that run independently of roads also need looking at, as so far these have not been studied well anywhere else in the world.

'However, the research to date does indicate that we should continue to avoid off-road cycle paths along roads with multiple driveways, and continue with fully segregated facilities. If there is no room for segregated facilities, the best alternative is normally on-road cycle lanes.'

Safety in numbers (and slowness)

A scan of overseas research demonstrates that slower traffic speeds mean safer roads for cyclists. Reductions from anywhere between 40km/h and 32km/h have been investigated for their impact on crash rates, with the number of fatalities and injuries suffered by cyclists (and pedestrians) dropping markedly alongside reducing speeds.

A US study found that only 5 percent of cyclists and pedestrians are killed when struck by a vehicle traveling at 32km/h, compared with 85 percent fatalities at double the speed (64km/h). Another US study confirmed the speed–fatality correlation, finding that, even though less than 20 percent of collisions occurred on roads with speed limits over 56km/h, they accounted for over half of all cycling fatalities.

In New Zealand, research has shown that there is safety in numbers, with the crash rate per cyclist decreasing as more cyclists take to the roads. Likewise if the number of cyclists remains constant, but the volume of vehicles drops, then crash rates go down. The reverse is also true, with more cars meaning more crashes for the same number of cyclists.

Shane says, 'Safety statistics from the current project support the UK hierarchy of measures, in that speed and traffic reduction measures should be considered first and segregated cycle routes last. These results are based on actual safety and any scheme design must consider these results and the perceived safety of routes for users of the facilities. The safety in numbers effects will only happen if we attract cyclists to use the routes we provide.'

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Cycle safety: reducing the crash risk
Research report 389

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Lowering discount rate has long-lasting impacts

A two-year study has looked at what the effect would be of significantly decreasing the discount rate used in cost–benefit analyses of transport projects.

Cost–benefit analysis is a method of evaluating the added benefits and costs to society over time from a new initiative, or set of initiatives, compared to the status quo. Effects from cost–benefit analyses are expressed in monetary terms, and the discount rate is used to convert these monetary impacts over time into a single present value figure.

NZTA-funded research conducted between 2005 and 2007 looked at the potential impacts that may flow from significantly decreasing the discount rate used in cost–benefit analyses of initiatives funded (in whole or part) from the National Land Transport Fund.

Project objectives

The research examined the effects that reducing the discount rate would have on funding priorities for transport initiatives. Project objectives were to:

- find the range of plausible discount rates
- assess the plausibility of a range of possible discount rates for altering the nature and mix of land transport investments
- evaluate how this changing mix of investments, and the nature of those investments, creates a sustainable transport future
- provide workable policy advice on how stakeholders could best respond to the effects of lower discount rates
- provide policy advice as to what the appropriate rate should be, taking sustainability into account.

In particular the research looked at whether lowering the discount rate would significantly affect the mix of land transport investments and what the implications might be for New Zealand's future land transport environment (provided that investment decisions are sufficiently influenced by the results of cost–benefit analysis).

Information gained through the research about the impacts of the differing rates could then be used to inform the debate about what the discount rate should be. It would also let transport stakeholders know what effect (if any) a reduction was likely to have, so that they could respond accordingly. The motivation is that there is a wide range of plausible discount rates that can be chosen (and have been chosen worldwide), and it is thus a judgement as to which discount rate to use. This judgement should be made in the context of knowing what the consequences of a discount rate change are.

The research also reviewed alternative formulations of the benefit-cost ratio (BCR) because the existing formulation did not cope with this sort of analysis.

Over 160 projects spanning a range of project types were collated and the relative effects that different discount rates (from 3 to 10 percent) would have on their priority were assessed. These projects had been appraised prior to the reduction in discount rate from 10 to 8 percent in mid-2008.

The analysis highlighted that a lower discount rate would probably lead to changing priorities. All projects perform better as lower discount rates are applied (because projects' benefits generally occur after the costs are incurred) and so BCRs across the board are greater. This would place increased demand on the available budget, meaning every dollar in the budget becomes more valuable. As a result projects that save an extra dollar of future cost are valued more than any project that produces an extra dollar of future benefit, all else equal. A lower discount rate would probably favour most initiatives that reduce the total cost of maintaining and operating the transport network. It would also favour long-lasting infrastructure investments. Conversely, initiatives with large future operating and maintenance costs would decrease in relative priority.

