

# **Reliability and freight – literature and practice review**

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# Executive summary

## Existing treatment in New Zealand

The value of travel time reliability is related to the value of travel time savings/losses, commonly referred to as the value of time. The NZ Transport Agency *Economic evaluation manual* (EEM) provides guidance on values of time for economic evaluation, with separate values given for work, commuting and other travel purposes, with differentiation by car driver, car passenger and public transport passenger.

For a long time, economic evaluation in New Zealand has included values of time for vehicles and, in the case of freight vehicles, for commercial drivers. The value of time for vehicles is from an allocation of vehicle operating costs to either distance-related or time-related components, with the annual time used to estimate an hourly time value.

The EEM provides for the evaluation of journey time reliability in private road vehicle trips using the reliability ratio, the ratio of the value of one standard deviation in travel time to the value of travel time. The value of an improvement in reliability is evaluated from the change in standard deviation of variability, the value of time and the reliability ratio. The EEM does not currently provide for the evaluation of reliability for commercial vehicles and freight.

In application, the EEM methods estimate changes in reliability based directly on changes in the level of congestion on road links, which means there is no provision to evaluate improvements in reliability that do not rely on a reduction of congestion.

There is some general advice on freight demand elasticities included in the EEM, mainly relating to freight commodity and with a very wide range of values. These derive primarily from reviews of overseas study findings. The values are not of much practical use for evaluating practical freight demand problems, such as mode shifts or the effect of increased fuel prices and road user charges on freight demand.

## Market segmentation

The market segmentation for freight is particularly complex. We have explored the data sources for freight volumes and freight movement and find that these are not well aligned to factors likely to influence freight value of time and reliability. The perceived costs of off-schedule delivery are expected to differ between the transport operator and the freight shipper, unless these are one and the same. Often, freight forwarders and transport operators specifically insulate themselves from delivery time risks in their contracts of carriage. It is the shipper's value of time saving and reliability of delivery that is most likely to reflect economic value, whereas the transport operator's perceptions will be reflective of the costs of vehicle and driver time and schedule adherence.

## Reliability theory and methods

The UK is one of the few, if not the only, overseas jurisdiction that formally incorporates reliability into project economic appraisal. New Zealand practice has followed the UK but has admitted a wider range of reliability ratios. Where the UK differs from New Zealand is in how reliability improvements are evaluated. Reliability is evaluated only for i) motorways and other multilane highways and ii) in urban networks.

Austrroads (2011) recently reviewed the question of including reliability but concluded that a number of methodological and measurement challenges needed to be overcome before the concept of travel reliability could become standard in project appraisal.

There are two general approaches to identifying and assessing the impact of freight time delays and variability. The first approach, usually called the 'factor cost method' involves an analysis of the consequences of lateness in the freight transport operation and the related quantifiable costs. The second approach is to elicit perceived values for journey time, departure and arrival punctuality from the shipper or transporter in relation to cost using any model of shipper or carrier behaviours. This can include stated preference and revealed preference techniques which, while requiring a sufficient understanding of the freight choices facing respondents so as to be able to design a logical and realistic survey, do not require any direct knowledge of cost consequences of delays and variability.

## Freight demand elasticities

Freight demand elasticities emerge from meta-analyses across a range of national and international studies and from individual studies of transport choice through revealed or stated preference. The meta-analyses give a wide range of results, and studies are inherently difficult to compare due to imprecise and varying definitions and factors that are not necessarily included in the underlying demand models.

Price elasticity of the total freight market size in the short run is expected to be very low, as transport costs are only 5% to 10% of total costs of the final sale price. Long run demand response can be expected to be more elastic than short run due to possible cost reduction in the longer term through industry relocation. These expectations are borne out by the New Zealand evidence which is mainly on freight demand elasticity with respect to road user charges and fuel costs, which indicate elasticities of -0.01 or smaller.

For transport planning and investment evaluation purposes, the mode choice response to increases in cost is more likely to be of interest than the whole of freight market demand elasticity. Real choice where freight is not completely captive to one or other mode occurs primarily for long-distance rail versus road freight (and sometimes also coastal shipping). Most study results relate to manufactured and/or containerised goods. Rail direct price mode choice elasticity values are typically in the range -1.0 to -2.0, while truck elasticities are generally lower, often in the range -0.5 to -1.0. There is insufficient evidence to draw any further conclusions on elasticity differences by market sub-segments such as specific commodity or travel distance.

Apart from segmentation by commodity, which reflects underlying attributes such as stock value, substitutability and freight form, a number of other factors are influential in transport choices, in particular reliability, but also damage risk, frequency and consignment size.

We conclude that studies on freight mode choice cannot be directly compared. The inherent differences in the models and inputs make it extremely difficult to reach a consensus. The results of these studies are variable and cannot be readily interpreted in a New Zealand context. There appears to be a strong case for undertaking research into New Zealand-based freight choice to gain better understanding of shipper preferences in the New Zealand mode-choice context but also in other contexts where time, reliability and cost vary within a single freight mode. Other service variables such as damage risk would be included, and the choice sample stratified into the freight market segments described above.

