Relative costs and benefits of modal transport solutions

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Abbreviations and acronyms

ARTA	Auckland Regional Transport Authority
BQP	Bus quality partnership
BRT	Bus rapid transit (system)
CBD	Central business district
EEM	NZTA's *Economic evaluation manual 2009: volume 2*
HOT	High-occupancy toll (lane)
HOV	High-occupancy vehicle
LRT	Light rail
NCT	Nottingham City Transport
NET	Nottingham Express Transit
NZTA	NZ Transport Agency

Contents

Executive summary

This report describes the outcomes of a study commissioned by the NZ Transport Agency (NZTA) to inform local authorities about the costs and benefits of transport modes. The aim of the study has been to provide general advice on the relative cost and benefits of alternatives with a focus on passenger transport in urban areas.

The report looks at issues decision makers face in estimating costs and sets out an approach to providing estimates. This approach provides parameter values such as cost per vehicle kilometre, which can then be applied to the number of vehicles and the distance they travel, so readers may tailor comparisons to their own situation.

Tables of quantitative estimates of cost and benefit parameters are provided (where possible). The issues and assumptions required to produce estimates and implications of differences across the modes are discussed. Appendices provide more detailed discussion. The tables cover:

- **public transport provision,** with information about the running costs associated with three types of public transport services: bus, light rail and heavy rail
- **traveller cost and benefits,** in terms of the cost per passenger kilometre for each mode. From a traveller's perspective, the findings show that costs per kilometre for car and taxi are relatively high, as is walking (due to the value of the time required), but in contrast bicycle and bus travel are relatively low cost
- **community impacts of transport,** with estimates of the monetary values of the impacts of transport on the community in general (including users of other transport modes). Findings show that active modes of walking and cycling have a net community benefit per kilometre due to a lighter burden on the public health system
- **transport infrastructure provision,** with the aim of giving some indication of the relative costs of providing infrastructure for each of the modes in the study. Infrastructure comes at significant costs including land acquisition, below rail/road/path building, surfacing, and stations and stops. Actual costs of infrastructure provision vary drastically according to the location and landscape of construction activities.

This information is then augmented by various perspectives from literature and international experience on some contextual issues, which affect, or are affected by, the cost and benefits of transport. The aim of this discussion is to evaluate these perspectives in a way that is relevant to local authorities when considering modal transport options. Relevant issues are discussed under three broad topic headings:

1 drivers of the transport mix

2 the relationship between land-use and transport planning

3 road space and traffic management.

Example case studies then illustrate some of the issues presented. The first three studies describe New Zealand cases and the fourth is from Nottingham in England.

1 Public transport in Christchurch, a large city with a very high level of car usage and consequent congestion. Improvements in bus service quality have doubled the bus mode from 3% to 6% of trips. It highlights:

   a strong partnerships between the organisations overseeing and operating services with improved service features and infrastructure provision

   b the car trips avoided by providing better alternatives represent significant benefits in limiting congestion growth and the environmental impacts of extra traffic.

2. Cycling provision in Hawke's Bay, a region which is home to a dispersed urban population with bicycle transport rather than public transport use providing the main alternative to a car. The environment is suited to cycling but safety concerns are a deterrent. Thus a cycling strategy has:

   a promoted safety through education and enforcement and developed an extensive network of on-road and off-road routes

   b required only modest expenditure for both networks with the cost of provision for travel by this means being considerably lower than the provision of extra roads or public transport.

3. Sharing the road in Auckland, New Zealand's largest city, which faces increasing traffic congestion. Both the terrain and the city infrastructure limit opportunities for building extra roads so there is considerable incentive for making optimum use of available road space:

   a the Northern Busway, a bus rapid transit system, shares the road space with State Highway 1 and carries twice the maximum number of car commuters able to use one lane of adjacent motorway

   b the Bus Rapid Transit system is a particularly cost-effective solution as it improves the productivity of the current investment in road space and saves on future investment while providing environmental benefits from and equity benefits in access from outer areas.

4. Public transport success in Nottingham, with some 667,000 people in its urban area, shows sustained growth in public transport at low cost to government:

   a cooperation between local authorities and operators has been key, as has the emphasis by public transport operators on quality not price

   b better service has stimulated demand for public transport with a 34% market share on key corridors and due to good patronage, 97% of bus services need no direct subsidy.

In concluding the report the influences on transport mode choices and the usefulness of benefit and cost assessment in comparing suitability of modes for local context is reviewed with reference to case study findings. The key messages are that:

- 'one size does not fit all'; the best mode choice depends on local conditions
- 'right moding' provides a transport mix to cater for travel needs now within a context of economic, environmental and social sustainability for the future.

Abstract

This report describes the outcomes of a study commissioned by the NZ Transport Agency to inform local authorities about the costs and benefits of transport modes. The aim of the study has been to provide general advice on the relative cost and benefits of alternatives with a focus on passenger transport in urban areas.

The report looks at issues decision makers face in estimating costs, and sets out an approach to providing estimates. This approach provides parameter values such as cost per vehicle kilometre, which can then be applied to the number of vehicles and the distance they travel, so readers may tailor comparisons to their own situation.

This quantitative exercise is supplemented by contextual discussion of some important issues in urban transport including drivers of the transport mix, the relationship between land use and transport planning, and road space and traffic management. A selection of case studies drawn from mainly New Zealand urban areas provides some specific illustrations of the issues raised.

1 Introduction

1.1 Study context

Section summary

The purpose of the study is to inform local authorities about costs and benefits of transport modes.

Key messages

General advice is provided on the relative cost and benefits of alternatives.

The focus is on passenger transport in urban areas.

New Zealand's local authorities are frequently faced with decisions on the best allocation of funding to meet the transport needs of their regions. While there is a significant amount of information on this issue, it may not be accessible or suited to a non-technical audience. Moreover it may sometimes offer conflicting advice. The NZ Transport Agency (NZTA) therefore commissioned GHD to undertake a research study to provide some general advice on the relative cost and benefits of alternative transport modes.

To provide information that is sufficiently detailed to be of value, but sufficiently succinct to be easily read, the study confined its consideration to the particularly important topic of provision of passenger transport in urban areas.

The study reviews the cost and benefits of transport provision for:

- active transport modes: walking, cycling
- public transport modes: bus, light rail, heavy rail, taxi
- private cars.

These are considered from the viewpoints of:

- service providers (as distinct from providing the infrastructure itself)
- travellers using each mode
- the community as a whole
- fixed infrastructure providers.

Indicative values to assist cost and benefit calculation in local contexts are provided.

To support the discussion, some contextual issues, which affect, or are affected by, the cost and benefits of transport are discussed. They are then illustrated by four case studies.

The first three cases address transport provision in New Zealand. The fourth study is from Nottingham in the United Kingdom and provides a good example of the provision of good public transport with only modest subsidies.

1.2 Providing relative modal costs and benefits

Section summary

Issues decision makers face in estimating costs and benefits of alternative modes are discussed and an approach to providing estimates is explained.

Key messages

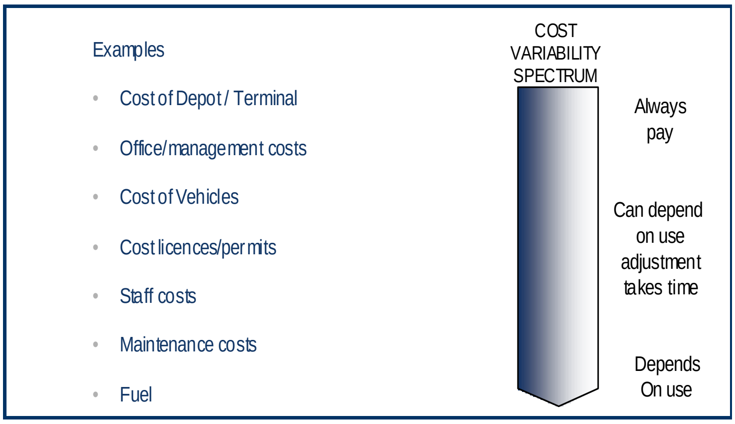
Costs and benefits are context specific.

Parameter values such as cost per vehicle kilometre can be estimated and then applied when the number of vehicles and the distance they will travel is known.

For assessment purposes costs need to be sorted by type, then quantified and finally, where appropriate, distributed between modes. Where there are benefits of transport by a mode, these benefits can be considered as negative costs, hence lowering the net cost per kilometre.

Type of cost: Costs can be fixed (those costs that are independent of the amount of travel, eg vehicle purchase) or variable (those costs that are dependent on usage or vehicle distance travelled, eg fuel). Their category helps determine how they are used but the distinction between fixed and variable costs is not always clear cut as the figure below shows. Where we attempt to calculate, say, a cost per kilometre of travel, it is necessary to split fixed costs over a number of annual kilometres in order to make these costs comparable with variable costs.

Figure 1.1 Variability of costs in public transport provision



This cost spectrum varies from mode to mode.

For example, about 70%[1] of bus costs can be considered variable, since extra distances require extra buses and drivers, adding significant costs.

At the same time, simply adding one extra passenger can impose close to zero additional costs.

Comparing like with like: The easiest way to compare impacts of different modes is to express them in dollars (monetisation). In some cases, such as the costs of employing a station attendant for one hour, costs are already measured in dollar terms and monetisation is simple. In other instances impacts may be challenging to quantify and more even more difficult to monetise. For example, while it is relatively simple to estimate the amount of emissions from motor vehicle tail pipes, quantification

[1] Source: Advice from bus operators

requires estimation of the numbers of people whose health is affected and monetisation requires putting a dollar value on illness and death.

Distributing shared costs: For example, where infrastructure is shared, such as roads for buses and private cars, the costs of road provision and maintenance need to be split between car and bus.

Context specific costs: However the major challenge in providing modal costs in any locality is that costs depend on the specific transport situation in that particular urban area. Land prices or terrain for infrastructure, numbers of passengers to share the cost, or numbers of vehicles needed to provide the service, may all vary dramatically between regions.

Cost parameters to costs: In view of context variations, single average cost values are not useful for local authorities to apply to their local situation. Instead the approach in this study is to find cost parameters and use them to establish costs by multiplication to values in the situation under consideration. For example, the estimated parameter 'dollars per vehicle kilometre' can be applied, when the number of vehicles and the distance they will travel is known, to give total cost. The process is further explained in appendix A.

We note that these are indicative values only. They are intended for initial 'back of the envelope' comparison of the relative cost and benefits or modes. They cannot be guaranteed as suitable for use in formal project cost-benefit assessment.

Where possible, the estimates provided in the next chapter are representative of a value that may apply in a New Zealand context.

2 Cost-benefit parameter estimation

2.1 Public transport provision

Section summary

This section provides information about the running costs associated with three types of public transport services: bus, light rail and heavy rail.

Key messages

Staffing costs of running public transport services are generally a greater expense than fuel costs.

While individual buses tend to have lower capacities, they are less expensive than light rail and heavy rail trains.

The first perspective of costs and benefits is that of an operator of public transport. While in many instances the actual operation of these services will be by private operators, a local authority is typically responsible for the funding of any operating shortfall or in paying the service contractor for provision. The costs and benefits accruing to individual travellers are explored in section 2.2.

Public transport operating cost estimates are of most use if measured in dollars per vehicle kilometres. This allows the reader to apply these factors to the actual (or proposed) service coverage in their area to establish the costs of the service.

There are two impediments to establishing reliable estimates:

- differing operating conditions and vehicles that prevail in each public transport area
- lack of adequate data (such as running costs and vehicle kilometres travelled) to make estimates.

Here, estimates have been gathered from publicly available information, consultant estimates and market prices for variables such as average energy usage per kilometre, staff wages, driving speeds and lifetime kilometres travelled by vehicles. Adequate public information about the operating costs of transport provision is generally difficult to find since it can either be commercially sensitive or lacking detail.

Within these limitations the values in table 2.1 show some relative sizes of the expenditures expected from operating each of the modes of public transport in New Zealand.

Table 2.1 Operating cost parameters for New Zealand public transport modes

2009 NZ$/vehicle km	Running costs			Vehicle purchase/lease	Total costs
	Fuel/ energy	Staff	Insurance and registration		
Bus	0.37	0.95	0.26	0.84	2.42
Light rail	0.28	0.95	0.26	3.34	4.84
Heavy rail	0.66	0.74	0.52	3.14	5.06

Source: White, P (2008, p60); Kenworthy, J (2003, table 4); ESAA (2009); public transport operators' websites; GHD internal estimates of insurance costs, various procurement notices for estimates of vehicle purchase costs and lifetime distances

Estimates of costs per vehicle kilometre show that diesel buses (typically with capacities of around 50 passengers) have running costs similar to those of rail vehicles (typically with capacities over 100 passengers). The 'whole of life' costs of acquiring a vehicle can be incorporated by spreading the purchase price of the vehicle over estimated total lifetime kilometres. These whole-of-life costs per kilometre are substantially higher for light and heavy rail than for bus.

It is possible to estimate fare revenues for each vehicle's operation, which (in combination with the cost information) would give an indication of the level of operating subsidy required to break even. However, such an exercise requires assumptions about the number of fare-paying passengers expected by mode, which is obviously context specific. As a guide, however, if each rail vehicle carries around twice the number of passengers than a bus does then the higher fare revenues are likely to make up for the higher costs per rail vehicle. From this perspective, operating shortfalls are likely to be lower where the public transport is appropriate to the level of patronage on a specific route.

There is usually little difference between the financial benefits of revenues from fares on different public transport modes and theses benefits seldom exceed costs.

2.2 Traveller cost and benefits

Section summary

The costs and benefits for individual travellers when taking a given mode of transport are now considered. This perspective is relevant since transport provision needs to ensure the availability of transport services for people on all levels of income to enable everyone to gain access to necessary services and opportunities.

Key messages

From a traveller's perspective, costs per kilometre for car and taxi are relatively high, as is walking (due to the value of the time required).

In contrast bicycle and bus travel are relatively low cost.

It is assumed that the mobility and accessibility benefits per kilometre of transport are the same across each mode. These benefits are therefore not considered in the comparison. Other benefits, such as health benefits, do differ by mode and are included in this comparison as negative costs.

The challenge from the perspective of a traveller is to convert all the relevant costs into a monetary cost per kilometre for that individual. This is necessarily context specific to some extent, and hence reliant on assumptions.

Several types of costs are unique to specific modes. For example, it is only for private cars that users incur parking charges, whereas only public transport users explicitly pay fares. These fares can be thought of as a substitute for having to pay for the vehicle, fuel, insurance and registration costs that are associated with private (car) transport. Parking charges vary much more than fares. In most suburban areas parking at home is free of charge as is parking in business or industrial areas. Travellers pay indirectly for the extra land needed for parking at home and few recognise the cost. However, parking charges in central business districts at levels such as $29 per day in Auckland can deter car travellers and provide local authorities with an opportunity to ration scarce road space in the city.

Some non-monetary costs are also included in the table of costs and benefits. These values attempt to approximate the costs (and benefits) associated with the physical and psychological experience of using the mode of transport to travel one kilometre. These include health benefits, which can be calculated from the extra health costs that are avoided by taking that mode of transport. The active modes (walk/cycle) have high (negative) values for this measure since their use is associated with reduced risk of cardio-vascular diseases and diabetes. Accident risks attempt to measure the likelihood, severity and medical cost associated with travel by a given mode. Finally, 'time' costs associated with each mode account for the fact that people place value on their time. Slower modes are associated with higher time costs. Similarly, modes that typically take longer to reach (or to wait for) are associated with higher time costs per kilometre.

Other costs included in the table are crime risks, which (qualitatively) capture the risk to the transport user of facing a personal attack or theft while travelling (a 'C' rating signifies a greater level of risk than 'c' and 'CC' yet greater risk). Other possible impacts on the traveller experience are also described. These impacts include exposure to weather, traffic congestion or crowded conditions.

In addition to the benefits per passenger kilometre of travel shown in the table the faster modes, especially car and train, offer benefits of access to a wider range of activities, people and places. The transport private modes, walk, bicycle and car also offer the traveller the benefits of time and destination flexibility with transport available 'on demand' to go to a chosen destination or to pick up or deliver passengers.