The table on the next page summarises the effects that a significantly lower discount rate would have on different types of initiatives. Because these effects may change over time (as the underlying network progressively changes) the effects are described over different time periods.

In summary, maintenance-orientated initiatives will obtain the greatest positive impact from a lower discount rate in the short to medium term (25 years) following a material reduction of the discount rate. In the long term one might expect that maintenance costs would be lower, but by how much lower and when would be governed by how much additional investment was made early to make the transport network more durable, especially road pavements.

Major capital works projects, such as motorway construction, bridges and major road realignments, would probably increase in priority in the short and medium term as well as the long term, because of the long-term net benefits that they generate. However even these projects could get displaced by spending on maintenance works in the short term.

Small to medium-size capital works are likely to be somewhat crowded out by the increased focus on maintenance and major capital works projects over the short to medium term. However, those small to medium capital works projects that have a strong cost-saving element would probably continue to hold their own.

Table XS1: Summary of possible effects on relative priorities from a lower discount rate

INITIATIVE TYPE	SHORT TERM (0–5 YEARS)	MEDIUM TERM (5–25 YEARS)	LONG TERM (25–60 YEARS)	VERY LONG TERM (60+ YEARS)
Maintenance	++	++	+	–
Major capital works	++	++	+/++	+/++
Small to medium-sized works:				
• user benefit oriented	–	–	~	+
• cost saving oriented	+	+	+	~
Public transport services (non-commercial)	–	–	~/–	+
Walking and cycling	~/–	~/–	~	+
Travel behaviour change	––	––	––	––

++ large relative increase in priority
+ relative increase in priority
~ no relative change in priority
– relative decrease in priority
–– large relative decrease in priority

The relative priority of public transport services could be expected to be lower following a decrease in the discount rate because public transport initiatives generally have relatively large ongoing operating and maintenance costs when compared to the initial investment involved.

The priority for cycling and walking initiatives may not change materially. However, travel behaviour change initiatives would probably experience a consistently large relative decrease in priority, from the short through to the long term.

A full discussion of the effects of the various discount rates, as they apply to different types of initiatives, can be found in the research report.

There are two other notable findings of the study. The first is the identification of a potentially significant oversight in how long-life road pavements (pavements with design lives of 40+ years) have been appraised. New Zealand is relatively unique worldwide with its widespread use of thin road pavements and has high costs to maintain the road network compared to other countries. The researcher suggests that when appraised using the more appropriate rolling-over method, long-life durable pavements may have always been the more cost-effective option, even at a 10 percent discount rate. This suggests that overall maintenance costs and road user charges for heavy vehicles in particular have been much greater than they should have been.

The second other notable finding is that there is an alternative BCR formulation that, unlike the current BCR formula, allows all types of transport investment to be appraised in a consistent, informative and intuitive way. This version also allows all projects to capture potential impacts to transport users and wider community (whereas currently maintenance projects are appraised on a cost-minimising basis only). However, this approach has a demanding technical requirement: that the NZTA explicitly places a value on the net benefits to society of expanding its budget at the margin – something made even harder when decisions are based on multi-criteria frameworks.

Overall, the research indicates that substantially lowering the discount rate would lead to a very large emphasis on upgrading the quality and durability of the transport network, in order to reduce whole-of-life costs in the long term.

With fixed budgets, this could crowd out much investment in new infrastructure and public transport services for a significant period of time, and measures that create increased funding for the system would have to be found.

Reducing the discount rate would increase the focus on the needs of transport users in the future and reduce the focus on the needs of users in the near term. Strategies would also have to be found to ensure that the needs of future users are not given excess priority over those who are paying for and using the network now. Borrowing from future generations may in that case complement a lower discount rate regime.

Lowering the discount rate may also lead to investments that do not naturally align with the targets in the New Zealand Transport Strategy 2008. Measures to counter or balance these effects were proposed in the report.

The research included a review of approaches that could be used to determine an appropriate social discount rate and suggests that the discount rate for transport be based on a social time preference rate (based on consumption trade-offs rather than investment trade-offs), which would be in the order of 3–5 percent rather than the current 8 percent. This is because transport is subject to a relatively tight budget constraint that (usually) restricts funding only to transport projects that are unambiguously beneficial (even if it does forgo investment in the private sector somehow), and because hypothecated transport revenues are probably more likely to displace private consumption rather than private investments.