## Reviewed priorities for subsequent stages

The discussion on market segmentation and the concepts of, and approaches to, reliability between passenger transport and freight and between private and public passenger transport lead us to the conclusion that there are as many differences as commonalities in the subject areas of the research. Also, the ongoing research scope under an omnibus project is very broad, with many specific areas that could



be pursued. In our view this would be more manageable if future research was compartmentalised within an overall framework.

We see three main divisions in the ongoing research:

- Reliability in general road traffic – common to private transport and buses in the general traffic stream and road freight; this area includes interventions to reduce variability of travel time in general traffic flow and/or its impact, and the treatment of reliability in traffic network modelling and evaluation using trip data.
- Reliability in personal transport – the research needs for reliability in personal travel are, in comparison to freight, more closely focused on the theory of reliability valuation, and the identification and evaluation of interventions to improve journey time reliability. The research does not specifically extend to identifying interventions to reduce delay.
- Value of time, reliability and demand elasticity for freight transport – the freight areas of research are more extensive in that they cover:
  - quantifying the impact of delays and identifying and evaluating interventions to reduce time delays and improve time reliability
  - developing new freight values of time and reliability
  - researching freight demand elasticities.

There is also more complexity in freight journey time reliability arising in the production and delivery chain, including linked trips, inter-modal transfers and intermediate storage, whereas reliability for passenger journeys is in most cases confined to within a single trip.

Research budgets are constrained, and it is unlikely that all areas can be pursued. For this reason we have made a comparative assessment of each topic using the following six criteria:

- **Importance of the knowledge gap** – in either preventing the application of potentially useful new methods or improving the quality of information applied
- **Size of each market segment** addressed by a research initiative – larger segments and those with potentially larger gains to be made should be prioritised over those that are smaller and/or where gains are likely to be relatively small
- **How New Zealand-specific the gaps are** – those less able to be filled by adopting and adapting existing or future overseas research should carry a higher priority
- **Chance of success** – the probability of achieving useful results
- **Intended research focus** – whether the topic is considered part of the intended research focus or has been/is being researched under other NZ Transport Agency projects or by others
- **Research cost** – the relative costs of items of research and in this regard market surveys form a potentially large cost.

The higher priority focus have been taken forward into a budget-constrained programme of work, with topics listed in assessed order of priority and some topics grouped together. The resulting programme and the way in which topics have been combined into research areas are detailed in chapter 10.

## Abstract

The NZ Transport Agency's *Economic evaluation manual* (EEM) provides guidance on the evaluation of journey time reliability in private road vehicle trips. The EEM currently does not provide for the evaluation of reliability for commercial vehicles and freight.

Austrroads has recently reviewed the question of including reliability into project economic appraisal but has concluded that a number of methodological and measurement challenges need to be overcome before the concept of travel reliability becomes standard in project appraisal.

There are two general approaches to identifying and assessing the impact of freight time delays and variability. The first approach, usually called the 'factor cost method' involves an analysis of the consequences of lateness in the freight transport operation and the related quantifiable costs. The second approach is to elicit perceived values for journey time, departure and arrival punctuality from the shipper or transporter in relation to cost using any model of shipper or carrier behaviours including stated preference and revealed preference techniques.

The research highlights the need for three main areas of further research:

- reliability in general road traffic
- reliability in personal transport
- value of time, reliability and demand elasticity for freight transport.

# 1 Introduction

The subject matter of this report covers four research themes in the NZ Transport Agency's ('the Transport Agency') 2010–2012 research portfolio, which were brought together in a combined research project, as follows:

- Journey time reliability for work commuting, tourism, other travel purposes and freight transport.
- The impact, including economic impacts, of time delays and journey time unreliability for freight, and the effectiveness and efficiency of measures to reduce these impacts. This also covers operational congestions at inter-modal transfers, rail yards, inland and sea ports and freight hubs.
- The value of journey time and journey time reliability for freight for application in the economic evaluation of projects. This includes component values for vehicle time based on vehicle holding costs and utilisation, driver and staff utilisation, and freight inventory and stock holding costs.
- Demand elasticities for freight, in particular demand elasticities for application in freight mode choice, and within-mode demand elasticities against cost and other level of service factors.

This research report addresses:

- a review of international and New Zealand literature and practice
- definition of terminology and development of a suitable market segmentation to form the basis of further market research
- development of market research plans
- a suggested programme for future research.

## 1.1 Scope

The report covers the second stage (the first was a short inception stage) of what was envisaged as a multi-stage project, with a detailed scope, work programme and budget to be agreed ahead of each subsequent stage. In the event, changing priorities within the Transport Agency led to the project being halted after the initial review of literature and practice. The currency of the review is approximately mid-2012, although the majority of the literature search was conducted in 2011. The review did not set out to be exhaustive of what is a very wide field, but was intended to be sufficient to develop the ongoing research direction, with further stages of review to be included in subsequent stages depending on the agreed research priorities. In particular, the later stages of a research programme involving the detailed design and execution of stated preference surveys has received relatively less attention.