Car travel also provides travellers with the opportunity to carry luggage and equipment for work or family needs. This benefit can have a significant influence on mode choice. Thus, an option such as home delivery of shopping may need to form part of plans to encourage public transport use.

Table 2.2 Traveller cost and benefit parameters

	Costs paid each trip			Annual costs		Cost of time			Cost of risks			Other impacts	Total
Costs/ passenger km (2009 NZ$)	**Fare**	**Fuel**	**Park-ing**	**Vehicle purchase/ lease/ service**	**Insur-ance/ regist-ration**	**Travel time (in vehicle)**	**Wait time**	**Access time**	**Health**	**Acci-dent risk**	**Crime risk**	**Descriptions**	**Quantifiable costs only**
Walk	0	0	0	0	0	3.62	0	0	-1.1	0.49	CC	Exposure to weather/contact with community	3.01
Bicycle	0	0	0	0.19	0	1.14	0	0.07	-0.54	0.33	C	Exposure to weather/pleasure from cycling	1.19
Bus	0.34	0	0	0	0	0.94	0.17	0.09	0	0.01	C	Traffic congestion experienced/exposure to weather	1.55
Light rail	0.34	0	0	0	0	0.91	0.11	0.09	0	0.01	C	Crowded carriages/exposure to weather	1.46
Heavy rail	0.25	0	0	0	0	0.59	0.11	0.15	0	0.01	C	Crowded stations/carriages	1.11
Taxi	2.55	0	0	0	0	0.68	0.04	0.04	0	0.06	c	Benefit for disabled/elderly	3.37
Private car	0	0.18	0.67	0.42	0.09	0.68	0.05	0.07	0	0.06	c	Traffic congestion experienced/separation from crowds	2.22

Source: Public transport operators' websites; NZ Household Travel Survey (1997/8); NZAA (2009); private parking operators' websites; VTPI (2009, table 5.3.7–1); GHD estimates and assumptions

Note: Health impacts for walk and bicycle are negative costs because each kilometre of use tends to reduce public health costs, ie they are a benefit to the traveller.

Table 2.2 shows relatively high costs per kilometre for walking, car and taxi modes. Travel time costs account for the majority of the costs of walkers, while fare costs dominate the cost of taxi travel. The lowest costs estimated per kilometre are for heavy rail and bicycle travel. For bicycles, the high accident costs and travel time are somewhat offset by the estimated health benefits due to exercise, while the long-distance nature of heavy urban rail tends to yield low travel times and relatively low fares per kilometre. The relatively low costs of all public transport modes apply if the traveller undertakes journeys with origins and destinations within five minutes' walk of a regular service. If this does not hold, the extra cost of accessing and leaving the station or stop by walking or by private transport needs to be considered and may affect modal decision making.

The quantifiable costs for car travel per kilometre are around twice those of bicycle and rail travel. However – as with estimates of all mode costs – these cost estimates are dependent upon the assumptions chosen. The challenge of this exercise is to turn fixed costs (such as car purchase or registration) and variable costs (ie those associated with one additional kilometre of travel) into a single average cost. This can be an important point because once a person has a car, the cost of making one extra trip is very low compared with the average cost estimated here. In fact, the more kilometres travelled, the lower a car's average cost will be as registration and purchase costs are spread across more and more kilometres. The basis of our assumption on average vehicle kilometres travelled was the New Zealand Automobile Association which quotes an annual distance travelled of 14,000 kilometres.

2.3 Community impacts of transport

Section summary

The monetary values of the impacts of transport on the community in general (including users of other transport modes) are estimated.

Key messages

Active modes of walking and cycling have a net community benefit per kilometre due to a lighter burden on the public health system.

Total community costs of each kilometre travelled by cars were estimated at between three and six times lower than those of a public transport vehicle.

However, when public transport services are well used, the costs per passenger are far lower than the equivalent costs per passenger in cars.

Community costs and benefits, sometimes called 'externalities', are measured per kilometre travelled by vehicles for each mode (taxi and private car are considered to have the same impacts and are combined here). These are not costs per passenger kilometre, but costs per vehicle kilometre; for example, it is the cost of one bus travelling one kilometre, rather than one bus passenger travelling one kilometre.

Advocates of public transport often base their arguments on the low levels of community costs imposed by public transport compared with car travel. However, such studies necessarily make assumptions about the number of passengers using the public transport service (the occupancy) and the number of people in each car. Costs per passenger are heavily dependent upon this assumption about occupancy. This study measures costs by vehicle kilometre because costs are imposed by the service running, even if empty (the slight impacts of loadings on cost are ignored here). This allows the reader to estimate average costs per passenger by applying occupancies relevant to the local situation.

The types of costs included in this analysis are:

- *Crash costs*: while many of the costs of crashes are borne by the users of the same mode (eg insurance covering damages and lost income), there are some costs that are borne by other modes or society in general, such as emergency responses, uncompensated damages, lost income and grief. Bicycle and walk modes are capable of causing externalities by forcing motorists to swerve to avoid them which can result in a crash.
- *Noise pollution costs*: the external component of noise pollution is from the noise and vibration of the engine or tyre and road noises.
- *Local air pollution costs*: costs on society from local air pollution stems from emissions from the exhaust pipe of motor vehicles. These can have effects on human health and local ecological systems.
- *Greenhouse gas emissions*: emissions of gases such as CO_2 and methane contribute to climate change and its expected economic and social costs.
- *Severance*: where traffic causes a physical barrier (eg a busy road) there are cost delays and difficulties that fall on users of other modes. High values would be expected from (heavy) railways, while on-street buses and light rail can be easier for pedestrians to pass.
- *Health impacts*: when people use active modes (cycling, walking, etc) there are benefits to the user's health which lowers the likelihood of heart disease and other causes of premature death. Since users do not 'internalise' all of the benefits associated with avoiding premature death or hospitalisation (due to 'external' grieving or the provision of public health care), there are some components of the health impacts that are considered external.
- *Upstream and downstream costs*: external costs are also associated with the processes undertaken at various stages in transport provision. For example, energy production before fuel is combusted, production and disposal of vehicles, and infrastructure renewal and construction.
- *Place making*: in urban areas, the transport uses of a public space can influence how pleasant it is to be in that space. The use by pedestrians of a market place may bring intangible but real benefits to people in the neighbourhood. There are likely to be some similar benefits, although smaller, from other modes such as cycling and light rail. Place-making benefits are estimated qualitatively from 'B' (small benefit) to 'BBB' (large benefit).

For costs such as crashes, the quantification and monetisation is not just complex, but involves some potentially uncomfortable assumptions, such as the dollar value of a life or suffering. When interpreting the information in table 2.3, it is important to keep the values in perspective since single estimates of such values are liable to vary significantly under different assumptions and contexts. Ranges of these values and references are provided in appendix B. (Note: values in the table compare one bus vehicle with one car with one light rail vehicle etc, in contrast with the per passenger values in table 2.2.)

Table 2.3 Community cost and benefit parameters

Cost / vehicle km (2009 $NZ)	Accidents	Noise	Air pollution	Greenhouse gases	Severance	Health impacts*	Upstream / downstream impacts	Place making	Total (quantifiable costs only)
Walk	0.003	0	0	0	0	-1.054	0.002	BBB	**-1.049**
Bicycle	0.003	0	0	0	0	-0.527	0.005	B	**-0.519**
Bus	0.316	0.022	0.237	0.109	0.017	0	0.157	-	**0.858**
Light rail	0.158	0.034	0.066	0.067	0.034	0	0.188	B	**0.547**
Heavy rail	0.158	0.068	0.131	0.1	0.101	0	0.204	B	**0.762**
Car	0.066	0.007	0.023	0.019	0.005	0	0.03	C **	**0.15**
Source: Austroads (2008, table 3.1); MoT et al (2005, tables B12.4, B12.5); NZTA (2009a, pp3–18); VTPI (2009, chs 5.3, 5.10); GHD assumptions									

*Health impacts for walk and bicycle are negative costs because each kilometre of use tends to reduce public health costs, ie they are a benefit.

** While car traffic may make streetscapes unpleasant and impose a cost rather than confer a benefit in place making, widespread availability of car travel may provide community benefits such as opportunities for children and adults to access and participate in a wider range of sporting and cultural activities.

In contrast with the benefits of community cohesion provided by access to a car, some European studies have estimated the cost of social exclusion for those without access to a car in car-dependent communities. These costs are likely to be less in New Zealand, which has a high level of car availability, but still apply to those too young or too old to drive or who are unable to do so because of health or disability reasons. Dodson et al (2004) provides more detail.

Note: Taxi is not considered separately to car here, as the impacts per vehicle kilometre are the same whether a car is used as a taxi or privately.

The costs and benefits presented in table 2.3 show that active modes have a net community benefit per kilometre due to a lighter burden on the public health system. The highest external impacts per vehicle kilometre are from public transport vehicles. Of these, diesel buses are estimated to have the greatest community costs due to their emissions, which take place in populated areas, whereas electricity-run light and heavy rail tend to produce emissions at the point of electricity production (or none if power is generated from renewable sources).

The impact of car kilometres is dominated by the crash costs borne by the community through the public health system. The total community costs of each kilometre travelled by cars were estimated at between three and six times lower than those of a public transport vehicle. Where the public transport services are only lightly utilised, these costs per passenger can be similar to those of car users; however, where a bus service runs with say 20 to 40 passengers, the external costs per passenger in the bus are likely to be only a small fraction of the car driver's. To illustrate by using these cost estimates, if a car carries just a driver (occupancy of one), while a bus carries six passengers, the external costs of each vehicle per passenger are approximately equal ($0.858/6 ≈ $0.15); every bus passenger in excess of six will divide the vehicle's costs by even more, making the cost per passenger lower and lower. Conversely, a car with an occupancy of four will have similar costs per passenger kilometre as a bus with 23 passengers.

2.4 Transport infrastructure provision

Section summary

The provision of transport infrastructure comes at significant cost for transport providers. Such costs include land acquisition, below rail/road/path building, surfacing, and stations and stops. This section aims to give some indication of the relative costs of providing this infrastructure for each of the modes in this study.

Key messages

Actual costs of infrastructure provision vary drastically according to the location and landscape of construction activities.

Upfront construction costs for light and heavy rail are much higher than for road; however, over the longer useful life of rail infrastructure, these costs tend to be more comparable.

In previous sections, the study attempted to provide quantified indicative values of costs and benefits. While it has been acknowledged that such values are subject to significant variability around these estimates, the values still give some broad guide to the ultimate values facing a local authority or the community. In the case of building and maintaining infrastructure, this study attempted the task of providing similar dollar values for the costs of providing a kilometre of road, rail, footpath, etc but it was ultimately decided that this was likely to be more misleading than helpful for decision makers.

The two key reasons for this decision were:

- the lack of sufficiently detailed information for costing of specific components of construction costs
- the sheer variability in unit construction costs as a result of drastically differing construction environments.

Ideally, 'per lane (or track) kilometre' costs would be estimated for the following components of urban transport infrastructure provision:

- construction or surfacing (ie bitumen or rail/sleepers)
- land acquisition
- signalling and signage
- stations, stops, shelters and interchanges
- parking, stabling and depots
- annual maintenance.

The costs associated with building urban transport infrastructure vary enormously according to the location and landscape. For instance, 10,000m^2 of land required for one kilometre of road in Auckland's central business district (CBD) would cost several hundred or thousand times more than a similar stretch of road in the outskirts of Wanganui. Similarly, the cost of building one kilometre of railway along a flat and straight parcel of land would be a tiny fraction of that required to construct adequate earthworks, bridgework and tunnelling to join Wellington's CBD with nearby Kelburn by rail.

In light of this issue, this study provides a qualitative indication of the relative costs associated with the infrastructure for each mode based on the assumption that each would be built along the same corridor, and hence with similarly challenging characteristics (see table 2.4). The rating 'c' indicates relatively low cost, 'C' higher and 'CCC' highest. Appendix B (Community impacts of transport, p61) provides a numerical example from Queensland to illustrate the potential magnitude of these costs.

Table 2.4 Qualitative estimates of parameter costs for infrastructure

Cost per lane or track km (2009 NZ$)	Upfront constructio n of lane/track	Whole-of-life constructio n of lane/track	Land cost	Signals / signage	Stations, interchang e stops, shelters	Parking / depots/ stablin g	Maintenanc e
Walk	c	c	C	C	-	-	c
Bicycle	c	c	CC	C	-	c	C
Bus	C	C	CCC	CC	C	C	CC
Light rail	CC	C	CCC	CC	CC	C	CC
Heavy rail	CCC	C	CCC	CC	CC	C	CCC
Car	C	C	CCC	CC	-	CCC	CC
Source: Parsons Brinkerhoff (2004); NZTA (2009b); ATC (2006, table 1.5.4); GHD assumptions							

Within each cost category, we can compare costs for the provision of infrastructure for each mode. Because the qualitative values cannot be added together, it is difficult to draw firm conclusions about overall costs of each mode's infrastructure. Despite this, it is clear that the 'per kilometre' costs of walking and cycling facilities are the lowest of all the urban modes.

The table assumes that buses will be provided with a dedicated busway or bus lane, which would require similar construction, land, signage and maintenance costs per lane kilometre as lanes for car use. A major difference in infrastructure costs between bus and car is that cars require parking provision at both origins and destinations (often in expensive prime locations), while buses require bus stops, interchanges and depots for overnight vehicle storage. Historically, bus depots have tended to be located in central areas for logistical simplicity, but it may be possible to achieve lower depot costs if located in lower cost areas. Bus stops tend to be located every 400 –500m and can vary dramatically in cost and complexity.

Light and heavy rail have the highest construction costs per track kilometre in urban settings. However, each of these modes has a much higher potential passenger capacity in the same space. For instance, the Auckland Regional Transport Authority (ARTA 2006, p6) cites figures that suggest that rail capacities are up to 25,000 people per hour in a 4–5m corridor, compared with 2400 people for cars. These rail capacities are also significantly higher than those of busways (12,000 per hour). Heavy and light rail stops are typically more expensive than bus stops, with more facilities and information, and are estimated as being more expensive per lane kilometre.

In considering investment in roads, solutions can also be dependent on the existence of an explicit or implicit road user hierarchy to guide local authority decisions regarding infrastructure provision. Road user hierarchies recognise that most roads are required to accommodate a range of users, The hierarchies aim to assist the decision maker in balancing the needs of different users. Hierarchies are usually framed around supporting a particular outcome, for example, economic growth or community equity. This is discussed further in section 3.3.

In addition, relative cost and benefits of infrastructure provision may change when viewed from a whole-of-life perspective. The infrastructure associated with light and heavy rail tends to last in the order of 100 years, compared with say 40 years for road infrastructure. Therefore, the higher upfront investment costs associated with rail when considered over the life of the asset are comparable to road costs.

While the costs and benefits of alternative transport modes are extremely important in determining good transport options, they need to be considered in the context of a range of other issues that influence transport choices both for the local authorities who supply transport and the communities who use it. The next chapter presents some of those considerations discussing local and international perspectives on the drivers of the transport mix, interaction between transport and land use, and road space issues.

3 Transport mode contexts

Chapter summary

This chapter outlines various perspectives from literature and international experience on the topics of the drivers of the transport mix, the relationship between land use and transport planning plus road space and traffic management.

The aim of this discussion is to evaluate these perspectives in a way that is relevant to a local authority audience when considering modal transport options. It aims to augment the tables that are presented in the earlier sections of this report, to expand considerations from those that can be monetised as costs and benefits to those that will affect the success of the modal decision.

3.1 Drivers of the transport mix

3.1.1 Supply and demand

All societies from pre-historic times to the present day have experienced a very similar set of drivers for their transport mix. These drivers can be considered either demand or supply factors.