The researcher suggests that because of the subtle but nevertheless important societal value judgements needed to determine the social time preference rate it is perhaps more appropriate that policymakers rather than economists preside over the specific values chosen.

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The implications of discount rate reductions on transport investments and sustainable transport futures, Research report 392

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Finding a solution to a sticky (tarry) problem

Many of New Zealand's older roads and state highways contain carcinogenic coal tar in their sub-layers. With these roads and streets fast approaching the end of their useful lives, ways need to be found to reuse (or dispose of) the coal tar-contaminated materials.

Coal tar binders were widely used in road construction in New Zealand until the 1970s. These road materials can contain over 1000 times more polycyclic aromatic hydrocarbons (PAHs) than bitumen pavements, and have been identified as a major source of PAHs in both Christchurch's and Auckland's waterways. In Christchurch alone it is estimated that around half of the city's streets are affected.

With many streets that contain coal tar binders now approaching the time when they will need to be reconstructed, decisions need to be made about what to do with the tar-contaminated road materials.

Excavating and disposing of the materials to landfill represents a significant financial and environmental problem. As an alternative, a recent NZTA funded research project has investigated the merits of in-situ recycling. The process would involve pulverising the contaminated material and stabilising it with foamed bitumen and cement. The compacted material could then form the construction base for the new road.

A historical problem

Coal tar-based binders are a by-product of coal gasification, a process which involved heating coal in large retorts at extreme temperatures. Crude coal tar was distilled from the retorts and from there into various products, with the tar residue used to make various grades of road tar binders.

Coal tar binders contain vastly greater concentrations of PAHs than bitumen-based binders. PAHs have been established to have carcinogenic (causing cancer), mutagenic (causing genetic mutation) and teratogenic (causing malformation of embryos) effects on animals, including humans. PAHs from tar that are released into the environment can accumulate in aquatic sediments, posing a long-term environmental risk to aquatic organisms.

Although research has confirmed the presence of coal tar-contaminated roads in Auckland and Christchurch, Craig Depree, Programme Leader in Chemistry at NIWA, says the reality is that most New Zealand roads that were built before 1970, which have not subsequently been rebuilt, probably contain coal tar in the subsurface layers. 'So it's a very widespread problem, but the general awareness in New Zealand of the environmental, human health and safety issues associated with these coal tar roads is very low,' says Craig.

In Europe, limits have already been placed on how much coal tar-contaminated road materials can be recycled into asphalt, with all materials over the limit having to be disposed of in a landfill.

Craig says, 'In Europe, any reclaimed asphalt containing more than 0.1 percent coal tar is considered hazardous waste, and the European Asphalt Pavement Association has proposed that to be considered inert, bituminous mixtures must contain less than 25mg/kg of PAHs. With reported PAH concentrations of 1500 to 4000mg/kg in New Zealand road seal layers, there is clearly a need for national guidance on how to best manage tar-contaminated road materials.'

Seeking a solution

The research project provides a step in the right direction by investigating the feasibility of using in-situ foamed bitumen recycling to provide an economically sound, practical and environmentally responsible solution to the problem of coal tar-contaminated materials.

Carried out between 2007 and 2008, the project undertook a combination of laboratory and field stabilisation tests on a Christchurch street. Coal tar-contaminated road materials from the street were first stabilised with foamed bitumen, before being subjected to batch leaching tests. The leachates were then analysed for contaminants and toxicity.

Craig explains, 'Our project aims were two-fold. The first was to analyse the extent of the issues that related to tar-contaminated roads in New Zealand. The second was to trial in-situ foamed bitumen and cement stabilisation techniques, in order to immobilise the tar-derived PAHs in the recycled materials. Our hypothesis was that by including bitumen we would reduce leaching of the PAHs by encapsulating them in the mix and also by excluding water from contacting them.'

The in-situ recycler at work during the study stabilising the contaminated material.

Although not necessarily for the reasons proposed in the hypothesis, the trials found that, based on testing for contaminant leaching and toxicity, reusing stabilised tar-contaminated materials as road base materials represents a minimal risk to the environment.

With respect to the benefits offered by foamed bitumen stabilisation, Craig explains, 'Reusing the contaminated materials as road base limits its exposure, because it is capped beneath a waterproof seal layer and is beneath a road, which is not an environmentally significant location. In addition, the contaminated materials do not need to be excavated, transported and disposed of – all of which would expose staff to the PAHs. A final benefit is that when stabilised with foamed bitumen, the contaminated base course is compacted to a denser state than it would ever be compacted in a landfill site, which makes it less susceptible to leaching.'