It should be noted that, in several countries, there now is research and debate on both the unit value of reliability (the 'P-side of reliability') and on how to forecast changes in reliability, the impacts of projects on reliability and the reactions of travellers and freight agents to it (the 'Q-side of reliability'). Some of these countries already have (provisional) unit values and/or reliability forecasting models in place (eg UK, Netherlands, Sweden). This research project focused on what is done in the UK and Australia. Several countries (eg Germany) are working at the moment to build something similar to what New Zealand already has.

## 1.2 Structure of the report

This structure of the report is as follows:

- Chapter 2 introduces the definitions, concepts and perceptions for journey time reliability and the types of interventions that may be considered to improve reliability or reduce the impact of travel time variation.
- Chapter 3 discusses the present treatment of journey time reliability in New Zealand and addresses the value of time for commercial vehicles and freight for use in economic evaluation.
- Chapter 4 addresses market segmentation of transport in relation to commuting, tourism, other (personal travel) and freight.
- Chapter 5 reviews the literature on the theory and modelling of reliability.
- Chapter 6 reviews the international and New Zealand literature on travel time variability for personal travel, interventions for improving the reliability of journey times and methods for evaluating interventions.
- Chapter 7 reviews journey time delay and reliability for road and rail freight transport, including freight terminals and modal interchanges with sea and air.
- Chapter 8 reviews the literature on freight demand elasticities, including examples of generalised cost models developed for freight demand and modal analysis and the techniques used to determine modelling parameters.
- Chapter 9 reviews the structure and content of an ongoing research programme, identifies specific topic areas warranting research and ranks each topic based upon defined criteria.
- Chapter 10 organises the higher priority focus areas into a suggested programme of work. The programme envisages a number of separate work packages conducted under an umbrella project management to ensure coordination and integration within a consistent overall research framework.
- Chapter 11 is a bibliography of material identified during the review stage.

Appendix A provides a supporting review of New Zealand evidence relating to road use and fuel consumption price elasticities; appendix B details of the international studies reviewed relating to freight mode choice situations and appendix C contains a glossary of terms, abbreviations and acronyms.

## 2 Definitions and concepts

### 2.1 Introduction

In this chapter we discuss the definitions, concepts and perceptions for journey time reliability, including journey time, departure and arrival time reliability and how reliability is perceived and understood by the transport user in different travel contexts, including private transport, public passenger transport and freight. We also discuss the nature of impacts stemming from unreliability in journey time and freight delays, the types of interventions that may be considered to improve reliability or reduce the impact of travel time variation, and what sort of evaluation frameworks may be suitable for assessing interventions.

This section makes some limited reference to the literature but is primarily an introduction to the later sections that review each aspect in more detail. Key references used in preparing this section are Batley et al (2008), McKinnon et al (2008) and Fowkes and Whiteing (2006).

### 2.2 Travel purpose

The research brief was to consider reliability for commuting, tourism, other trip purposes and freight. In this section we define the travel purposes.

#### 2.2.1 Trip purpose categories

The commonly used trip purposes for passenger travel in traffic and transport planning in New Zealand are 'work', 'commuting' and 'other'. These are the categories used in the NZ Transport Agency (2010) *Economic evaluation manual* (EEM) procedures and for which typical traffic composition data has been published for various classes of road. 'Work' refers to travel made as part of paid work time, 'commuting' to travel to and from work, and 'other' is all other trip purposes. 'Other' trip purpose includes social and recreational travel, along with personal business and education trips. Social and recreational trip purposes, along with education trips, are sometimes identified in transport study demand surveys and modelling. Tourism is a subset of social and recreational travel.

**Work** – work travel purpose was not specifically included in the research brief but needs to be separated from commuting and other trip purposes for consistency with the EEM. The value of time for work travel in the EEM uses the marginal productivity of labour approach whereas the value of time for other trip purposes is based on behavioural studies. Work travel purpose refers to travel during the course of paid employment and does not include commuting. It is a very small component of public transport travel in New Zealand (urban bus and suburban rail) and a relatively small component of private car travel. Bus and truck drivers' time is work trip purpose. If a value for reliability is required for commuting and other travel, then a commensurate amount of effort should go into improving the research base for journey time reliability in work travel.

**Commuting** – is the most straightforward and refers to commuting to and from the workplace, primarily from home, known as home-based work trips in transport studies. Commuting trips may be by private or public transport. The context for commuting is primarily within the urban commuter radius but also applies to work commuting trips to jobs located in rural areas.

**Tourism** – is not commonly used as a trip purpose definition in road traffic and transport planning, and does not have a clear definition. The definitions in use and corresponding data sources on tourists and tourism travel are reviewed in more detail in chapter 4 which looks at market segmentation. From the

*Government policy statement on land transport funding 2012/2013 – 2021/2022* (MoT 2011b) and from the new state highway classification system<sup>1</sup> which includes numbers of tourists as one of the classification criteria, the government's focus of interest appears to lie in travel time reliability in the context of inbound international tourism more than the domestic tourism market.