Demand side factors include:

- the need or desire to get to other places to see other people or move goods
- distance between where people are and where they need to go
- time available for travel
- private income and general economic conditions
- individual tastes and societal customs

Supply side factors include:

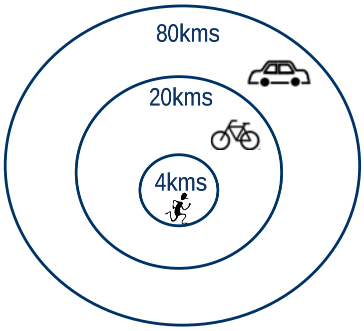
- availability of means of transport (from horses to jumbo jets)
- availability of routes
- price of transport and speed of transport
- regulations and requirements of authorities.

The pull of demand and the push of supply factors interact and there is a large amount of literature considering their various influences. Here we consider three particular sets of influences on the transport mix in New Zealand’s urban areas.

3.1.2 Technologies

Until early in the 19th century, domestic transport in New Zealand towns was by foot, horse or wagon. Then in rapid succession new transport technologies began appearing: first bicycles and trains, then trams, buses, trucks and cars. These changes both increased the distance that people could travel and increased the numbers of people who could travel at affordable prices at first by public transport in trains, trams and buses and later by private car.

Figure 3.1 Travel in an hour



Road construction technologies advanced at the same time in both pavements and structures. In particular, large-scale construction equipment meant that roads and bridges could be built more quickly. This was particularly attractive to local authorities in the mid-20th century when they were catering to the increased ability to travel, which in turn led to changes where people lived and worked.

Improvement in automobile technologies led to cheaper cars, which combined with newly available sealed roads and greater distances to travel, led to the growth in private motor vehicle travel. By the end of the 20th century, this growth had resulted in traffic congestion in many urban areas. Trips by car in peak periods could be slower than trips by bicycle. Limitations on land availability, the cost of road building and greater understanding of the current cost of road transport on society, as discussed in chapter 3, have led road authorities to look for ways to manage demand for road transport and reduce its impacts.

Some people hoped that information communication technologies (ICT) might reduce the need for travel. However, evidence shows that travel increased as people had the opportunity to contact others further afield and hence increased demand to trade with or visit them. However ICT in intelligent transport systems can reduce car travel indirectly by improving public transport service with real-time information about services and convenient integrated ticketing systems. It can also reduce car travel directly by providing the technology required for efficient road pricing. While tolling and cordon or entry charges do not necessarily require technology, the availability of automated systems means their application is now an issue of policy rather than technology.

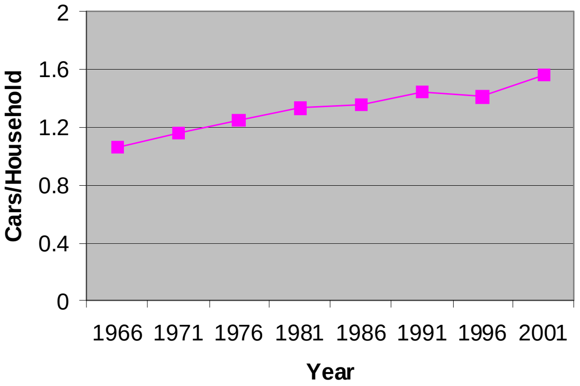
3.1.3 The impact of government policies and regulations

Government initiatives and support for particular modes have shaped the transport mix in New Zealand quite dramatically as the following examples show:

- *Legislation:* in the 1920s New Zealand passed legislation to protect tram systems from competing services by bus and thus maintained greater demand for tram services than may have otherwise been the case, particularly on popular routes.
- *Urban planning:* the period from the 1950s to the 1970s saw the development of master plans for New Zealand's urban motorways which effectively moved the dominant urban transport modes from public transport (trams and buses) to more road-based private transport solutions.
- *Funding and budgetary considerations*: the 1960s saw lower funding for public transport initiatives, although strongly advocated for, as patronage was falling during the period. Without reinvestment in mass transit systems such as rail, service levels and patronage continued to fall, creating a larger operating shortfall from these services.

- *International trade policy*: the removal of tariffs on imports led to reduced car prices and much greater import of second-hand cars. Coupled with privatisation initiatives in public transport, the greater affordability of new and second-hand cars effectively reinforced the dominance of private vehicles.

Figure 3.2 Cars per household in New Zealand 1966–2001



- *Fare policies*: petroleum prices rose steeply over 1973–79 and restrictions on use applied. Since people's choice of transport modes depends on relative 'generalised cost' – made up predominantly of fares and cost of time – public transport use might have been expected to rise. However it did not because bus fares also rose steeply during this period.

Thus the rapid growth in car ownership has been assisted by supportive policies; however, the growth in car use can itself be a major factor in promoting further growth in car use.

3.1.4 Societal influences and preferences

Growth in incomes and wealth is an obvious influence on increasing car ownership, but indications are that a major motivator for increased car purchase by New Zealand families has been additional opportunities for social and recreational travel to destinations that could not easily be reached by public transport. Car availability has led to growth of leisure activities requiring cars. For example, children are now driven across the city to 'away' sporting fixtures. When cars are available they tend to be used, thus children are driven to school because their parents feel it is unsafe to walk due to increasing traffic which is paradoxically caused partly by people driving their children to school.

At the same time car travel makes it easy to carry equipment of all kinds for work or family needs. Additional car trips are low cost. As shown in chapter 3 while cars may on average be expensive to use, the cost of additional (or 'marginal') trips can be quite low.

Where travel patterns are customary, behavioural change is required to change the transport mix. Initiatives to reduce household car travel have particularly targeted children. Travel blending programmes working through school communities encourage car sharing, increased walking especially for short trips and use of public transport 'where appropriate'. These last words are very important in the quest for sustainable transport futures. The aim of these schemes is to help select the right mode for each journey.

A sustainable urban transport system must connect people to their activities. Thus walking and cycling might not be sustainable options for long trips. At the same time a bus may not be a sustainable option for a trip from a place were few people live to another where few people work. A trip by a fuel-efficient car shared by more than one passenger may be far more efficient. This is just one reason why taxis are an important public transport mode.

Travel blending also advises consideration of combining or foregoing trips. The 'right' transport mix in the short term depends on individuals making the right number of trips by the right mode. It also depends on supply side initiatives which support these choices. These include reliable and frequent public transport, safe cycle and foot paths but extend to home delivery of shopping. This will result in the right transport mix for the urban area in the short term. Longer-term changes to the transport mix depend on changes in land use.

3.2 Land use and transport

3.2.1 Urban structure

Considerations of land use and transport planning are interdependent concepts. Decisions on land use will ultimately affect requirements for transport infrastructure and service provision while transport planning policy can shape the land use of a region dramatically and can encourage or preclude certain types of land use or activity. Land use and transport interactions have two key features which are evident from discussion of the transport mix: urban structure, the way the city is laid out, and path dependency, the way change is governed by existing structure and form.

Transport demand and suitable modes for meeting demand depend on the structure of the city. Structure is predominantly described as the relative location of the activities in the city and the location of the people who need to reach them. The transport literature refers to these as 'attractors' and 'generators' of travel demand.

At the same time, the structure of the city depends on available transport. Thus the growth of railways then tramway lines led to residential development spreading along corridors out from city centres and the growth of private motor vehicles and roads to carry them led to cities spreading further afield or as some commentators say 'sprawling'. Lower land prices more distant from city centres allow lower density developments.

Such development can be difficult to service by public transport for two reasons:

1 Low population densities mean low passenger numbers with attendant low frequency services.

2 Dispersed development means many trips begin and end in locations with low population densities. In Sydney Australia 80% of all household trips are of this type.

3.2.1.1 Urban form

Numbers of authors make the valid point that different urban forms with more concentrated residential development produce higher public transport ridership and hence less private car use. Quantification of the impacts suggests a 10% increase in urban density can result in a reduction of 1%–3% of vehicle kilometres travelled per capita.

However, the corollary that increasing urban densities will increase ridership is not necessarily valid unless access to required services is considered. For example high-density residential blocks built on the outskirts of cities distant from work places and other services will be unlikely to suit public transport provision. International research showing 'residents on the urban fringe drive 10%–30% more vehicle kilometres than those of central neighbourhoods indicates the impact of distance from services.

3.2.1.2 Multi-centred cities

In larger urban areas multiple centres are required to provide the appropriate level of access to all. Whether this is a formal programme undertaken under a 'city of cities' strategy or a just the way the city has grown (like multi-centred London) this type of structure is not only suited to public transport but also to walking and cycling. Such multi-centred cities can provide numbers of the urban features found to discourage car use including:

- greater land use mix
- relatively better connected streets and non-motorised networks
- streets considered attractive and safe as well as accommodating pedestrian and bicycle travel.

Again international research suggests that neighbourhoods with a relatively good land-use mix typically have 5%–15% less vehicle miles than neighbourhoods with more stratified land use.

Local centres then need to be connected by appropriate mass transit systems which research shows can lead to reductions in vehicles in the order of 10%–30% and a reduction in vehicle miles of 10%–30%. However, the land-use transformation options depend on current land uses.

3.2.2 Path dependency

Current contexts: When considering the land-use transport mix in cities, planners might be reminded of the old Irish joke where the response to a traveller's request for directions was 'I wouldn't start from here'. While we might prefer a different style of city we need to work with what we have. The applicability of international examples of land-use transport balance to New Zealand urban areas needs to be assessed in the context of existing land use.

A definition of land-use planning by Land Transport NZ in 2007 incorporates concepts of context consideration:

> *…a term that is often used interchangeably with that of town planning, urban planning, regional planning and urban design. Land-use planning is used to encompass the process of managing change in the built and natural environments at different spatial scales to secure sustainable outcomes for communities. It includes both spatial elements, such as the physical design and layout of neighbourhoods, cities and regions, as well as strategic considerations that take account of social, economic, cultural and environmental factors.*

Pace of change: In practice, cultural and social changes can seldom be very rapid. Thus while the idea of minimising the distance for communities to access services has led to a strong focus on planning circles of urban intensification or increased density as a response to urban sprawl, general change has been slow in part because of community resistance.

The planners expect that, among other benefits, urban intensification will increase a sense of community through greater social interaction and, if progressed in tandem with appropriate transport planning, reduced reliance on private vehicles. However, residents in low-density neighbourhoods often feel they already have friendly neighbourhoods and are concerned about negative consequences such as increased anti-social behaviour, localised congestion and reduction in amenities. A holistic approach to changes in density to allay such concerns is needed.

Urban village concepts attempt to address these concerns but may fail if linkages outside the urban village are not properly addressed. A particular benefit of urban living is the wide range of specialist employment opportunities on offer whether as merchant bankers or members of a symphony orchestra. This makes them engines of the economy and cultural centres. Thus land-use transport integration patterns are required both to reduce the need for travel for common tasks such as shopping or eating out and offer connection to specialist locations

Land use drives transport in the short run: However, whatever land-use plans are put in place, whether by new development on greenfield sites or by retrofitting, city transport planners need to remember:

- transport supply will need to meet the demand of urban areas much like those of the present day for the short to medium term
- in the longer term, land-use transport sustainability of the cities will depend on planning today.

Thus while transport influences land use over time, current provision needs a primary focus on existing land use in allocating constrained funds. Strategies to make best uses of existing road space are therefore important in most urban areas.

3.3 Road space issues

3.3.1 Fit to available space

Transport management agencies must consider the use of road space when planning new road infrastructure as well as when planning to improve the operation of the existing road network. The use of new or existing road space comes sharply into focus when people experience the negative impacts of congestion. This section adds to the information presented in tables 2.3 and 2.4 in evaluating the effectiveness of road space allocation options.

Congestion, along with considerations regarding environmental and social impact of different transport modes, often leads to the spatial consideration at a route or network level of what is the most efficient use of this space if the prime purpose of that road space is to move people. The figure below indicates, from a purely spatial perspective, the road space required to move the same amount of people is dramatically different depending on mode, and that road space is maximised by moving all people by bike. If the solution really was this simple all road space would be reallocated from cars towards mass transit operations or cycling and pedestrian activities.

Figure 3.3 Space required to transport same number of passengers by different transport modes

However, decisions to reallocate road space involve more than just considerations of spatial efficiency. Many other factors play on the movement of people in reality, including but not limited to the perceived cost of each mode to the user, the origin and destination of the user, the accessibility of different modes and the purpose of travel. Many of these factors and their impacts on transport policy and investment decision making are discussed elsewhere in this report. We concentrate here on measures to address road space issues.

3.3.2 Measures to address road space issues

There is a broad range of measures, which can and have been used to address road space issues. Measures can be loosely placed into two groups.

3.3.2.1 Capacity enhancement measures

These enhance the road space available through increasing capacity or maximising the use of existing road space. Table C.1 in appendix C categorises, describes and assesses a range of these measures. The effectiveness of the measures can be measured by looking at throughput and delay indicators. A recent example of a capacity enhancement is the idea of hard shoulder running where the hard shoulder (or breakdown lane) on arterials or highways is opened to traffic during peak periods. Signals above the carriageway indicate when the hard shoulder is open. Research from The Netherlands has found that on two-lane motorways this measure has increased peak road capacity by 36%. The passenger carrying capacity of the road may be increased by a preference measure to encourage ride sharing/car pooling.

High-occupancy vehicle (HOV) lanes, or transit lanes, are reserved for vehicles with more than one passenger. While some operate all day, they are particularly valuable in peak periods offering a faster trip.

However high levels of enforcement are needed for successful operation. Fortunately advances in

Amount of space required to transport the same number of passengers by car, bus or bicycle.
(Poster in city of Muenster Planning Office, August 2001)

intelligent transport systems, from in-lane cameras to infrared detectors, allow continuous policing. The latter sensors were designed in the United States to pick up dummy passengers where HOT (high-occupancy toll) lanes allow free travel on toll roads for car or van pools.

Figure 3.4 HOV lane at Mt Wellington northbound on-ramp

Source: www.aucklandmotorways.co.nz

3.3.2.2 Road space reallocation measures

In contrast this second group of measures explicitly aims to reallocate road space from one mode to another or away from transport. The objective of this reallocation may be efficiency or to achieve other objectives such as improving amenity or reducing externalities associated with car travel. These measures are often focused on reducing car or commercial vehicle travel by giving preference to public transport modes, walking, cycling or high-occupancy private vehicles. One example is traffic calming as discussed below. Table C.2 in appendix C categorises, describes and assesses a range of these measures.

While local communities may often request traffic calming measures, residents and businesses may oppose implementation. Slowing response time of emergency vehicles or moving problems to another part of the network are potential problems to be monitored.

Traffic calming: 'the use of legal and physical measures to reduce traffic speeds and improve safety and the environment' is an approach to urban design, which makes streets more attractive, enjoyable and safer for those on foot.

Variations include measures that aim to slow the speed of traffic such as road humps and speed cushions, traffic islands, pedestrian refuges, roundabouts and chicanes as well as measures that visually, audibly, or through vibrations direct a driver's route, promote spatial separation between road users or encourage effective carriageway positioning. Diversions, one-way streets and street closures to traffic are also methods of traffic calming.

Figure 3.5 Methods of traffic calming

Source: *Land Transport New Zealand research report 300* (Charlton and Baas 2006)

3.3.3 Determining appropriate road space-related measures

Whatever the purpose of the measures which impact on road space, the decision maker will need to consider their appropriateness to the local context and also the likely effectiveness of the initiatives.

To aid this activity some threshold levels or 'warrants' have been utilised by transport planners to indicate whether a particular measure is required. For example when considering bus lanes, research has indicated: 'from the standpoint of person capacity, 20–30 buses per hour (800 to 1200 seats) can accommodate more people than are usually carried in cars in an equivalent arterial street lane (600 to 700 people per hour)' (Levinson et al 1976).

Austroads (the Association of Australasian Road Agencies including the NZTA) recommends considering temporal and location dynamics to decide where and when different measures will be appropriate (Austroad 2007).

Solutions depend on whether the problem to be addressed occurs at peak, off peak or only as a result of irregular events. They also depend on the extent of the problem. The range of solutions advocated by Austroads is shown in table C.3, appendix C.