The net effect is that there is no more risk to the environment from recycling tar-contaminated materials in this way than there would be from recycling conventional bitumen-only pavements. There is a limitation to this application when the pavement layers are relatively thin (eg <150mm) and there is no possibility of adding any make-up aggregate to increase the thickness.

Craig gives as an example the road base used in the trial, which following recycling had a particularly dusty surface. This was because of insufficient pavement thickness causing the sub-grade material to be incorporated into the stabilised layer. The dusty nature of the surface prevented good adhesion between the base and chipseal wearing course. As a result, the road surface had delaminated in places within nine months, exposing the road base and hence leading to the possibility for coal tar-contaminated materials to be lost to the environment through abrasion or erosion.

This is just one scenario, however, and there have been numerous other projects in and around Christchurch, and throughout the rest of the country, where the process has been carried out successfully.

Alternatives to in-situ foamed bitumen stabilisation for vulnerable streets are currently being investigated, so that the benefits of managing coal tar-contaminated road materials within the existing road can be realised without compromising the structural performance of the recycled pavement.

'The full test results are discussed in the report,' says Craig. 'We found that, despite the potential for failure in situations of very thin existing road construction layers, it is a good option to use foamed bitumen to stabilise the tar-contaminated materials within roads. Compared to the financial and environmental costs of transporting these materials to landfill, the reuse option offers substantial benefits.'

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Reconstruction of coal tar-contaminated roads by in-situ recycling using foamed bitumen stabilisation, Research report 388

Freely available online at *www.nzta.govt.nz/resources/research/reports/388*

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Adding accuracy to the modelling equation

Improving modelling of pavement response and performance was the purpose of an NZTA funded research project, which started off local, but ended up as an international affair.

Increasing the amount of recycled and marginal pavement materials that are used in building New Zealand roads is a key step towards achieving more sustainable use of natural resources. However, if these alternative resources are to be used successfully, there is a need for more reliable pavement response and performance modelling. This in turn depends on how accurately the contact stress distributions between tyres and road surfaces can be portrayed.

Robert Douglas of Golder Associates in Canada headed up a recent multi-agency project that sought to achieve just this. 'When we set out there was very little high-quality measured data available on the subject and this was limiting the modelling that could be done,' says Robert. 'So the project's goal became to find a way to accurately measure full-scale tyre–road contact stress distributions, in all three of the coordinate directions – vertical, longitudinal and transverse.'

Out of the purpose, four objectives emerged:

- Measure the contact stresses imposed by various types of tyres, inflation pressures and wheel configurations.
- Use the data in numerical models of pavement response.
- Use the data in analyses of pavement rutting.
- Support existing research into scuffing effects (this research relies on tyre forces as inputs).

Robert says, 'The challenge was, could we design, build and successfully run an apparatus from scratch to measure the contact stresses. When we started, I was based at the University of Canterbury, but then I shifted to my current position at Golder Associates. The project carried on regardless, with input from the university, the NZTA's CAPTIF facility and the Technische Universitaet Dresden in Germany.

'The great thing was that, despite the distances, we did successfully build and run our apparatus, with the pins made in Canada and the rest made and tested in New Zealand. As far as I know, there are only a handful of other apparatuses capable of making these measurements

A change in approach

Asphalt pavements have traditionally been designed using empirical design methods, with the types of materials used and the thicknesses of the different structural layers selected according to set design criteria.

However, in recent years, efforts have been increasing worldwide to develop mechanistic approaches. Such approaches evaluate the stresses and strains at critical points in the structure of the pavement. The theory is that knowing the values of these stresses and strains enables the pavement's service life to be estimated more accurately than is possible with the more traditional design approaches.

Acquiring reliable measurements for stresses and strains (from experimental investigations) is a prerequisite for any successful mechanistic pavement design. The traditional design approach has assumed a simple contact stress distribution, with a uniform vertical stress at the interface between the tyre and the pavement. This approach is acceptable for thicker asphalt pavements, but becomes inaccurate for pavements with thinner layers, such as those usually found on New Zealand roads.

In adopting a mechanistic approach to pavement design, it becomes crucial to be able to measure, and therefore know, how the actual tyre/road contact stresses are distributed, in order to accurately predict how the pavement will perform.