**Other** – it is probably not a good idea to try and redefine 'other' travel purpose as excluding tourist travel. Instead, the existing definition of all travel purposes excluding work and commuting would remain, but recognise that in some cases, where tourist trips are significant in numbers or as a proportion of the traffic demand, they may deserve special attention.

**Freight** – freight transport is the carriage of goods either for hire or reward (commercial freight operators) or carriage of the owner's goods as an ancillary activity to an enterprise, such as a milk company's use of its own tanker trucks for farm collection. Small parcel couriers and mail are included in freight transport. However, household vehicles used for goods movement (mainly shopping) and tradesmen's vehicles (plumbers, electricians etc) are excluded.

## 2.3 Reliability and travel time variation

### 2.3.1 Personal travel

Reliability of travel or journey time is an area of study requiring care in terminology and definitions. Batley et al (2008), in a scoping study for the UK Department for Transport on the subject, prefer to use the term 'travel time variability' or 'journey time variability' which is more descriptive of the intended focus of study than is 'reliability', which can have broader connotations. They go on to define 'reliability', 'variability' and 'variance' to ensure a common understanding of terms and we do the same here.

We use journey time or travel time interchangeably to mean the time taken for an entire trip. For private transport this can be taken to mean the in-vehicle time although, for completeness, there is a (minimal) access time at the home end of the trip and a (sometimes significant) access time at the non-home end. For private transport, research on reliability concentrates on the in-vehicle trip time. For public transport, differences between the traveller's preferred departure and arrival times at the ends of their trip and the timetabling of the public transport service are more evidently significant and an aspect of research interest.

The dictionary definition of 'to rely' is 'depend on with confidence or assurance' or 'be dependent on'. It implies a relationship between the traveller and the transport system in which the traveller either through experience, or through information received, forms an expectation of the transport system's performance. Reliability is then the degree to which this expectation is realised. Reliability can refer to many aspects of transport service but it is only the reliability of journey time that is of interest here.

'Variability' describes the variation in the length of time taken for a journey or segments of it when the same journey is undertaken on multiple occasions. While 'travel time variability' or 'travel time variation' is the main subject of interest, there is also the potential for the value of variation in the expected length of the trip to also vary – so that unexpected early arrival may be valued differently from unexpected late arrival and the value or cost of late arrival may vary with the degree of lateness; that is there may be non-linearity in the cost of variation from the expected journey time.

The degree of travel time variability about the mean or expected value of journey time can be quantified statistically from the distribution of journey times over a number of similar trips. Variance, standard

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<sup>1</sup> Criteria, thresholds and categories for classifying the state highway network, accessed September 2011 from [www.nzta.govt.nz/planning/process/doc/criteria-and-thresholds.pdf](http://www.nzta.govt.nz/planning/process/doc/criteria-and-thresholds.pdf)

deviation (the square root of variance), coefficient of variation (standard deviation divided by the mean) and percentile measures are all used to quantify variability. If the distribution of travel times can be fitted to a probability distribution that facilitates mathematical analysis, then this is an advantage.

### 2.3.2 Freight

For shippers and consignees of freight, it is dependability that goods will be delivered to their destination at an expected time, set either at the time of ordering the goods or at some later time agreed between the consignee and the shipper, such as at the point of despatch. There may or may not be value in earlier than expected delivery and varying consequences of late delivery. The time of delivery agreement between the consignee and shipper may be more or less formal and could involve, at the extreme, contractual sanctions for lateness including financial penalties and on-going reputational damage.

Within the overall time period between order and receipt of the goods, there may be several stages starting with goods assembly and including one or several freight transport links possibly involving aggregation of small consignments into larger loads, line haul, local pickup and delivery, and mode transfers either inland or at ports and airports. So within the overall shipper to consignee journey there may be several linked transport and related activities, with the goods transferred between two or several parties, with delay risks at each stage.

Contractual relationships will exist between the parties involved which, apart from the shipper and consignee could also involve freight agents/forwarders and one or more transport operators. Just how the responsibilities for on-time performance are transferred between the parties will potentially influence each one's view of the consequences and so the importance of delays. There may be scheduling deadlines along the way that need to be met, such as sailing times, opening and closure of premises and driver hour limitations.

## 2.4 Variation in travel time and reliability

### 2.4.1 Traveller perception of variability and lateness

The time taken for a particular journey will vary, with the degree of congestion on the transport system providing the main source of variation. To some extent, transport users will be able to predict variation in journey time between congested and free-flow conditions and when those conditions are likely to occur. The perceived unreliability is the variation in journey time that the transport user is not able to predict and accommodate in their organisation of activities before and after the journey. This implies some lower, probably non-zero, threshold of variation or normal range of expectation within which the user considers the transport service to be fully reliable.

For scheduled services, including public passenger transport and some scheduled freight services, it is the lateness on the scheduled arrival time that constitutes the main expression and value of unreliability, together with late arrival at inter-modal or inter-service connections. However, as discussed later, when planning a trip by scheduled transport, the traveller will have some final destination arrival time in mind. This may influence their value of lateness of the transport service, depending on the service headway and the slack time between scheduled arrival and their final destination preferred time.