Additionally local authorities may have established hierarchies of road users to set priorities for access. The hierarchy order will depend on local priorities. A common hierarchy based on economic productivity sets freight deliveries first followed by commercial service vehicles then traveller for work purposes before commuters and other road users. In contrast, the NZTA in its *Pedestrian planning guide* (Land Transport NZ 2007) considers the various users of road space and provides a road user hierarchy for promoting walking that puts mobility impaired pedestrians and wheelchair users first and 'car borne commuters' last.

Overall, whether considering broad scale city-wide urban planning or traffic calming on a particular road, the most appropriate response will be highly contingent on localised factors. The next chapter provides case studies to set some of the concepts discussed in context.

4 Case studies

Chapter summary

This chapter provides example case studies to illustrate some of the issues presented in chapter 3 and the cost and benefit assessments from chapter 2.

The first three studies describe New Zealand cases. The fourth case is from Nottingham in England.

4.1 Christchurch: enhancing bus service quality

Case summary:

Christchurch is a large city with a very high level of car usage and consequent congestion. Improvements in bus service quality have doubled the bus mode share from 3% to 6%. This has been achieved through:

- strong partnerships between the organisations overseeing and operating services
- improved service features with denser routes and improved frequencies
- moving from 'one size fits all' to location specific solutions:
  - cross city services to cater for trips not CBD centred
  - free city centre shuttle, with low-emission vehicles
- support from infrastructure provision including a high-quality interchange facility and especially bus priority systems.

The car trips avoided by providing better alternatives represent significant benefits in limiting congestion growth and the environmental impacts of extra traffic.

4.1.1 Case context

In population size, Christchurch has recently become New Zealand's second largest city. The strength of the economic growth, which has brought it so far, is not expected to abate, regardless of the current recession. The total number of inhabitants is forecast to grow from 350,000 in 2006 to over 430,000 in 2021.

Despite a strong and vibrant CBD, albeit one acknowledged in the current urban development strategy and elsewhere as needing some degree of revitalisation, the overall urban area is characterised by relatively low-density housing and numerous suburban centres of both retail and employment activity in particular.

The generally very flat topography has fostered a strong tradition of cycle use, easily the highest in a New Zealand urban context. However, the greatest driver of Christchurch's transport make up is the very high level of car ownership, even by New Zealand standards. This will have been strongly influenced by the city's layout and structure.

Increasingly, therefore, traffic congestion has become of major concern. This is all the more so when looking just a few years into the future. As road networks reach close to their design capacity, relatively small further increases in volume can have significant undesired consequences. Hence, on present trends, a forecast increase in traffic growth of just over 20% between 2006 and 2021, would be likely to increase congestion by 160%, extending commuter journey times by 26%.

The various transport strategies and plans for the city not surprisingly focus upon ways and means to promote and deliver alternatives to private car use. There is an emphasis on enhancing both cycling and walking options as well as travel demand management (seeking to reduce overall demand levels). But a major thrust is the recognition of the role of public passenger transport as an effective means of travel for many urban travellers based on the premise that, where there is a good network of services, it can offer a cost-effective option for many trips over a range of distances.

If both a single harbour passenger ferry and the city's vintage tram route, the latter in reality a tourist attraction, are excluded, public transport in Christchurch means buses. For various reasons which can be deduced from the preceding paragraphs, it is far from ideal bus operating territory. Accordingly, it is not surprising that bus use had, until relatively recently, fallen to very modest levels of use. Figures for the 1991/92 year, representing the lowest point in its decline, indicated less than seven million bus trips in total. This was less than 3% of the overall market and an average of only 20 trips per year for each resident. The figure was also less than half the total which had been recorded seven years earlier.

Most recent demand figures indicate current usage for 2007/08 at over 16.5 million trips, with a target of 25 million by 2015/16. Market share appears on target to reach 6% of all travel by 2011. This is an impressive turnaround by any standards.

The remainder of this case study focuses on how this is being achieved.

4.1.2 Service provision and innovation

One of the more obvious requirements in offering a public transport network to provide a credible alternative to car use is an adequate level of service provision.

This is primarily managed through the regional council (Environment Canterbury), given the need to provide operating subsidies to most routes. Under its Regional Passenger Plan, various key policies to underpin service provision are laid down. The Christchurch City Council and Environment Canterbury Metro Strategy supplies further detailed direction and is key to achieving patronage growth. There is strong emphasis upon community involvement and commitments to partnerships between the key players, similar to that seen in the Nottingham (overseas) example described later.

A key objective is that at least 90% residents be no more than 500 metres from a bus route (the rationale being that this is no more than five minutes normal walk time). The focus is then upon a radial pattern of core services to/from the CBD on simple, direct routes with key interchange points supplemented by circular connections.

Service performance standards are also defined, covering various aspects of quality (vehicles, operating speeds, punctuality and reliability etc) but especially frequency.

Core services, defined as those operating along principal travel corridors, have desired minimum frequencies of 10 minutes in the peak, 15 minutes off peak and 30 minutes in evenings. A relatively dense network of good frequency services radiating to and from the city centre is thus provided.

Recognising, however, that many desired trips are increasingly less focused on the CBD, attention has recently been given to planning for cross-city circular services. The intention is to link to radial routes by well-designed suburban interchange facilities. A separate marketing of 'Orbitor' and 'Metrostar' services draws further attention to this development.

Promoting bus provision is, as noted, also carried out within the context of an emphasis of creating a better environment and alongside similar 'friendly' modes, a specific example being the current trials involving the fitting of bicycle racks to certain buses. More established is the Central City Shuttle, a zero fare CBD operation using hybrid electric technology. Buses are battery powered, with a small natural gas fuelled turbine to maintain its charge.

Branding of the bright yellow vehicles of the shuttle is deliberately unique. In all other cases, however, a common branding under a 'Metro' theme is a requirement of all contracted services. The regional council also provides passenger information on all services, routes and timetables, regardless of operator – currently three separate companies provide services in a contestable market.

While conventional information provision through printed timetable leaflets and telephone enquiry answering remains in place, Christchurch has pioneered the development of real-time information for bus services. As all contracted service vehicles are required to be fitted with transponders (a small electronic device, the signal from which allows a positional fix to be determined), it follows that it is then possible to predict arrival times at bus stops. The system has been extensively developed in recent years and is now available for bus stops throughout the central area and the majority of suburbs. The intending bus user has up to four options for accessing information. These are by internet, WAP-enabled phone, interactive push button terminals at some bus stops and real-time information screen at others. Information given covers estimated arrival times, bus number and route as appropriate. A unique identifying number of the relevant bus stop is available on the stop post/sign to assist occasional users or those in unfamiliar locations.

The fares and ticketing system shows high levels of innovation, designed to offer a simple and flexible system, commensurate with rapid and easy boarding. While conventional single fare tickets remain, with a single flat fare zone covering services within the city boundary (adult cash fare $2.80), the emphasis is on promoting more frequent and easier use through electronic ticketing offered at discounted fares. This approach, using Smartcard (stored value) technology provides an immediate 25% discount on single (cash fare) journeys. Further discounts are likely to be available if purchasing an all-day or weekly travel ticket. In addition, all ticket types permit at least one free transfer in the city zone within two hours of commencing a journey. Overall fare levels are set so as to recover 50% of total service costs. There is scope to enhance the system further by moving to online payment.

4.1.3 Supporting infrastructure

Two separate types of development are worthy of comment here, namely the central city bus interchange and the extensive plans for systems of bus priority, currently on a large number of key radial routes to and from the city centre, but with consideration also being given both to outer circular service routes and within the city centre itself.

As part of the initial strategy to revitalise bus services in the late 1990s, an off-street terminal facility was constructed. With high-quality waiting facilities and associated services, the bus exchange was a seemingly a popular innovation, assisting patronage growth. Building an interchange complemented an overall network redesign which reduced unproductive central city routing and introduced new cross-city services which passengers could use without the need for an interchange. However, for those services and travellers using the interchange, capacity problems were soon evident as a result of its success. Accordingly, a new transport interchange is planned.

A project in excess of $100 million, funded by the Christchurch City Council and the NZTA, land has already been acquired for the purpose. Commencement of construction is imminent for a scheduled opening in 2013/14.

Of possibly greater significance to enhancing the relative attractiveness of bus services, and certainly to protect against otherwise certain deterioration in peak-hour provision (journey times and reliability), is the current programme of bus priority measures on key radial routes. A total of 10 corridors have been identified focusing on the worst areas of current and forecast traffic congestion for buses. It should be noted that this has been able to be measured by monitoring of actual service reliability using the bus transponders mentioned earlier. The first three corridors, at a cost of approximately $3 million, will be implemented in the 2009/10 financial year, with others planned to follow shortly after.

It is important to note that the proposals take a more holistic approach than the more traditional approach of simply reserving road space (a bus lane), often for only limited times of the day. Included in the approach, for example, is the use of B-signals. These can be used at a traffic light intersection where there is a bus lane. The B (for bus only) signal is activated upon detecting a bus in its lane prior to offering a green light to other vehicles. It thus allows the bus to 'jump the queue'. A critical evaluation is also undertaken of bus stop location, both from a passenger convenience perspective, but also for operational reasons. Rationalising the number of stops and the (re)location with respect to road junctions, traffic lights/B-signals and so forth, can contribute significantly to journey time improvements.

Finally, a comment should be made regarding the planning of transport infrastructure in new and greenfield sites. The opportunity arises in parts of Christchurch due to the anticipated relatively rapid population expansion as noted previously. As is well known, land-use patterns and urban form in general exert strong influences upon transport demand. There is evidence of an appreciation of this matter and its importance in promoting an alternative to car use. The newly adopted South-West Christchurch Area Plan, covering one major area of new population growth, aims to provide 'a transportation system that gives priority to active and energy efficient ways of travel and minimises the effect on the environment'. In the specific case of bus transport, the planning of services, their routes, priority schemes and the like are integrated within the overall land-use and highway network plan at the outset. In short, 'design all roads to facilitate good public transport accessibility and achieve safe and walkable communities'.

4.1.4 Closing remarks

After many years of decline in and lack of attention given to urban public transport in Christchurch, its community, decision makers and transport professionals alike have embarked upon a journey to promote vigorously several key alternatives to private car use. This case study has focused on both achievements to date and future plans to enhance the city's bus system. It must be recalled that it is part of a wider strategy which also promotes other modal options such as cycling and walking. The benefits sought and reasons for so doing relate to many factors including efficiency, environment, safety and overall quality of urban life. There appear to be several innovations and useful lessons in a New Zealand context, which could be adopted elsewhere in pursuit of similar objectives.

4.2 Hawke's Bay: enhancing provision for cycling

Case summary

The Hawke's Bay region is home to a dispersed urban population with bicycle transport rather than public transport use providing the main alternative to car travel. The environment is suited to cycling but safety concerns are a deterrent. Thus a cycling strategy has:

- promoted safety through education and enforcement
- developed an extensive network of on-road and off-road routes
- required only modest expenditure for both networks, for example between $20,000 and $67,000 per route kilometre for the off-road routes.

The cost of provision for travel by this means is considerably lower than provision of extra roads or provision of public transport. Cycling is particularly well suited to servicing the wide variety of short- to medium-length trips in the region.

4.2.1 Case context

The Hawke's Bay region is home to over 150,000 people. The majority, just over 80%, inhabit the so-called 'twin cities' of Hastings and Napier. Taken together, they form New Zealand's fifth largest urban area, albeit encompassing two significant city centres separated by just under 20km. There are also several other significant and semi-free-standing suburban centres.

This somewhat unusual pattern of dispersed and often disparate settlement, with high levels of interaction between many of its parts, has given rise to a car dominant transport society. Public transport, in particular, has a very low market share.

Cycling, by contrast, has always made a relatively significant contribution, albeit as a clear secondary mode after car use. Even after many years of declining use, in common with trends elsewhere, there remains a strong base of ownership, close to one bicycle per household. In the Hastings District, 40% of students regularly use a bicycle for travel to and from school. More than one in 20 workers regularly travels to work by bicycle. This figure is broadly equal to the numbers of car passengers, the second most popular means of travel in Hastings, and about 75% of the number in Napier.

There is good reason for cycling to be favoured as a mode of transport in the twin cities. The entire urban area is, in effect, contained within the flat terrain of the Heretaunga Plains. Hawke's Bay also enjoys an excellent warm, dry climate. The urban form results in many origins and destinations requiring short- to medium-travel distances. The primary deterrent is personal safety. Concerns relate to motorised traffic volumes and speeds, especially in the context of road design, maintenance and general lack of specific provision for bicycles. Driver behaviour and negative attitudes, up to a level of intolerance or non-acceptance of cycling activity on the public highway, is a further serious concern.

Recognising all the above, both Hastings District and Napier City Councils developed and published cycling strategies in 2001. Each underscores a commitment to planning and providing for the effective, safe and convenient movement of cyclists both within and between the main urban and suburban areas. Accordingly, the two strategies were developed in parallel and are strongly interlinked.

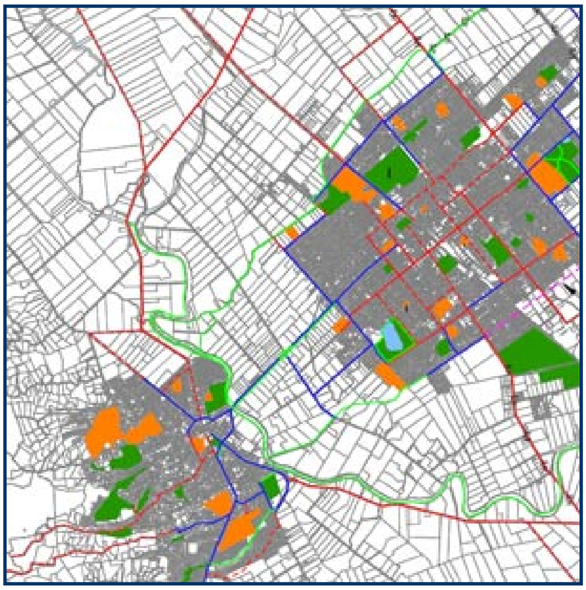
Cycling is promoted in order to reduce traffic congestion, improve the environment and improve health and fitness. A recognised objective is also to improve the safety of cyclists. This extends to education (of cyclist and motorists alike to share road space safely), encouragement of cycle use (premised on the safety benefits of higher volumes of cyclists on the road) and enforcement (again aimed at both motorists and cyclists).

Most significant, however, is the development of an extensive network of both on- and off-road cycle routes, upon which the remainder of this case study is focused. The safety benefits and encouragement to cycling of the latter, in particular, are self evident. Even where development, as in a number of the off-road pathways, is targeted somewhat more towards recreational usage, there is an obvious contribution to a 'think bike' emerging culture and the encouragement of higher levels of overall (safe) cycle use.

4.2.2 Developing a cycle and (walkway) network

At the time of publication of the two cycling strategies, there was very little special provision of either on- or off-road infrastructure in the area. Only a single plan for a short section of off-road cycle and walkway on the coast north of Napier was being considered. Remarkable progress has been made since then in planning for and linking the twin cities, local centres and smaller coastal settlements via an integrated system of cycleways (and many off-road walkways) for locals and tourists alike.

Figure 4.1 Cycle network map



Source:www.hastingsdc.govt.nz/property/roading/cycling/

Critical to its success, especially in developing the dominant off-road sections, has unquestionably been the involvement of all Rotary clubs in the area. Working in partnership with local, regional and central government expertise and funding, they have been the catalyst for community support and involvement, not least in accessing necessary financial donations and grants.

The Rotary Pathway Trust was formed in 2002. An initiative of Napier City Council and the combined Rotary clubs of Napier, its express purpose was to build a walk/cycleway in stages that would eventually surround the city. Very shortly thereafter, it was paralleled by the formation of the Rotary Centennial Pathway Trust, essentially representing the Hastings District clubs (and supported by its local council). While the two bodies remained as separate entities for administrative and financial reasons, a region-wide approach was now possible.