The apparatus designed to accurately measure tyre-road contact stress distributions.

in existence worldwide, so it was a significant achievement for international team work.'

The apparatus consists of 25 pins, each 5mm square, housed in a strong steel box that is mounted flush with the pavement. The pins protrude 1mm above the surface of the box and are arranged in a closely spaced row across the width of the intended tyre path. They are equipped with very sensitive semi-conductor strain gauges to measure the vertical, longitudinal and transverse contact forces that are imposed on them by tyres.

The tests

Load testing using the apparatus was carried out at the CAPTIF indoor testing facility in Christchurch. Two wheel types (single and dual), two wheel loads (40 and 50kN) and three inflation pressures (280, 550 and 690kPa) were used in the tests, with at least five passes of the wheel made for each combination of load and pressure.

Typical results obtained for the vertical pin loads agreed with results already seen in the literature from previous studies. However, longitudinal and transverse pin loads differed. 'We put these differences down to lateral tyre scuffing,' says Robert.

Pin load data from the testing was input into a pavement response model developed by the Technische Universitaet Dresden. Comparisons were then made to see if using the non-uniform contact stresses data from the pins gave different results (in terms of elastic pavement stresses, strain and displacements) than the results obtained by using a uniformly distributed pressure as the input loading (the usual approach).

Small but measurable differences were found. For example, vertical stresses at the top of the sub-grade, vertical strains in the base, and vertical surface displacements were all found to be greater for single tyres when the non-uniform contact stresses (derived from the pins) were used.

Where the difference between the uniform and non-uniform contact stresses did become significant was with respect to modelling for predicting rutting as part of pavement performance. For a typical New Zealand pavement, at the loadings used in the comparison, predicted rutting was approximately 25 percent greater at one million passes when the non-uniform contact stress data was input into the pavement performance model.

Robert says, 'From the contact stresses we measured, we were hoping to be able to identify the more benign combinations of tyre type, inflation and wheel configuration, in particular with respect to the thin seals and asphalt pavements commonly found in New Zealand. This wasn't possible, as the tyre scuffing effect confounded the results.

'We also didn't pursue the project's fourth objective, as carrying out research into the effects of tyre scuffing came to be seen as beyond the scope of the project. However, we did build a much clearer picture of what would be needed to properly conduct such research.'

The project's second and third objectives were achieved however, and Robert says that the results provided ample justification for using more realistic contact stresses in pavement response and performance models. 'The small differences we found when using non-uniform contact stresses in pavement response modelling translated into significant differences when then used for pavement performance modelling, which would of course impact on pavement design approaches.'

The project's report contains a full literature review, analysis of the test data and an explanation of the numerical modelling used. To support others pursuing similar research, the full set of data is publicly available at www.golder.com/Contact_Stress_Study.

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Tyre/road contact stresses measured and modelled in three coordinate directions
Research report 384

Freely available online at *www.nzta.govt.nz/resources/research/reports/384*

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Low-emission fuel-efficient light vehicles

Research report 391

TERNZ Ltd

Freely available online at
www.nzta.govt.nz/resources/research/reports/391
Hard copy $50.00

To help meet climate change commitments, there is a target to reduce the per-capita greenhouse gas (GHG) emissions from transport to half the 2007 levels by 2040. Light vehicles contribute 93 percent of the total kilometres travelled by the fleet in New Zealand, and about 81 percent of the GHG emissions.

This report reviews the range of light vehicles available today. It considers the fuel and engine technologies that are available currently or will become available in the near future. For each of these vehicle, fuel and engine technologies, the emissions and fuel efficiency performance is evaluated.

The transport demand for light vehicles is assessed, and a range of options for improving the fuel efficiency and emissions performance of the New Zealand light-vehicle fleet are considered.

Public transport network planning: a guide to best practice in NZ cities

Research report 396

Royal Melbourne Institute of Technology (RMIT), Australia

GAMUT Centre, University of Melbourne, Australia

Massey University, New Zealand

Institute of Transport Economics, Oslo, Norway

Freely available online at
www.nzta.govt.nz/resources/research/reports/396
Hard copy $35.00

This research explores the potential for the 'network-planning' approach to the design of public transport to improve patronage of public transport services in Auckland, Wellington and Christchurch. Network planning, which mimics the 'go-anywhere' convenience of the car by enabling passengers to transfer between services on a simple pattern of lines, has achieved impressive results in some European and North American cities, where patronage levels have grown considerably and public subsidies are used more efficiently.