Defining unreliability as the unpredictable variation in journey time presupposes that the transport user has some basis of expectation of the average or most likely journey time. For regular journeys, such as work commuting, there is likely to be a firmer estimate of the expected journey time based on experience of carrying out the same journey at the same time of day than for a one-off trip for which there is no prior experience. In the case of infrequent trips on unscheduled services, the expected arrival time will be

influenced by external information. In the past this took the form of printed information about distances and times but increasingly is from online sources and based on current traffic conditions.

## 2.4.2 Usual, unusual and exceptional travel time variation

**Usual or day-to-day variation** is that which occurs for the same trip (origin, destination and route) made at the same time of day with no unusual influences such as traffic incidents (breakdowns, road works, crashes). The variation is made up of microscopic effects that are not readily predictable arising from the timing of many individual trips and variation in driver behaviour that give rise to small peaks in traffic concentration on certain links and intersections. While most variation is demand-side, there is also a supply-side contribution from traffic signals, influences of light and weather.

At high levels of saturation small random peaks can cause instability in traffic flow speeds and create transient waves of congestion. Usual variation is something that the regular traveller can make allowance for, consciously or unconsciously, by either providing some buffer time to avoid unacceptable lateness on schedule or by accepting the consequences of early or late arrival.

**Unusual or incident-related variation** is that arising from abnormal demand patterns, for example event traffic, from traffic incidents such as breakdowns and crashes, and from changes to network capacity, such as from closures and restrictions for road works, and traffic signal breakdowns. This is variation that travellers will not normally make allowance for in scheduling their journey, although if there is a high cost of failure to meet schedule (eg missing an air flight), then some additional buffer allowance may be made.

Currently the cost of traffic incidents is not specifically provided for in New Zealand evaluation practice. These unusual events are likely to be associated with longer but more infrequent delays than day-to-day variation and the implications and perceived cost to the traveller for a long delay may differ to that for a short delay.

It is important to understand where the dividing line lies between day-to-day and unusual variation in journey time and reliability when reviewing the body of international research and practice. If methods deal only with usual variation/reliability (as is currently the case in the EEM procedures), it is important to know how much of the unreliability and its consequences are captured and how much is ignored.

**Exceptional variation:** lower frequency exceptional events such as extreme weather, seismic or volcanic activity can cause major disruption to transport networks and introduce issues of lifeline resilience. This area has seen much research activity but is not the focus of this project. However, there does need to be some agreement as to where more frequent natural hazards fit as incidents or emergencies, such as roads prone to surface flooding or snow and ice closure, where events occur at a frequency of a few to several times a year.

## 2.4.3 Reliability and congestion

Early research into traveller willingness-to-pay (WTP) values did not draw a distinction between the two attributes of congestion and reliability. Reliability and congestion were recognised to be theoretically separable but in practice highly correlated effects, so that congested traffic implied a degree of unreliability in journey time, and a common measurement could be applied for both.

This has given way to a separation of the two effects, recognising that there is a disutility from travelling in a congested stream of traffic attributable to the need for increased driver vigilance and effort and less driver control of travel speed which are separable from whether there is uncertainty in journey time and arrival time. In public transport the disutility of crowding was separated from the disutility of lateness of arrival somewhat earlier than in car driving.

While congestion/crowding and journey time reliability may be recognised as separate contributions to the disutility of travel, for practical application there must be a means of independently measuring each effect.



This becomes important when considering ways in which journey time reliability can be improved in congested traffic through better demand management.

When reviewing the international literature it is important to observe how congestion and reliability have been treated in experimental design and whether congestion has either been controlled for, or has been separately incorporated as an attribute.

## 2.5 Measuring reliability and delay

### 2.5.1 Reliability and travel time variation

As noted, the traveller's perception of reliability is the extent to which the journey or arrival time falls within an expected range, based on the traveller's accumulated experience of that trip and/or uptake of information provided on its expected duration or schedule. It follows that within this range of travel times for a reliable trip the traveller is indifferent to any variability in travel time. Only when the travel time exceeds this threshold is there an unexpected delay with an associated disutility. The expected range of times is likely to be broader for unfamiliar trips than for regular trips, such as work commuting as there is less prior experience to draw upon.

When attempting to measure reliability in the field it is not possible to know each traveller's expectations of their journey time. So, for timetabled services, measurement has to be confined to adherence to schedule or, for frequent but un-timetabled services, variation in service headway. For completeness we would need to measure the access walk or park-and-ride trips to public transport and how variation in these access times and any slack time arising between the service schedule and preferred arrival time acts as a buffer to unreliability in the scheduled service.

For general traffic on roads, it would be desirable to measure all journey times between each origin/destination pair for each daily flow period to obtain the mean journey time and measures of variation, such as percentiles and standard deviation/variance. In practice, unless all vehicles are electronically tracked, measurement must resort to sampling the traffic stream over sections of road, and then use the data obtained to estimate the mean and variation in section travel times and in some way aggregate this data to estimates of mean and variation in full journey times.