This was further ensured by the involvement of the Hawke's Bay Regional Council, as it was quickly realised that many proposed off-road pathways, such as along waterway corridors and stock banks traversed their land. Just as the local councils have maintenance responsibilities for cycle-way provision on most roadways, the regional council's role will increasingly be to provide long-term maintenance for many off-road sections after construction. Central government is also involved as both state highway and transport funding agency (now through the NZTA). A 10-year plan for an integrated system of cycleways and pathways across the Heretaunga Plains is thus moving to reality.

Design and construction expertise rests with the relevant expert authority, as does individual project oversight, including tendering and costs. A variety of construction standards, materials and widths have been adopted, depending on location. Hence, the most heavily used off-road sections can feature up to a 3.5m width asphalt or concrete surface, while quieter 'riverbank' style routes are more likely to be of 2.5m width and use compacted limestone surfacing.

4.2.3 The off-road network

From the opening of the first short 1.7km section in November 2003, described above, the network had grown by late 2008 to around 60km, allowing maximum continuous rides on a dedicated route of up to 30km. The two separately developed networks are physically linked and the 'around Napier' concept is nearing reality. Plans are in place for a further expansion of at least 50% in network length, prompted at least in part by public response to current schemes, leading to demands for more route options.

Overall unit costs have been modest, with capital costs of under $4 million. The 46km of off-road paths directly supported by the Rotary Trusts (some projects have been directly funded by Napier City) reveal expenditure totals of $3.1 million or just $67,000 per route km. Within this, there is significant variation due to construction standards, the simplest lime sand compacted tracks being in the $20,000–$40,000 range. The short 1.5km Napier Breakwater – Marine Parade section represents the highest cost at some $650,000. It includes two railway level crossings, two heavy truck road access crossings (all relate to Port Company operations) and a concrete supported wooden cantilever boardwalk over Breakwater Beach.

Funding has come from a variety of sources, including local authorities, central government and Rotary itself, the last named being a mix of its own fundraising and a large number of grants and bequests.

4.2.4 The on-road network

If the most obvious example of planning for cycling is represented by the developments so far described, even a further considerable extension of this network will not, in itself, deliver the complete aims of the two local authority cycling strategies. Accordingly, both councils are active in enhancing the on-road environment for cycling.

Napier’s approach appears relatively pragmatic seeking to build cycling facilities when new roads are being planned or others upgraded and/or resealed. A strategic route network, focusing on principal corridor movements, is being developed. This includes an approximately 8km route between the main tertiary education campus and the city centre where, to date, some 75% of the route features designated cycle lanes.

Hastings has adopted an even more structured/tiered approach, designating key preferred route corridors for cycle paths (alongside the road), and others for cycle lanes (within the carriageway). Selection is strongly oriented towards routes to and from schools with the choice between path and lane likely to be strongly influenced by engineering feasibility. A network of 17.3km to date has been established, 78% as cycle lanes. Two further subordinate levels of routes are also designated. Here, lower levels of treatment will apply, specifically focused on road safety, such as segregation or delineated space at roundabouts. A total of 10, some 20% of the area’s total number of roundabouts, has been achieved. Funding appears to have been between $300,000 and $500,000 per annum from a specific cycling budget, but may also have been assisted by ‘free’ contributions where cycling enhancements are subsumed within more general road improvement and maintenance projects.

4.2.5 Cost benefit appraisal

The expenditure sums quoted in this case study are extremely modest, especially by comparison with others elsewhere in the report. However, any comparison of relative worth of such projects over expenditure on other modes, requires good information on demand/usage in order to inform an appropriate cost benefit appraisal. Unfortunately, accurate usage data on cycling is rarely collected and this case is no exception. It is based, nevertheless, on recent work in the United Kingdom (Department for Transport 2009), recently adopted as government policy, which prescribes a ‘rule of thumb’ test whereby expenditure of £10,000 (say $25,000) is justifiable over a 30-year project lifetime if it reaches a break-even cost benefit where it attracts one extra cyclist. Thus, the $500,000 higher-end budget above would be justifiable if it attracted just over 20 new cyclists. Therefore, this case study would certainly appear to pass such a test.

4.2.6 Closing remarks

Despite New Zealanders owning almost as many bicycles as motor cars, any strategy seeking to reverse the many years of decline in bicycle use, especially for other than occasional recreational use, must address the fundamental deterrent of conflict and safety risk arising from on-road use. By combining all that is discussed above, it becomes possible to see how such a strategy can be devised and turned into reality. Even if the expansion of safe and attractive cycling environments is recreationally driven, as has clearly been the case here, the building of a culture of cycling use, and with that, critical volumes of ridership, is in itself a major safety positive and is widely recognised. Both cyclists themselves and other road users learn mutual respect and acceptance of each other through greater interaction.

4.3 Auckland: sharing the road space

Case summary

Auckland, New Zealand's largest city, faces increasing traffic congestion. Both terrain and the city infrastructure limit opportunities for building extra roads so there is considerable incentive for making optimum use of available road space.

- The Northern Busway, a bus rapid transit (BRT) system, shares the road space with SH1.
- While the busway itself is just 6.25km it provides a congestion free trip for buses entering it from multiple routes.
- Even with current peak-hour bus patronage, the busway carries twice the maximum number of car commuters able to use one lane of adjacent motorway, yet further significant increases in busway numbers are expected and perfectly feasible.
- Accordingly, there are significant benefits of travel time and cost savings due to congestion relief, together with the environmental and safety benefits of reduced car use.

The BRT system is a particularly cost-effective solution as it improves the productivity of the current investment in road space and saves on future investment while providing environmental benefits from and equity benefits in access from outer areas.

4.3.1 Case context and description

A major innovation to get maximum value from road space and reduce congestion, in the busy city of Auckland, makes use of the SH1 motorway. Opened in February 2008, the Northern Busway infrastructure is a two-lane fully segregated routeway. Unique in New Zealand and with relatively limited but a growing number of parallels elsewhere in the world, it can be classified as a bus rapid transit (BRT) system. This is rubber wheel technology using its own carriageway rather than a steel-wheeled fixed-track rail vehicle based system. It is 6.24km in route length, commencing at its southern entry point, some 2.5km north of the Auckland Harbour Bridge. A single southbound 2.5km bus lane, linked to the busway proper, presently covers this section. There is scope to extend to two lanes in the future.

From the northern exit point, several routes using the busway continue on the SH1 motorway proper to the major and expanding suburban area of Albany, a further distance of 2.7km. The spine of the enhanced bus system, as perceived by the travelling public, in effect runs between Albany and the Auckland City CBD (over the Harbour Bridge) with the segregated bus-only section eliminating the major road congestion, especially in peak hours, prevalent on SH1. The extra lane capacity of the combined motorway and busway can be accommodated at peak times by the use of 'tidal flow' increase in the bridge's directional capacity as appropriate. Comparable journey times along the corridor of 30 minutes by bus and up to one hour by car have been claimed by several sources.

Albany and Constellation 'stations' are major park and ride sites with capacities of 500 and 370 free car parking spaces respectively. The three other stations on the busway each have good 'kiss and ride' car passenger drop off and pick-up facilities, secure bicycle racks and lockers, pedestrian access and transfers from local bus where necessary (through-ticketing, without penalty, is offered). All stations offer platform (level) boarding and alighting, are fully accessible, weather protected, with seating, shelters, toilet facilities, night lighting and CCTV.

Figure 4.2 Albany Bus Station

Source: www.busway.co.nz/index.php/Gallerycycling/

Bus services on the spine route are operated by modern, high-capacity articulated vehicles, with the initial through service marketed under a 'Northern Express' banner. This service, to and from the two park and ride sites at Albany and Constellation, commenced in late 2005. Within six months, passenger loadings were 50,000 trips per month, of which 39% had transferred from using a car. Most of the current expanded range of bus services, as described below, plus the stations and associated information and publicity material are marketed by the Auckland Regional Transport Authority (ARTA) under a MAXX common branding.

Not all buses travel the full length (to and from Albany) and not all buses stop at all points. One of the key advantages of a busway over a fixed track rail system is the ability of bus routes to use all or part of the infrastructure and continue beyond it without the need for passenger transfers. Given its design and location, this applies in reality to all buses which use the dedicated roadway infrastructure. However, the point to note here is that an extensive number of bus routes divert from the spine route to and from various points within the North Shore. An extensive system of bus priority measures on conventional highways, including HOV lanes which also allow cars with three or more occupants to use them, together with associated measures such as bus stations, shelters, and real-time information has been introduced to support an overall improvement in bus service standards and reliability. Priority measures have been introduced throughout the North Shore and also within Auckland city, the latter specifically oriented towards improved bus access between the Harbour Bridge and the central city.

The Northern Busway is thus a key component in developing a rapid transit network for Auckland into an area where improving existing rail services, as elsewhere in certain parts of the isthmus, was not an option. Note that a prime potential interchange point for onward journeys in downtown Auckland is Britomart, thus connecting to the passenger rail network. Improved journey speeds, reliability, comfort and high frequency on the spine route, in particular, offer a more credible alternative to private vehicle use. Trips diverting from car to bus reduce road congestion and the consequent pressures for greater road building, and also offer environmental improvement.

4.3.2 Costs and funding

The cost of the Northern Busway, taken as a comprehensive public transport and traffic management project as a whole, has been approximately $300 million. It represents extensive collaboration between four agencies, each of which held different roles and responsibilities:

- *Transit New Zealand*: The former state highway authority, now part of the NZTA, undertook the busway construction, its commissioning and management. Its costs were some $210 million.
- *North Shore City Council* constructed the five busway stations and interchanges. It was also fully responsible for all supporting bus and HOV priority measures within its boundaries. The former costs were around $85 million with just under 60% of this being a grant from ARTA on behalf of the by then wound up Infrastructure Auckland.
- *Auckland City Council* provided bus priority measures within its boundaries.
- *ARTA* provided bus services and information. This included signal pre-emption at lights and real-time information for bus services and busway stations in North Shore and Rodney with MAXX branding and long-term development of electronic and integrated ticketing (to be Auckland wide but critical to long-term busway capacity – see below).

4.3.3 Patronage and overall benefits

Special note: While limited aggregate figures are available to allow the following broad brush assessment, a comprehensive busway post-implementation study is being carried out by ARTA and is soon to reach conclusion. A more robust analysis should thus soon be available.

As a scheme to promote public transport use, the busway project appears to have been highly successful. The initial popularity of the first Northern Express services operating without the segregated carriageways has already been noted. If morning peak (7–9am) bus passenger flows over the Harbour Bridge are taken back to before these services were introduced, then figures ranging between 3000 and 3500 per morning peak have been estimated. After one year of full operation, the current figure is around 7000, with bus market share up from 28% towards 33%. Note that this is an increase within a rapidly expanding total market. As ARTA notes, the bus share is equivalent to an additional two lanes of motorway (and/or Harbour Bridge) capacity, if all passengers use private cars at normal peak hour occupancy rates.

The significant increase in bus use is achieved by a combined operation of services providing some 70 buses per hour south of Akoranga, the last station before the bridge and a minimum average frequency along the spine route of every three minutes. The nominal carrying capacity, at least, is far from exceeded by current loads, though an average of 50 passengers per bus is high and will result in many running fully laden. The design capacity of the busway though, operating for buses only, is 250 per hour. Hence, considerable spare capacity remains to be developed if necessary. This is, however, predicated on passenger boardings of three seconds per passenger, which can only be achieved by pre-paid electronic ticketing.

Another way of viewing the positive contribution of the busway to keeping Auckland moving is to consider the capacity of the Harbour Bridge. At the date of funding the project, peak hour directional capacity was assessed at just over 9000 vehicles per hour. This translated into a little over 11,000 person trips. This would leave limited spare capacity, especially without extensive 'peak spreading', wherein the highest volumes of traffic extend for longer periods of time. It was also judged that this volume was sufficient to cause major delay and disruption in the event of any significant incident. A 2011 forecast of southbound cross harbour movement, due principally to the anticipated major expansion of many areas north of the bridge was, nevertheless, 18,000 person trips per hour. The contribution of harbour ferries to meeting this demand was no more than 1100 persons. Thus a busway desired demand of almost 6000 passengers per hour was postulated.

4.3.4 The busway and HOV combined option

From a relatively early point in its development, the project came to be planned as a busway combined with an HOV system. A key reason for this was the additional postulated benefits from high occupancy car travellers combining with buses on the same carriageway, thereby maximising its (free-flow) capacity. There is an obvious logic to this, given that maximum capacity of the route is unlikely to be reached by buses alone for some time, if ever (see previous section on capacity).

However, experience from elsewhere in the world suggests that it is unusual for BRT systems to be designed in this way. Regulating an optimum level of non-bus traffic is a first issue to contend with as is optimising physical design around bus stations, access and egress points for cars and so on. That the proposal has not been pursued is largely due to the failure to complete road capacity expansion on the Auckland city side of the bridge around the Victoria Viaduct. This currently restricts the capacity of the corridor as a whole. The matter may be revisited when this project, which enjoys very high priority in the current government's road programme, is completed.

4.3.5 Closing remarks

The Northern Busway is a major innovation within New Zealand's transport system. It is part of a seemingly growing interest in BRT systems worldwide. This case study has focused largely upon the efficiency of use of road space delivered by its infrastructure, not least in terms of carrying capacity, especially if aligned with appropriate vehicle types and electronic ticketing. The further potential to maximise that capacity through combining with HOV operations remains a matter of conjecture, but surely one for further debate. The passenger benefits to bus users throughout the relevant network – not just on the spine route – over previous operation have also been discussed. This arises, in part, due to the flexibility of this type of operation over a fixed track public transport alternative. By achieving modal transfer from car use to a significant degree, the full suite of environmental benefits, rehearsed elsewhere in this report, will also accrue.

4.4 Nottingham: the United Kingdom public transport success story

Case summary

- Nottingham, with some 667,000 people in its urban area, is an example of sustained growth in public transport at low cost to government.
- Cooperation between local authorities and operators has been key, as has the emphasis by public transport operators on quality not price.
- Better service has stimulated demand for public transport with 34% market share on key corridors.
- Due to good patronage, 97% of bus services need no direct subsidy.
- The successful light rail line was built at relatively low cost by using existing rail corridors.

- Ongoing initiatives include developer financial contributions to integrated transport measures. A workplace parking levy (to fund further public transport improvements) is also under discussion.

Overall there are cost savings to the local authority and benefits to the community from reduced car congestion and its associated negative environmental effects.

4.4.1 Case context

Nottingham is a large English city, its urban area making it the seventh largest in the United Kingdom. It is situated in the East Midlands, some 200km north of London. The population of 288,000 within the Nottingham City council area is an anachronism of long outdated local government boundaries. Much of the surrounding area, in Nottinghamshire County, forms a contiguous urban agglomeration of 667,000. Population density is relatively dense (37 persons per hectare) by New Zealand standards. The city is very prosperous, with a GDP per capita second only to London in England and fourth overall within the United Kingdom. It is a major shopping, educational and cultural centre.

Nottingham's public transport story is one of remarkable achievement. It is without question the most obvious example of sustained growth in public transport at low cost to the public purse that can be found in the United Kingdom over the last 20 years. Over 75 million public transport journeys per year give an impressive 34% total market share on key corridors.

Bus services form the basis of its success with growth since the year 2000 at a time when all other areas of Great Britain outside London were still largely in the continuing downward spiral of demand which has been ongoing for several decades. As well documented elsewhere, the bus deregulation experiment of open competition in the market, introduced to all of Britain outside London in 1986, has done little to change this and can, in many cases, be seen to have made things worse. Accordingly, bus use per person is higher than anywhere else in the United Kingdom outside London.

Nottingham is one of only six locations within the United Kingdom in the last 20 years to see a new light rail (LRT) scheme developed. It has succeeded where many others, including much larger British cities, have failed. Light rail in Nottingham, which opened in 2004, has boosted total public transport use as would be expected. It also achieved its forecast demand levels, and did so very quickly, in contrast to most of other recent United Kingdom LRT schemes. Yet despite a public transport market share of around 13%, bus patronage has continued to rise.