Three overseas cities provided examples of best practice in public transport service design to compare with services in Auckland, Wellington and Christchurch. The comparisons revealed that New Zealand's three largest urban regions had considerable potential to build on the increases in public transport patronage and mode share that have been achieved during the last decade.

Current public transport operating practices in Auckland, Wellington and Christchurch were assessed and key areas were identified in which public transport planning could be improved, namely:

- A public institution is required to plan a network across the whole urban region, to let best value tenders for the delivery of part or all of this system, and to manage the political processes of change.
- Successful network operations require simple and direct lines, 'forget-the-timetable' frequency in key corridors, and marketing that targets new and occasional users.

Utilisation of the kerbside through-lane at signalised intersections

Research report 398

GHD Ltd

Traffic Engineering Solutions Ltd

Freely available online at
www.nzta.govt.nz/resources/research/reports/398
Hard copy $65.00

Lane under-utilisation is commonly experienced at signalised intersections. This has significant effects on intersection capacity, which has consequences for congestion, especially in the urban environment. Ultimately, this results in overly optimistic design predictions. Little research has been undertaken in New Zealand and Australia on this topic. The main focus of this study was to determine the effect of short kerbside through-lanes on utilisation.

The results of the study show a positive relationship between lane length and utilisation. However, it was not found to be a strong link. Increasing auxiliary lane length only resulted in minor improvements in lane utilisation. Based on the small sample analysed in this study, it is therefore concluded that increasing the total upstream and downstream length of the short kerbside through-lane is likely to result in only marginally higher rates of use for both two-laners and three-laners.

Low-cost alternative/improvement treatments have been suggested as a part of this study. Since a relatively small sample was studied, further research with a larger sample is recommended to further confirm these findings and measure the significance of the results. Further research will also enable the other causes of lane under-utilisation to be determined and measured.

Kilometres travelled and vehicle occupancy in urban areas: improving evaluation and monitoring

Research report 399

Capital Research Ltd

Pinnacle Research & Policy Ltd

Freely available online at
www.nzta.govt.nz/resources/research/reports/399
Hard copy $25.00

This report lays some foundations for improving how interventions (eg travel plans) are evaluated and monitored in cities. The main data source used is the New Zealand Household Travel Survey (HTS). Some census results on distances between home and work are a useful complement.

Distance travelled to work in main urban areas (ie urban areas with populations of 30,000 or more) is a major focus because these are the settings for the vast majority of travel plans. Because travel plan monitoring surveys typically estimate distances by assuming that workers take the quickest route from home to work, we checked on the extent to which actual routes taken are longer than the quickest route.

The report also analyses distances travelled to school in main urban areas. In particular, it provides HTS results that help to judge when distances collected by school travel plan surveys are implausibly long.

Vehicle occupancy is the report's final topic. Mean occupancy (per kilometre driven) in main urban areas was 1.54 and has not changed detectably since the 1997/98 HTS.

Minimising traffic delays during resealing

Research report 400

Opus Central Laboratories

Fulton Hogan

Freely available online at
www.nzta.govt.nz/resources/research/reports/400
Hard copy $35.00

This research demonstrated that:

- racked-in seals can handle the stress of high-volume traffic
- racked-in seals can be constructed in an eight-hour working period including any sweeping and road marking
- closely controlled chip application rates result in minimal loose chip on surface
- minimal loose chip results in minimal chip being flicked by vehicle tyres
- speed restrictions can be lifted to 50–70km/h at the completion of the line marking
- unrestricted traffic can be placed on the seal the morning after resealing.

The requirement for a newly sealed chipseal road to be opened to traffic speeds of at least 70km/h for peak evening traffic could be included in the construction specifications. This would help minimise motorists' frustration at the traffic delays caused by road sealing.

Implementation of the review of the NZTA Research Programme

All information about the implementation of the review of the NZTA Research Programme including the 2010/12 transitional Research Programme are posted on NZTA's website at www.nzta.govt.nz/resources/research/funding-process.html

NZTA research

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NZTA research is published quarterly by the NZ Transport Agency. Its purpose is to report the results of research funded through the NZTA Research Programme, to act as a forum for passing on national and international information, and to aid collaboration between all those involved. For information about the NZTA Research Programme, see www.nzta.govt.nz/resources/research/index.html.

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