Global positioning system (GPS) or induction loop measurements will not give each traveller's expectations of their journey time (or their preferred arrival time (PAT)). It would, however, be possible to collect data that combines interviews with individual travellers on their expectations and preferences (possibly web-based). Data on specific trips and travel speeds can be obtained from GPS or specific transponders.

So for both scheduled services and general road trips, there are measurement issues for travel time variation as well as a difference between travel time variation and reliability.

### 2.5.2 Statistical distribution of travel time variation

The frequency distribution for this unpredictable travel time can be expected to be positively skewed, with the most likely delay less than the mean delay and a tail of infrequent larger delays. The shape of the distribution may vary with mode (private vehicle, bus, rail), trip distance and level of congestion (with some suggestion that the skew reduces at higher levels of congestion).

### 2.5.3 Models for reliability – the mean–dispersion approach

The mean–dispersion approach hypothesises that travellers perceive uncertainty in journey time as a component cost of their utility of travel, so are responsive to changes in travel time variability about the

expected (mean) journey time ( $\mu$ ) as well as to travel time and other costs (fares, fuel etc) when making decisions such as mode, route and time-of-day choice.

A convenient measurable statistic for variability is the standard deviation ( $\sigma$ ), variance ( $\sigma^2$ ) or coefficient of variation ( $\sigma/\mu$ ) of the journey times being compared. The utility model then hypothesises that the traveller will trade off changes in the mean journey time with changes in the variability in journey time, the relative values between the value of time and the value of reliability elicited from studies involving choices between journeys of varying mean journey time and differing variability in journey time.

This is discussed further in section 5.2.2.

The mean–dispersion approach has the advantage that the reliability of each segment of a trip can be individually measured and the overall trip reliability then estimated by a combination of the variances of the segments. However, this estimate requires the sequential segment variation to be uncorrelated, and this is perceived as a weakness, as discussed in section 5.3.

#### 2.5.4 Models for reliability – the scheduling approach

The ‘scheduling’ or ‘schedule delay’ approach originated in models of departure time choice. The choice of departure time was seen to be one of minimising the costs to the traveller of early or late arrival around a PAT.

Different disutilities are hypothesised per minute of early arrival (schedule delay early), per minute of late arrival (schedule delay late) and for being late at all (L – either 0 or 1). Within this construct, the traveller makes a choice involving a trade-off between the amount of safety margin or ‘headstart’ at the beginning of the trip and the risk of early or late arrival around the PAT. This allows the utility or value of travel time saving to be used as a means of deriving utilities for each of the schedule delay factors. Three components of schedule delay are hypothesised on the basis that there may be a different traveller value to arriving ahead of time rather than late (late probably being a higher disutility) and that there may be penalty for being late at all irrespective of the degree of lateness, the severity depending on the consequences of missing the schedule.

This is discussed further in section 5.2.3.

#### 2.5.5 Approaches for road traffic and public transport

The reliability ratio approach (i.e. ratio of the value of one standard deviation in travel time to the value of travel time) is the model more readily applied to reliability in general highway traffic where the departure time is selected by the traveller and the variability is contained within the journey time. It does not require an understanding of the PAT which is difficult to observe, and it is this model that is most commonly used in practice. It does not even require a period choice (departure time choice) model. PATs might come from surveys or from a reverse-engineering approach.

For scheduled public passenger transport the situation is more complicated. Assuming that the traveller has a PAT, they have to contend with variability in departure time which, for a frequent service, could involve a choice between selecting an earlier or later departure. There is then the variation in the arrival time around the published schedule, and that the scheduled arrival time may not exactly coincide with the PAT.

It appears that current practice conflates the public transport operator’s idea of lateness with that of the traveller, so that variability around the scheduled departure and arrival times becomes the measure of reliability and it is assumed that the traveller’s PAT coincides with that of the schedule. It would be a convenience for modelling if this was borne out through empirical research and there is some evidence to support this.

## 2.5.6 Measuring delay and reliability for freight

For freight transport, lateness on a specified receipt time seems to be the way to best conceptualise reliability, making a scheduling model of variability more appropriate than standard deviation of travel time variability.

### 2.5.6.1 Road

The research scope includes the impact of freight *delays* as well as the impacts of *variation* in freight journey times. A good deal of the dissatisfaction of the freight industry with road conditions stems from the general delaying effects of congestion in the main urban centres and on some higher volume inter-urban freight routes as much as it does on uncertain journey times.

The base point for measuring road freight delay on the road network as it exists is the journey time under free-flow conditions with no traffic interaction. The free-flow journey time is limited only by road geometry, vehicle performance, traffic signal response times and speed limits. Delay is any time in excess of the free-flow journey time.

Road infrastructure improvements are a way to reduce delay, such as from upgrading from urban arterials and rural two-lane roads to limited access expressways and motorways with grade separation. Prioritisation measures that favour freight vehicles, such as signal pre-emption and reserved lanes are other alternatives to reduce delay. So interventions should include improvements that lower the measurement baseline for travel time as well as reducing the delay measured above the baseline.