Operating subsidy to operators is barely 3% and targeted to specific services. As noted above, the local government structure is fragmented. There is more than one principal provider of public transport services, all operating autonomously from local government (or at least 'at arm's length'), and an open competitive environment without quantity controls.

4.4.2 Bus services

The principal operator is Nottingham City Transport (NCT), with a fleet of some 320 buses. It carries around 50 million passengers per year out of a total bus market of over 65 million. NCT was corporatised upon United Kingdom bus deregulation in 1986, remaining 100% owned by the city council until 2000, when international public transport company Transdev, the operator of the city's LRT system, took an 18% interest, clearly linked to their joint operating interest in the LRT system discussed below. Trent Barton, a merger of two large companies provides other services.

The bus network is provided almost without operating subsidy, some 97% of services being commercial. The city council provides just over £1 million in revenue support for the remainder. Interestingly, all support is given to specific services, mostly operated by NCT but under discrete branding, including park and ride services, a high-quality link to East Midland Airport, around 15 minibus routes to residential and industrial estate areas otherwise not served by commercial services. There are also several special links for health and education purposes with relevant agency contributions both to capital and operating costs as appropriate. Table 4.1 shows the features of the system as provided on the Nottingham City Council website:

Table 4.1 Buses in Nottingham – 'the facts'

• use per person higher than anywhere in the United Kingdom outside London • use has increased by over 5% per year since 2004, despite a new tram route • satisfaction levels of over 85% amongst users, up from 75% four years ago • services run every 10–15 minutes down 35 main routes • services run through to midnight on 20 main routes • excellent punctuality and reliability records – one of the best in England • 20km of bus lanes, including throughout the city centre	• excellent value – unlimited travel for around £2 per day • 85% of households have regular daytime services to the city centre, employment sites, hospitals and universities • highest levels of accessibility outside London • all buses on main routes are under five years old • over 95% of buses are low floor and fully accessible • brand new waiting facilities at all main bus stops • over £2 million is invested each year in all areas of bus travel on all key routes.

The combination of all the above creates a network of generally high-frequency services with high area penetration and hence accessibility. An estimated 85% of all city residents are within 400 metres of daytime services.

4.4.3 Light rail

The city's LRT, named Nottingham Express Transit (NET), commenced operations in early 2004, construction having started four years previously. The period from conception to implementation has been estimated to be 16 years. The capital cost for the current system was £220 million (NZ$560 million) or NZ$3.9 million per route kilometre.

The NET was actively campaigned for and promoted by both the city and county councils and gained permission through central government to offer Private Finance Initiative Credits covering 82% of the total cost. In effect, money is then loaned from banks with undertakings to repay over a lengthy time period, in this case 27 years. Sponsor equity and various grants make up the balance.

Construction was by a consortium of transport experts (Bombardier, Transdev and NCT) together with private equity financiers. Operation of the completed system is a joint venture between Transdev and NCT. The involvement of the principal local bus operator and the further cross-ownership of Transdev's 20% share in NCT is not a common feature of the United Kingdom's new LRT systems.

The single main route length is 14km with a short spur of approximately 1km half way along to serve a major park and ride site adjacent to the M1 motorway. It runs from the city's main railway station, via the city centre, north to Hucknall, a contiguous former coal mining town. There are two further national railway interchange points and a high level of bus feeder services. In all, there are five park and ride sites with a capacity of 3000 car parks (free to all tram users). Over 10km of route, the remainder being city street running, uses either an existing rail corridor with surplus capacity (this has permitted parallel running on separate tracks) or wholly disused rail corridors. This has all had a major effect in lowering costs. As found elsewhere in the world, including the United Kingdom, achieving such savings is critical to scheme viability.

Service frequency is high, with a combined frequency in the city of five minutes peak and six minutes inter-peak. Services split 50%–50% between Hucknall and the Phoenix Park (M1) park and ride site. One in five passengers is estimated to be foregoing a car journey when travelling on the NET.

Fares for tram-only tickets are the same as or slightly cheaper than NCT buses, except for a peak period single. Smartcards (stored value electronic tickets) are inter-available between NET and NCT services. After one month of operation 40% of passengers were using this ticket type. The inter-availability of fares and ticketing and a joint interest in public transport network planning would appear obvious benefits of cross-ownership.

Perhaps as a major consequence of the above factors, and unlike most other new LRT services in Britain, the NET was a patronage success from the start, carrying 9.7 million passengers in 2005 and having been designed with an expectation of 11 million after five years of operation. The services are provided without any form of direct operating subsidy.

Plans are well advanced for two more lines (Lines 2 and 3), to the south and west of the city. These total 17.4 route km, of which 60% is on segregated tracks, and a target patronage of eight million passengers per annum.

4.4.4 Governance and planning

All the above has been achieved without strong direction from government authorities such as is common in larger United Kingdom conurbations and elsewhere throughout Europe. However, perusal of planning documents immediately reveals the high extent of collaboration between the city and county (regional) councils on all public transport matters, together with high-quality analysis and detail. In summary, both have met their statutory requirements and responsibilities (strategies, five-year plans etc) in full. As evidence of this, and given that many planning documents submitted to the central government are formally assessed for their quality, excellent 'report cards' have been awarded on at least two occasions. This has resulted in additional funding allocations.

Moreover, it is important to stress here the existence of a fundamental partnership principle, namely working towards a common goal both between local government and with operators – and more importantly than common actions – a shared commitment to high-quality public transport as a cornerstone of the city's character.

The jointly agreed aims of both operators and local government are stated as:

- congestion relief: enhance quality and reliability of service
- integrate different private operators while keeping/increasing commercial services
- increase accessibility (all aspects)
- facilitate sustainable developments

In this context, it was entirely logical that Nottingham was one of the first British cities to establish voluntary 'bus quality partnerships' (BQP) with public transport providers. Mooted early in the 1990s as a response to the considerable negative impact of bus deregulation, in particular the stifling of investment due to uncertainty, it is essentially a joint commitment wherein local authorities fund infrastructure and bus/LRT priority measures, in return for which operators agree to invest in vehicles and services.

The BQP concept has been applied to all main route corridors. The package from the local government perspective has included the features shown in table 4.2.

Table 4.2 Features of bus quality partnerships

• bus priority measures: 22km of bus lane, and a city centre clear zone (NET and bus only including turning points) • enforcement of bus priority: bus lane tow away operations • parking controls • parking pricing: differential to favour park and ride over city centre parking • planning controls • waiting facilities and interchange enhancement: shelters, real time information, information poles, accessible stops	• public transport network information (printed and electronic, including SMS texting of next bus) • network ticketing: Smartcard extended to pay for libraries, leisure and retail • network promotions • safety/personal security measures: CCTV, lighting, dedicated police support • commuter planning/employer toolkit • subsidised link bus services;

The bus operator response, as evidenced by its substantial investment in a modern and accessible fleet, has already been commented upon. In addition, services on BQP routes are colour branded, specifically promoted and receive a commitment to operate with the most modern vehicles, customer care trained staff and the highest possible standards of punctuality and reliability.

Mention should also be made of the city council role in research and monitoring, including customer satisfaction surveys noted in the introduction. This further encompasses a Bus Punctuality Improvement Programme, which includes specific targets of improved punctuality, reliability and journey times. Remedial action is sought where necessary, with journey time delays in the city centre area receiving specific attention.

4.4.5 Funding

While the great majority of public funding is through conventional means and planning processes, Nottingham is at the leading edge of proposing new and innovative ways of funding public transport improvements. It is one of several urban areas pursuing accelerated development zones as in the United States, allowing borrowing of central government money to fund transport infrastructure schemes which is ultimately repaid by local businesses. Both the city and county councils have already implemented a system of developer contributions towards integrated transport measures, including but not exclusive to public transport as allowed for under United Kingdom planning legislation.

The local authorities have also jointly mooted a workplace parking levy, a proposal well received in principle by central government. The view is that such an approach should be more acceptable to the community than road pricing. This debate continues.

4.4.6 In summary

Nottingham shows how commitment, unity of purpose and partnership, applied over a sustained period, can achieve many positive outcomes. Bus operators have managed to avoid the negative aspects of bus deregulation by deterring low-cost but low-quality transient entrants, a feature encountered elsewhere in the United Kingdom. By contrast, their market strength has been used to invest in quality and gain profits through maximising patronage over net revenue. While operating at 'arm's length', the ownership interests of the city council in NCT, will also have been telling in this respect.

Although it is not heavily involved in service planning and/or tendering, the city and county have taken a somewhat more holistic approach to supporting public transport, essentially creating the best environment for its provision than many elsewhere. This clearer separation of function probably does much to retain the functioning and effectiveness of the informal partnership approach. Mutual benefit abounds but more through independent, albeit understood to be interdependent, actions. Quantitative and qualitative improvements in public transport supply, pursued consistently over many years, have clearly stimulated increased demand.

5 Conclusion

Chapter summary

In concluding the report, the influences on transport mode choices and the usefulness of benefit and cost assessment in comparing suitability of modes for local context is reviewed with reference to case study findings.

Key messages

'One size does not fit all' the best mode choice depends of local conditions.

'Right moding' provides a transport mix to cater for travel needs now within economic environmental and social sustainability contexts for the future.

5.1 Costs and benefits are context specific

An appreciation of the costs and benefits of alternative transport modes is very useful in planning transport provision for local areas. Transport needs are by their nature situation dependent. As set out in chapter 3 of this report, urban form, that is population density and styles of housing, affects transport needs. However, the structure of the urban area in the location of key destinations at workplaces, schools, shops and recreation areas, together with the roads and railways that link them have a larger impact. Both are subject to government policies and regulations and both are subject to history.

It is therefore important to recognise the current land-use patterns in local areas and the community lifestyles based on these uses. The resultant pattern of travel origins and destinations needs to be met by transport mode supply. The primary aim of transport supply by local authorities will almost always be to cater for existing or expected travel needs.

While numbers of authors point to the value of transport provision for changing behaviour, for example rail stations encouraging higher-density living, it is important in a local context to consider the value of change. Where land is inexpensive and available in areas where population numbers are not high, there may be limited advantage in increasing densities. If the only benefit is an increase in rail use, then the value of increasing rail use to the wider community compared with alternative transport provision may need to be considered.

As the case studies in chapter 4 demonstrate, 'one size does not fit all' for transport mode provision. Cycling is an ideal second transport mode for trips to disbursed destinations on the predominantly flat terrain of the Heretaunga Plains around Hawke's Bay. In contrast, the population densities and trip patterns in Nottingham in England provide sufficient demand for bus services to run with little subsidy. However, in both urban areas, as in all urban areas of New Zealand, the car is still the dominant mode and transport provision would expect to cater for car travel within current planning horizons, albeit hopefully in cars with far lower or no pollution emissions.

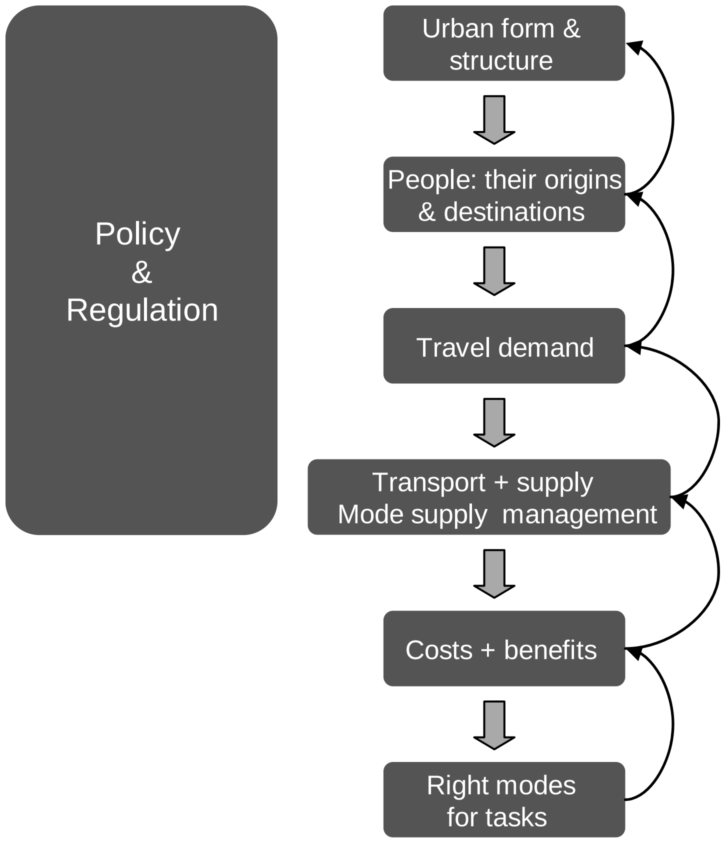
Care is thus needed in assuming that preference for particular transport modes such as cycling or light rail will automatically provide environmental or community benefits. Reference to the cost and benefit parameters in chapter 2 and appendix B shows that a poorly patronised public transport service can produce more emissions per passenger kilometre than travel by private car. The costs and benefits of options thus need to be assessed locally rather than being assumed to be the same as those experienced in other cities across the world that may be very different from New Zealand urban areas.

The challenge is to select the best mix of transport modes to match the range of transport tasks in the local area.

5.2 'Right moding'

Figure 5.1 summarises the interactions between land use, policies, travel patterns, transport demand and supply and their relative cost and benefits as discussed in chapters 2 and 3 and illustrated by the case studies in chapter 4.

Figure 5.1 Interactions between land use, policies, travel patterns, and transport demand and supply



As the illustration shows, while the local context influences the transport needs and best transport solutions for any particular situation in the present, there are feedback loops. Thus, transport decisions made by local authorities now may influence the area for years to come. Therefore, in catering for the immediate future one needs to consider likely changes within that planning horizon.

Effective transport by any mode is dependent on provision at a suitable level of quality. Quality requirements depend on local preferences but almost always include safety, reliability, connectivity and timeliness. Thus, in allocating budgets for transport provision, it is important that sufficient funding is available to meet such core requirements. As such, a bike path to 'the middle of nowhere' or a bus service running every two hours is unlikely to provide benefits.

Where limited budgets are available, it is important to make optimum use of existing infrastructure, particularly road space, as is shown in the case study of the Northern Busway where it shares the freeway in Auckland. Careful allocation of road space is important in view of increasing congestion in local areas. In particular, making sure that there is sufficient road space to allow economic activity in movement of freight and commercial service vehicles, travel for work, and at the same time sufficient space for key community service access to emergency services and health services, dictates that it will be important to provide alternatives to car travel for suitable trips.

Commuter trips in peak hours to city centres and school children's travel to school in peak hours are two examples where alternative provision gives a number of benefits to both the traveller and the community. Provision of alternatives for these trips, thus reducing pressure for new road infrastructure, are likely to have long-term benefits for transport budgets.

At the same time, assessment of the benefits of access and equity in areas with low car ownership or special needs as well as the cost of provision may justify higher subsidies for public transport provision.

Overall, a suitable mix of transport mode provision planned on the basis of full cost and benefit assessment is likely to ensure economic environmental and social sustainability for the future.