### 2.5.6.2 Rail

For rail freight, total delivery time includes road access trips where rail does not directly serve the freight origin or destination, loading/unloading times between road and rail including any intermediate freight yard storage and waiting time, and the actual rail transit time.

The rail transit time is governed by train weight and loco type/power, gradients, maximum running speeds on track sections, any intermediate stops to drop or pick up wagons and delays caused by other traffic on the system. The section running speeds are governed by a variety of factors including track weight and condition, low-speed curves, steep gradients, negotiation of turnouts and other track structures, speed limits through tunnels and over bridges depending on their condition. Journey speeds on the New Zealand rail system are also constrained by the narrow gauge. Both freight and passenger trains operate on some sections and freight movement is limited to certain schedule windows, particularly during the night when the passenger services are not operating.

KiwiRail operates general inter-urban freight services between depots on overnight, two or three day delivery depending on the distance and whether an inter-island link is involved. Latest acceptance times and expected availability times at the destination end are published, so lateness on these schedules could be used as a measure of delay.

KiwiRail also provides 'hook and tow' services to those customers with their own rail siding or grid. Depending on the size of the operation, these may be rakes of wagons that are shunted by KiwiRail to one of its yards for make up into a train load, or may be hauled as full train loads in the case of some bulk commodities such as coal, logs and steel, using specialised wagons. Where the traffic is available, KiwiRail also operates unit train services on shuttle services, such as that between the Southdown rail/road Metrorail freight terminal and Port of Tauranga.

As for road, using the existing operating schedules as the base point for measuring delay is to accept the existing design and operating constraints of the rail network. Earlier delivery times would be possible with

infrastructure upgrading to provide higher running speeds and more opportunity for services to cross, or to separate freight and passenger on busy sections.

## 2.6 Valuation of reliability

### 2.6.1 Random utility modelling framework

Transport modelling and evaluation use microeconomic utility theory as an underpinning, expressed in generalised cost models for travel demand, mode and route choice. These random utility maximising models adopt the premise that the traveller will make travel choices based on a basket of travel attributes some of which have market prices (eg fares, fuel) while others have values that can be inferred from choices in which one combination of attributes is chosen over another. The models therefore indicate a travel choice that maximise the traveller's utility, which is usually expressed as a linear combination of attribute measures (eg travel time minutes) and behavioural values to convert attributes to a common numeraire, usually generalised cost. The models are random in that they include a random statistical error term that represents the residual variation between the model prediction and the observed data, and include unmodelled choice variables as well as random taste variation which, for a good explanatory model, should be of minor significance. A transformation of the model coefficients also allows them to be interpreted as demand elasticities, though the full probability formula is needed to derive these from logit models. Non-linear model forms can, for instance, be found in Mackie et al (2003).

The attributes included in generalised cost functions for highway traffic models will normally include, at a minimum, travel time and direct travel cost (or travel distance as a proxy). The models include some assumptions regarding traveller perception, for example that car owners only perceive a portion of their marginal cost of operation when making travel choices (often assumed to be the fuel cost). For models of public transport, the choice variables typically include fares, in-vehicle travel time, walking and waiting time, transfer penalties and modal taste preferences to take account of other features of each mode (smooth running and other comfort attributes, vehicle internal ambience, security etc) that are not specifically modelled. The research has not considered multi-modal models with a mode choice sub-model.

The variables considered in a traffic model need only achieve a sufficiently accurate estimate of behaviour if all that is required is an estimate of travel demand on parts of the network and if they are constrained by the model specification. However, using the traffic modelling output for input to economic evaluation depends on a traffic model that models choice using a random utility maximising specification. It should be noted that if choice models using this specification are available, the logsum changes from these could be used in project appraisal, instead of time and reliability changes combined with exogenous value of time and value of reliability.

In the economic evaluation framework, the EEM recognises travel time, congestion/crowding and reliability as separate components of utility, together with the resource costs of vehicle operation and values for road crashes and injuries; that is some variables that are not recognised as choice factors (at least explicitly) in behavioural modelling appear in the national economic evaluation as they involve changes in resource cost.

### 2.6.2 Modelling under traveller uncertainty – expected utility theory

Introducing reliability adds another dimension of traveller's uncertainty in one of the choice attributes to that of modeller's uncertainty in understanding the traveller's choice preferences.

The equivalent theory for decisions under uncertainty with a number of outcomes that can be accorded a probability (risk) of occurrence is expected utility theory. This provides for a choice to be made by the traveller based on maximising the risk-weighted outcomes according to the values attributed to each

choice attribute. The fact that only travel time is included as an uncertain variable is a matter of convenience and significance; there could be uncertainty in the direct cost of travel (say the fare for a taxi journey), or a lack of knowledge of fare structures or road tolls for an infrequent user.

The choice of traveller under uncertainty may not be risk-neutral. The traveller may be risk averse or be a risk taker. In the first case the traveller would make choices based on a wish to avoid negative outcomes (being late in this case). The difference between this position and a risk-neutral choice is referred to as the 'risk premium' in the literature. This can be thought of as a willingness to forego some time saving in exchange for a lower risk of being late. For risk takers, the decision would be to 'hope for the best' that there would be less than the normally expected delay, giving a negative risk premium.