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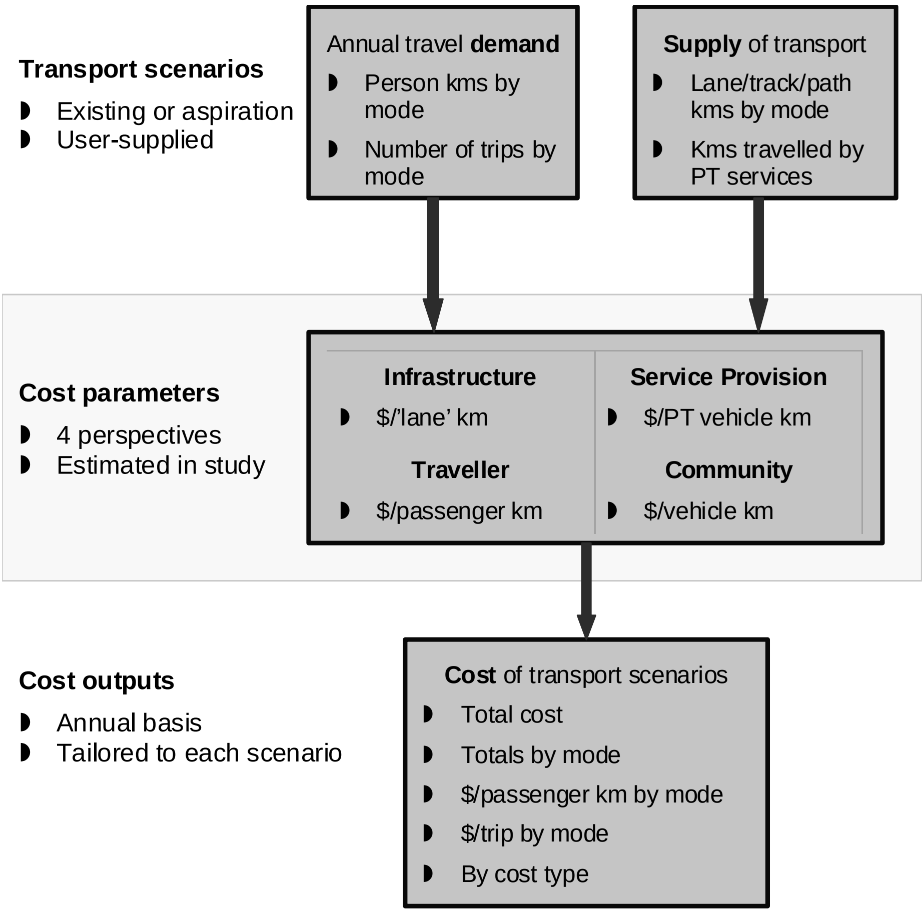
Appendix A: Cost estimation process

Cost estimation approach using parameters



For a given local authority area, a range of inputs is required about the existing (or hypothetical) supply and demand for transport, such as the annual distance travelled by buses on the network and the number of trips taken by that mode. This study will then seek to supply example parameter values for multiplication to arrive at total costs (and benefits) from each mode. This approach will allow local authorities to estimate indicative relative costs for alternative scenarios, such as different mode shares.

These estimates are given as parameters in units that, to the extent that is possible, do not assume a particular level of usage (or supply of) transport services. This is necessary because in many cases the costs associated with a mode are dependent on the level of use of that mode as well as other modes. For example, the accident cost and frequency for bicycles decrease with the number of cyclists and increase with the number of car users.

Appendix B: Further information on costs and benefits of transport modes

Public transport provision

Chapter 2 of this report discussed the costs associated with the provision of public transport – with the exception of the fixed infrastructure. The costs of providing public transport include: fuel/energy, staffing, insurance and vehicle purchase. These costs are required in NZ$ per vehicle kilometre. The following subsections describe how the estimates in the report were arrived at.

Fuel or energy

High and low estimates of energy per heavy and light vehicle kilometre were sourced from Kenworthy (2003). Estimates of energy prices were from ESAA (2009), with high values taken from Tasmanian prices to reflect the cost differential between the North and South Islands. Diesel consumption per kilometre was sourced from White (2008), with a diesel price sourced from www.pricewatch.co.nz/ The values used in the text averaged the high and low values estimated here.

Staff costs

Staff costs per kilometre were estimated by first finding a wage rate for transport drivers ($13 an hour from www.stuff.co.nz/dominion-post/news/wellington/639945) then combining this with an assumed operating speed for the transport. An uplift factor was applied to account for additional staff costs from non-driving staff. Uplifts of 20% –60% were applied for low and high estimates of staff costs, which were averaged to provide the values in text.

Insurance and registration costs

These costs were ascertained from internal sources about total annual insurance bills and annual kilometres travelled for public transport providers.

Vehicle purchase/lease costs

Upfront purchase costs were estimated from a range of publicly available procurement sources where new buses, light or heavy rail vehicles are purchased (eg www.smh.com.au/news/national/hills-district-to-get-20-new-buses/2008/06/18/1213468480137.html). High and low values for these purchase costs were selected from the top and bottom ends of these values. Kilometres travelled over a vehicle's useful life were sourced from publicly available estimates of economic lives and annual kilometres travelled (eg www.dpi.wa.gov.au/mediafiles/alt_confjamieally.pdf). The per kilometre costs involved sharing the total cost over the vehicle's lifetime kilometres.

Traveller costs and benefits

Chapter 2 discussed the costs and benefits for individual travellers in using each of the modes to travel one kilometre. This section of the appendix further explains this process with specific reference to high and low estimates for the parameters and their assumptions and sources.

Fares

- **Taxi**: several operator websites were surveyed in Auckland, Christchurch and Wellington to establish per kilometre charges and flagfalls. Per kilometre charges ranged from $2.30 to $2.60; flag falls from $2.80 to $3.50. Flag falls were split among each kilometre of an average travel distance of 9km, which was taken from the 1997/98 New Zealand Household Travel Survey. The lower costs were split across two passengers in the 'low' estimate; higher costs were used for a single passenger in the 'high' estimate.
- **Bus and rail**: fares were estimated from the distances and fares of a number of journeys in a range of cities: Auckland, Invercargill, Christchurch and Wellington. Representative trips of various distances were measured according to their land distance by Google Maps, with fares calculated between those origins and destinations according to website fare calculators.

Fuel

- **Car**: high and low values were derived from the NZAA's (2009) *Petrol car costs*. Low values assumed an average small petrol car surveyed by AA with a fuel use of 6.35 litres per 100km; high values assumed an average large petrol car using 12.27 litres per 100km. The low fuel value further assumed a petrol cost of $1.67/litre (AA's 2009 value); the high value was assumed at $2.15/litre (AA's 2008 value during the run-up in world oil prices).

Parking

- **Car:** low values for car parking costs assumed that drivers did not need to pay for parking. This was likely to be the case in less built-up urban and suburban areas. High values assumed drivers paid for private parking in a central city area of Auckland or Wellington (estimated at $20, based on hourly rates of surveyed operators) in between the two legs of a 15km round trip.

Vehicle purchase and maintenance

Vehicle purchase and maintenance costs are typically annual or long-term expenditures that must be assigned to each kilometre travelled in the table. For both car and bicycle these costs were estimated and apportioned according to assumed values for distances travelled.

- **Bicycle**: upfront purchase cost of $500 (low) or $1500 (high) was spread over the assumed number of kilometres over the useful life of the bicycle. In the low-cost value, the bicycle was assumed to be used for five 10km round trips per week for 50 weeks of the year for 10 years; the high-cost value assumed four 10km round trips per week for 30 weeks of the year (ie not used during colder months) for five years. The annual maintenance costs ($50 in 'low' value and $100 in 'high') were split across average annual kilometres.
- **Car**: upfront purchase costs of average small (low – $23,331) and large vehicle costs (high – $56,760) were divided by average annual vehicle kilometres (14,000) over an assumed life of 10 years. Values were sourced from the NZAA's (2009) *Petrol car costs*. The vehicle's sale value after 10 years was calculated by first deriving the NZAA's average annual depreciation rate for each vehicle class (the publication cites an 'average vehicle value at start of 3rd year') and applying this rate of depreciation to the vehicle's purchase value for 10 years. This sale value was then discounted to the 2009 dollar value by discounting at an interest rate of 8% per annum. This discounted sale value was divided by lifetime kilometres travelled and deducted from the purchase cost per kilometre. Annual running expenses such as tyres, maintenance and oil were taken from

the NZAA's pamphlet and divided by annual kilometres travelled and added to the net purchase cost.

Insurance and registration

Car costs were taken from the NZAA's (2009) petrol car costs for small (low-value) and large (high-value) cars and divided by the average kilometres travelled (14,000). The included costs were annual licensing ($248), insurance (comprehensive with no claim bonus for a 35-year old male for private use – $563 versus $957) and warrant of fitness ($45).

Travel (in-vehicle) time

The dollar value that people place on their time varies from person to person according to incomes, purpose of the trip, and even whether the time is spent 'in transit' or waiting. Guidance from the NZTA's (2009) *Economic evaluation manual* was followed in choosing the values of time – high values represented average values from the urban arterial roads ($19.35/hour in 2009 dollars), low values were assumed at $12/hour to represent lower time-value travellers' costs. Vehicle speeds were assumed based on consultant judgement. The monetary costs for one kilometre of travel by each mode was therefore the time value ($19.35/hour or $12/hour) divided by the speed of each mode (in km/hour). The assumed values are shown below for each mode.

Table B.1 Travel time cost parameters – high and low

	Low-cost value	**High-cost value**
Value of time ($/hr)	12.00	19.35
		Speed by mode (km/hr)
Walk	5	4
Bicycle	18	12
Bus	20	15
Light rail	23	15
Heavy rail	30	25
Taxi	30	20
Private car	30	20

Waiting time (including car space search) and access time

The approach to waiting time is similar to that for in-vehicle time, with the same time values assumed. Waiting times (in fractions of one hour) were assumed for each mode to represent the average time that travellers would either wait for a public transport service or take to search for an available car parking space. These values are shown below.

Access time costs were calculated in the same way as waiting time costs and represent an indicative cost of the time required to walk to or access a service (or car). The time values assumed are shown below.

Table B.2 Access and wait time cost parameters – high and low

	Wait or search time (minutes)		Access or walk time (minutes)	
	Low cost	**High cost**	**Low cost**	**High cost**
Walk	0	0	0	0
Bicycle	0	0	0	2
Bus	5	7	1	5
Light rail	3	5	1	5
Heavy rail	3	5	3	7
Taxi	0	2	0	2
Private car	0	3	0	4

Health impacts

Avoided health costs from active transport were split between the individual and the public health system. The estimates used here followed the NZTA's (2009) *Economic evaluation manual: volume 2* (EEM) in assigning per kilometre values for walking and cycling to the travellers themselves. The low 'cost' (high benefit) value was the most recent guidance (2009), while the 'high' value used the previous version of volume 2 of the EEM from 2005/6.

Accident costs

Low values for accident costs converted US dollar 'per mile' values from the VTPI manual (2009) into 2009 NZ dollar values 'per kilometre' for each of the modes (though some assumptions were made where data was unavailable, such as taxi and light rail). These values were based on the principle that what mattered was the cost caused by a kilometre of travel by that mode (eg the inherent danger imposed on others by walking – very low). Another way to think of this cost is the cost imposed per kilometre if all travel was conducted by that mode.

High values for accident costs take the car accident costs as a benchmark from the VTPI value above and factor this by proportion of fatalities associated with each of the other modes (regardless of which mode caused the crash) drawn from BTRE (2002). Under this method, walking was calculated to have a 15 times higher accident cost per kilometre travelled than car use, while public transport was calculated to have 17% –19% of the cost of car travel. These estimates represent the costs that are associated with a kilometre of travel by a mode (eg the average cost of accidents involving pedestrians – high), so translate well to the costs that an individual user faces given the current transport mix which is dominated by car use.

Table B.3 Traveller cost parameters – high and low

2009 NZ $/passenger km	Estimate	Fares	Fuel	Parking	Vehicle purchase/ lease/ service	Insurance/ registration	Travel time (in vehicle)	Wait time	Access time	Health	Accident risk
Walk	Low	-	-	-	-	-	2.40	-	-	-1.3	0.061
	High	-	-	-	-	-	4.84	-	-	-0.22	0.911
Bicycle	Low	-	-	-	0.04	-	0.67	-	-	-0.7	0.061
	High	-	-	-	0.33	-	1.61	-	0.14	-0.09	0.607
Bus	Low	0.17	-	-	-	-	0.60	0.10	0.02	-	0.003
	High	0.50	-	-	-	-	1.29	0.23	0.17	-	0.010
Light rail	Low	0.17	-	-	-	-	0.52	0.06	0.02	-	0.003
	High	0.50	-	-	-	-	1.29	0.17	0.17	-	0.010
Heavy rail	Low	0.16	-	-	-	-	0.40	0.06	0.06	-	0.003
	High	0.34	-	-	-	-	0.77	0.17	0.23	-	0.012
Taxi	Low	1.31	-	-	-	-	0.40	-	-	-	0.061
	High	3.79	-	-	-	-	0.97	0.07	0.07	-	0.061
Private car	Low	-	0.11	-	0.22	0.06	0.40	-	-	-	0.061

Community impacts of transport

High and low estimates

A wide range of estimates exists for the externalities of urban passenger transport. As with several of the measures in this study, the main difficulty was to locate sources that measured these externalities in a sufficiently transparent way so that values could be calculated per vehicle kilometre. Estimates typically embody their own assumptions about the number of people travelling in each vehicle. The various sources of estimates typically do not cover all modes relevant to this study. As a result, in several cases assumptions were required in order to provide indicative values of costs. This section provides more detailed references and explanations for the estimation of the cost values provided in chapter 2 and documents indicative ranges for each of the values.

Table B.4 Community cost parameter estimates – high and low

2009 NZ c/vehicle km		Accident costs	Noise	Air pollution	GHG	Severance	Health impacts	Up-/downstream impacts
Mode								
Walk	Low	0.00253				0	-131.7	0.1
	High	0.00342	0	0	0	0	-0.22	0.2
Bicycle	Low	0.00253				0	-65.9	0.4
	High	0.00342	0	0	0	0	-0.09	0.5
Bus	Low	0.26899	1.04805	17.9768	10.4717	1.04805	0.0	12.5589
	High	0.00342	0	0	0	0	-0.09	0.5
Light rail	Low	0.13449	2.87189	5.5748	5.69090	2.09611	0.0	15.1
	High	0.18196	3.88550	7.54244	7.69945	4.61856	0	22.6
Heavy rail	Low	0.13449	5.74378	11.1497	8.47046	6.28835	0.0	16.3
	High	0.18196	7.77100	15.0848	11.4600	13.8556	0	24.5
Car	Low	0.05633	0.52402	2.2027	1.57208	0.31086	0.0	2.62014
	High	0.07621	0.94147	2.30928	2.3	0.72831	0	3.45504

External accident costs per kilometre are estimated in VTPI (2009, p39) for walk, cycle, bus and private car. In the absence of further information, this study made the assumption that the accident rates and costs for light rail and heavy rail were half those of buses owing to the greater level of segregation of these modes from other modes. High and low values were simply estimated as plus and minus 15% of the VTPI estimates.

Noise pollution costs

Noise externalities imposed by walking and cycling were assumed to be zero. Three main sources were drawn on to establish a suitable range for public transport and car noise pollution costs. Austroads (2008, table 3.1) provided a range of values for car noise pollution and a low value for bus noise pollution. MoT et al (2005, table B12.5) contained a higher value for buses than the top of the Austroads range, so the former is reported as the upper bound for bus costs. Estimates for light and heavy rail noise pollution costs proved more difficult to source. ACT TAMS (2008, p91) provided rail estimates per carriage of A$0.0204 per rail car kilometre. This value was converted to 2009 NZ dollars and applied to a four-car heavy rail vehicle and a two-car light rail vehicle; high and low values were assumed at plus and minus 15% of these values.

Local air pollution costs

Local air pollution imposed by walking and cycling was, as expected, zero. As with noise pollution values, three main sources were drawn on to establish a suitable range for public transport and car local air pollution costs. Austroads (2008, table 3.1) provided a range of values for car local air pollution and a low value for buses. MoT et al (2005, table B12.5) gave a higher value for buses than the top of the Austroads range, so the former was reported as the upper bound for bus costs. Estimates for light and heavy rail local air pollution costs proved more difficult to source. ACT TAMS (2008, p91) provided rail estimates per carriage of A$0.0396 per rail car kilometre. This value was converted to 2009 NZ dollars and applied to a four-car heavy rail vehicle and a two-car light rail vehicle; high and low values were assumed at plus and minus 15% of these values.

Greenhouse gas emissions

Estimates for the cost of emissions of gases such as CO_2 are surprisingly difficult to come by for public transport modes. The estimates in this study largely reflect three sources: the Austroads (2008) range, VTPI (2008) estimates and Kenworthy (2003) estimates of energy intensity of average Australian and New Zealand public transport services. The greenhouse gas emissions cost of light rail (and heavy rail) were assumed to be in proportion to the energy usage of this mode compared with bus. High and low values were assumed at plus and minus 15% of these values.

Severance

There are few quantitative estimates of the severance imposed on communities by vehicle kilometre travelled. Austroads (2008, table 3.1) provided ranges for cars and buses, which were used in this study. Values for walking and cycling were assumed at zero, though in very high concentrations of pedestrians or cyclists it is conceivable that some severance would be present. For light rail and trains, severance per vehicle kilometre was assumed at multiples of the bus values due to: a) the greater vehicle lengths, and b) since their tracks are often in separate rights of way which can cause greater hindrance to pedestrian mobility than a bus on a mixed-use roadway. The multiples assumed were two times bus (light rail) and six times bus (for heavy rail).

Health impacts

Following guidance in NZTA's (2009) EEM, half of health benefits from taking healthy modes (walk and cycle) were considered to accrue to the individual with the other half falling on the community. The range of per kilometre health values chosen were those provided in successive EEM reports. The value in the main report placed 80% weight on the 2008/9 value, with only 20% weight allocated to the earlier value. Health impacts of the public transport and car modes were assumed to be zero, although most included some amount of exercise in walking to access the mode.

Upstream and downstream costs

Austroads (2008) provided a range of estimates for the externalities associated with the upstream and downstream production required for the operation of bus and car systems. These costs were used as the basis for estimating costs of other modes. Costs for walking were assumed at 5% of car requirements due to the externalities in production of footpaths and footwear. Similarly cycling costs were assumed at 15% of car costs due to externalities in production of cycleways and bicycles (and parts). Rail upstream and downstream costs were assumed to be higher than bus costs due to the greater infrastructure requirements (such as overhead lines and electricity transmission); bus costs were factored up by 20% for light rail and 30% for heavy rail.

Transport infrastructure provision

This section of the appendix provides a numerical example of the costs of providing infrastructure. As discussed in section 2.4, the costs of infrastructure vary dramatically even for a given mode, so only qualitative guidance is given in order to compare costs.

The case of the Gold Coast Light Rail project was selected for more detailed analysis in this appendix to illustrate the types of costs involved with transport infrastructure provision. The project involves the construction of 13km of north-south light rail line across the Gold Coast. The project was recently announced as being the recipient of A$365m of Infrastructure Australia funding, with a current total price tag of A$894m.

Attempting to break down this total cost gives an idea of the difficulty of providing a reliable range of costs according to the categories the study requires (construction, land, signalling, depot and maintenance cost). More specifically, the only publicly available detailed information about the project related to a 2003 proposal for the project when the total cost was estimated at A$345m for 17km of track and stops.

Ultimately we had to translate the $A cost estimates from 2003 into 2009 $NZ per track km values. In doing this, we also wanted to account for: a) the updated cost figures contained in the latest announcement; the non-fixed infrastructure costs (such as rolling stock) accounted for in the 2009 figure; the inflation effects over the 2003–2009 period; and the shorter span of works covered in the 2009 figure.

Step 1 was to examine the overall cost per lane km in 2003 and 2009 estimates. These were A$34m/km (= $894m ÷ (13km x 2 lanes)) in 2009 against A$10m in 2003. Step 2 was to account for how much of the total increase in project cost per lane km over the period was due to higher 'real' construction costs and how much was due to inflation. This was done by inflating the 2003 estimate by the percentage change in the 'Road and bridge construction' index for Queensland between 2003 and 2009, which showed that general construction costs had increased by 45%, meaning if the scope of works per kilometre stayed unchanged, the A$10m would equate to A$14.5m in 2009. Step 3 was to convert the original 2003 unit costs to 2003 unit costs that reflected the new information about 'real' costs of the proposal, ie factoring them up by 34/14.5. In step 4, these factored up 2003 $A costs were converted to 2009 $NZ using the exchange rate and New Zealand inflation rates. These cost estimates are shown in table B5.

Table B.5 Cost per 'lane' kilometre for Gold Coast Light Rail proposal

Cost component	$NZ 2009 estimates
Construction of lane/track	19.2
Land cost*	1.4
Signals/signage	0.4
Stops/interchange	1.1
Stops/shelters	2.4

*Includes land resumption costs only

The estimates suggest that the bulk of infrastructure costs are associated with the construction of the track and associated road works. These costs can vary significantly according to the conditions on the site, such as degree of earthworks, roadworks, bridges and tunnelling required. A second important point to note is that the land cost of transport infrastructure projects is rarely accurately accounted for since the landowners and transport providers are often the same entity. In reality, the land will have an opportunity cost, in that it could be used for a different and valuable purpose. This opportunity cost should be included in this component of infrastructure cost.

Further variability in the example cost figures is 'non-linearities' in some variables. This means that if either the length or the width of the service was to double (or increase 10-fold), the costs of the line items would probably not increase proportionally.

For example, the size and costs of stabling and maintenance facilities would not need to double if the length of track doubled. The size of the rolling stock fleet would be the main criterion for scaling maintenance facilities. Likewise, the number of stations, stops and shelters is not necessarily a function of the number of lanes or tracks featured in a transport infrastructure.

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Appendix C: Road space-related measures

Table C.1 Capacity enhancement measures[1]

Group	Aim	Category	Measure	Description	Effectiveness[1]
Capacity enhancement	Increase peak capacity	Lane management	Road layout reallocation	The creation of an extra lane or lanes by the reallocation of road layout or the use of the hard shoulder during peak periods	7%–50% travel time reduction. 4%–35% travel speed increase. 1%–37% travel delay reduction. 23%–30% accident reduction
			Tidal flow/reversible lanes	The switching of lane direction according to the direction of greatest demand during peak period. A further subset of this measure is where these lanes are used for high occupancy vehicles or commercial vehicles/buses	
			Variable speed limits	Varying speed limits to reflect prevailing traffic conditions.	
		Intersection traffic control	Signal coordination	Coordination of traffic signals to regulate vehicle flow in urban areas and ensure the delays are minimised at intersections	
			Ramp metering	Signals at freeway entrance ramps to regulate the number of vehicles entering and optimise freeway performance.	
			Access management	Limiting road access points and intersections to smooth traffic flow, direct tailback and reduce collision hazards. Often descried as entrance ramp closures	
		Vehicle control	Automatic vehicle control	Systems that automatically control vehicle speed and spacing (using radar or radio-based technologies). It should be noted that these systems are still at an experimental stage and large scale application is not expected in the next decade	
	Manage temporary loss of capacity through advanced flow management	Incident management	Detection, verification and report to traffic incidents	Can involve the use of advertising, signage, emergency lanes, ccv cameras on network connected to a response centre in order to preventing incidents reducing the capacity of the network and to restore capacity as soon as possible	6%–42% travel time reduction. 7% travel delay reduction. 35% accident reduction
		Work zone management	Management or road work areas (relating to construction, maintenance or utility work)	Can involve changing speed limits, timing of operations to low peak times, signage and other markers, diversions	
		Special events management	Management of traffic systems to cope with special events	Can involve pre event coordination and planning, land management and intersection traffic control.	
	Provide users with information	Traffic information systems	Systems that provide road users with information on traffic conditions to enable them to react to road conditions	Information on delays (due to congestion, road closure, construction, crashes, weather etc) is conveyed to road users either prior to departure or during travel, via the media, the internet, telephone, roadside variable message signs, or transmitted direct to in-vehicle displays	5%–30% travel time reduction. 16% travel speed increase. 44% travel delay reduction
		Route guidance systems	Systems that utilise electronic street directories to track vehicle location and provide route guidance to the driver.	Can involve the use of gps and other display or voice systems in vehicle or over the internet or via mobile phone	

1. Booz Allen Hamilton (2006)

Table C.2 Road space reallocation measures[2]

Group	Aim	Category	Measure	Description	Effectiveness[1]
Road space reallocation	modal priority	Bus lanes	With-flow priority lane	Taking at least one of the lanes in the direction of the major flow and dedicating it exclusively to bus use. in Auckland saw reductions in average bus times and reduced variability in bus times, patronage increases of between 12%–40% and very high benefit cost ratios	International case studies of bus lanes found 'significantly increased bus access to city centre', bus ridership increased 20% above national average, 10% of those with modal shift option switching to buses and 'seven-minute time saving'. With flow bus lanes
			Contra-flow priority lane	Taking a lane from the direction of the minor flow and dedicating exclusively to bus use	
			Median priority lane	Where physically possible provide a lane for the exclusive use of buses in the middle of the carriageway. This lane can be reversible, ie operate in peak flow direction.	
			Bus only street	Streets set aside exclusively for use by buses and pedestrians	
			Bus track	Bus operating in centrally located exclusive bus tracks sometimes in combination with trams	
			Busway	Creation of a segregated roadway for the exclusive use of buses	
			Exclusive priority ramp	Providing a motorway or freeway ramp either on and or off the route exclusively for use by buses	
			Bus gates	Gates used to meter traffic on to a road. Buses could bypass tollgates which other traffic must pass through	
		Traffic signal priority	Priority traffic signal setting	Involves incorporating the volume and flow of buses in the fixed-time plan of traffic signal setting	International case studies of priority signal setting found reduction of preferred mode travel times and reductions in delays
			Selective vehicle detection	The presence of a bus approaching a signalled junction is detected by placing a detector prior to the stop line. The presence of the bus then triggers a phase change either to end the existing phase if currently green or bring forward a green phase	International case studies of selective vehicle detection indicated reductions in preferred mode delays, increases in bus patronage and reduced journey times through junctions and thus length of route
			Queue relocation	Traffic signals can be used to meter traffic away from narrow sections of road onto wider sections of road	Unknown
			Pre-signals/bus advance areas	Pre-signals for buses at traffic lights so that buses get a green signal through the lights whist other modes going in the same direction get a red signal, enabling buses to gain further advantage over other modes. Needs to be utilised in conjunction with bus lanes	Unknown
			Gap generation facility	Creating a gap in traffic to enable buses to move off into the general traffic stream after stopping at a bus stop.	Unknown

Group	Aim	Category	Measure	Description	Effectiveness[1]
		Other traffic control measures to give one mode priority	Exclusive turning movements	Allows the preferred mode permission to make certain turning movements, eg 'No right turn – buses excepted'. Enables the preferred mode to bypass congested sections of road, take the direct route through an area or get closer to demand areas.	Unknown
			Metering of traffic onto arterial	Giving priority to preferred mode at signalised entry points onto arterial routes or having preferred mode only entry or exit points	Unknown
			Bus stop treatment	Parking, waiting or loading restrictions or extension of footpaths into carriageway to improved access of preferred mode from stopping points and rejoining the traffic stream	
	increased people movement	High occupancy vehicle lanes	HOV lanes	Providing a section or roadway accessible only by vehicles carrying a threshold number of passengers. The type of vehicle is not relevant but buses can usually use these lanes regardless of actual occupancy. 1. Separate rights of way – roadway or lanes developed exclusively for use by HOV. 2. Exclusive (barrier separated) rights of way – lanes constructed within the roadway separated from general purpose lanes and used exclusively by HOVs for all or part of the day. 3. With flow HOV lanes a lane in peak direction of travel that is not physically separated from other lanes. 4. Contra-flow HOV lanes – typically separated from the off-peak direction general purpose lanes by some type of changeable treatment (eg plastic pylons)	International case studies of HOV lanes found reductions in travel time savings for HOVs and for non HOV trips, increased use of carpooling, reduction in single occupant car modal share, increases in car occupancy rates
		High occupancy toll lanes	HOT lanes	Lanes available without charge for high occupancy vehicles whilst other vehicles can use the lane if they pay a toll]	Most effective in major urban areas with large employment centres, heavy congestions and supportive travel demand management policies
	traffic calming	Traffic calming – speed control	Physical vertical deflections	Road humps and speed cushions	Speed impacts downstream of a sample of traffic calming schemes were measures as falling from between 0.3 and 7.7 miles per hour and were highest when 14 foot humps were introduced. (Ewing 1999)
			Physical horizontal deflections	Traffic islands, pedestrian refuges, roundabouts, chicanes	
			Superficial measures	Measures that visually, audibly, or through vibrations direct a drivers selection of appropriate vehicle path, promote spatial separation between road users or encourage effective carriageway positioning Rumble devices, overrun areas, gateways, road marking, signing and contrasting surfaces	
		Traffic calming – volume control	Street closures	Street closures	Volume impacts of a sample of traffic calming schemes saw average percentage change in volume (as measured by vehicles per day) fall from between 5 and 44% with the highest
			One-way streets	One-way streets	

Group	Aim	Category	Measure	Description	Effectiveness[1]
			Diversions	Diversions	
2. Booz Allen Hamilton (2006a)					

Table C.3 Austroads travel demand management selection table[3]

		Where does the problem occur or where could a solution be targeted?					
		Individual building or site	**Group of sites**	**Link**	**Route**	**Corridor**	**Area/Region**
When does the problem occur?	Weekday peak	• Parking provision and management • Travel plan • Multi-modal access guides • Changing cost of car travel • Raising travel/environmental awareness • Improved ped. and bike facilities • Promoting walking and cycling for health • Ride-sharing carpooling or car-sharing • Teleworking, teleconferencing • Alternative hours • Smart growth or transit orientated development • Travel coordinator • Events and challenges	• Parking provision and management • Travel plan • Multimodal access guidelines • Changing cost of car travel • Raising travel/environmental awareness • Improved ped. and bike facilities • Promoting walking and cycling for health • Ride-sharing carpooling or car-sharing • Teleworking, teleconferencing • Alternative hours • Smart growth or transit orientated development • Transportation management association • Travel coordinator • Events and challenges	• Advanced traffic management systems – signal priority, access metering, lane restrictions • Public transport and HOV lanes • Improved ped. and bike facilities • Local area traffic management/ traffic calming	• Advanced traffic management systems • Advanced traveller information systems • Changing capacity • Public transport and high occupancy vehicle lanes • Improved ped. and bike facilities • Local area traffic management /traffic calming	• Advanced traffic management systems • Advanced traveller information systems • Advanced user payment systems • Changing capacity across routes • Public transport and HOV lanes • Improved ped. and bike facilities • Local area traffic management/ traffic calming • Community based travel behaviour change programme (eg travel smart)	• Advanced traffic management systems • Advanced traveller information systems • Advanced user payment systems • Physical restraint through area limitations (traffic cells/mazes, area licenses • Changing cost of car travel • Vehicle registration and purchase taxes • Campaigns to raise environmental awareness, reduce greenhouse gases or promote public transport • Community based travel behaviour change programme (eg travel smart) • Promoting walking and cycling for health • Ride-sharing carpooling or car-sharing • Smart growth or transit orientated development

		Where does the problem occur or where could a solution be targeted?					
		Individual building or site	**Group of sites**	**Link**	**Route**	**Corridor**	**Area / Region**
	Weekday off-peak or weekend	• Parking control and management • Travel plan • Teleconferencing	• Parking control and management • Travel plan • Local area traffic management/traffic calming • Changing cost of car travel • Campaigns to raise environmental awareness, reduce greenhouse gases or promote public transport • Transportation management association	• Advanced traffic management systems – signal priority, access metering, lane restrictions • Public transport and HOV lanes	• Advanced traffic management systems • Advanced traveller information systems	• Advanced traffic management systems • Advanced traveller information systems	• As above
	Variable – linked to special event timing or seasonal factors	• Public transport to special events • Subscription buses or shuttle buses • Alternative hours	• Public transport to special events • Subscription buses or shuttle buses • Alternative hours • Transportation management association	• Advanced traffic management systems – signal priority, access metering, lane restrictions • Public transport and HOV lanes	• Advanced traffic management systems • Advanced traveller information systems • Changing capacity • Public transport or HOV lanes	• Advanced traffic management systems • Advanced traveller information systems • Advanced user payment systems • Changing capacity • Public transport or HOV lanes	• As above
3. Austroads (2007)							