Alternative approaches, such as prospect theory may be worth consideration (see Kahneman and Tversky 1979).

### 2.6.3 Behavioural modelling versus evaluation

Traffic modelling has the dual aims of ensuring: 1) the road and traffic networks are sized and configured to accommodate and/or manage demand and 2) to provide a basis for national viewpoint economic evaluation of user benefits against intervention costs.

Being able to reliably use the outputs of transport modelling for economic evaluation relies on the models of demand, mode choice and route selection being a sufficiently close approximation to travellers' choice processes, including all of the significant choice factors and their relative values discovered from market surveys (revealed preference (RP) or stated preference (SP)) undertaken in similar choice contexts.

It is recognised that the parameter values that described travel behaviour do not always align with economic resource costs, for reasons of travellers either misperceiving their true costs, or at least not taking all of their marginal costs into account, and because market prices differ from economic resource costs due to transfers (indirect taxes and subsidies).

Consequently, drivers are commonly assumed to perceive only their fuel costs and not the other variable costs of vehicle operation. On the other hand, fuel costs include a large indirect tax component, including excise duty and GST. Where the driver is not the owner or does not face the full cost of operation this may also affect decision making. Similarly drivers travelling as part of paid employment may make decisions that exhibit a different value of time (and reliability) to the costs incurred by their employer.

As well as making corrections for these differences between behavioural and resource costs, the economic evaluation procedures can incorporate policy positions, for example to not recognise travel time savings above the legal speed limit or to ignore some income related differences in behavioural values.

In similar fashion, the economic evaluation procedure for reliability may be arranged to look beyond the transport user responses and the behavioural values that can be inferred from them or elicited from market research. This recognises that the individual interests of parties involved in travel choice decisions will not necessarily sum to the collective national interest.

Even if individual travellers ignore or misperceive transport system reliability, there may still remain a case for valuing its effects in a national economic viewpoint analysis if unreliability leads to higher national economic costs. Conversely, for example in freight transport, reliability may be highly valued over a part of the journey because of contract conditions between parties, but not carry as much or any national economic cost consequences. Similarly, there could be a policy of penalising bus operators for off-schedule running, but this may not flow through into reduced travel costs for passengers.

So the context in which values of reliability are used may be important; whether they are for purposes of modelling travel behaviour, or to improve business efficiency and financial bottom line of transport operators, or for national economic viewpoint analysis.

## 2.7 Reliability in traffic networks and modelling

### 2.7.1 Introduction

In the literature, application of reliability in traffic networks and modelling the effects of reliability improvements falls within what are known as ‘supply side’ issues.

The majority of applications of reliability in transport modelling have been for private transport in traffic networks, primarily in traffic assignment and in the evaluation of reliability improvements. Application of reliability has been in traditional staged models of period flows with separate generation, distribution, mode split and assignment sub-models, allowing the issue of reliability to be confined to the assignment stage under a fixed demand assumption, although the variable demand effects of supply side constraints need to be tested in some congested urban conditions. This accounts for a large section of the urban traffic analysis that is carried out in New Zealand. The assignment algorithm will usually be iteration to a user equilibrium in which all used paths between an origin/destination pair have iterated to the same user cost and no user can change route and achieve a lower cost.

Reliability has been applied less, if at all, to dynamic models where unsatisfied demand is allowed to cascade from one time period to the next, or in micro-simulation assignment models. The most practical applications of reliability in cost-benefit analysis take assignment as ‘a given’ and calculate the reliability benefits as a post-processing of the traffic model outcomes.

### 2.7.2 Issues

There are a number of issues involved in applying reliability concepts in traffic modelling applications, including:

- Field measurement and representation of reliability is most easily carried out for road segments and intersection movements – how can travel time variability over these sections of routes can be realistically combined into time variability over complete trips?
- How can causal factors that affect network performance be modelled, in particular delay responses to demand variation (through volume/delay relationships for links and intersections) and traffic incidents that reduce capacity?
- How can the effects of user information be incorporated into route choice modelling, in an era where real-time information on network congestion can be fed back to drivers so that route selection decisions can be automated and changed during the trip?
- Data such as GPS-based data may not be able to distinguish cars from buses and trucks.

### 2.7.3 Congestion and reliability linked models

There has been empirical and theoretical research over the last decade to develop models of link travel time variation with speed/flow functions for different types of link. The output is a model formulation linking the coefficient of variation (CoV) of travel time (standard deviation/mean) with a congestion index.

Other research has worked with complete journeys, fitting models to observed data, which loses the ability to easily decompose the journey into links. These whole journey models have found the CoV to reduce

with trip length, indicating some degree of interaction between the reliability on consecutive journey segments, with higher reliability on one segment being possibly associated with lower reliability on adjoining segments. There is the possibility that the dynamics of diurnal flow into and out of urban areas is also an influence, whereas the traffic assignment models are generally static.

#### 2.7.4 Delinking components of reliability

A problem with models that link congestion directly to reliability is that they fail to provide for the consideration of interventions that might improve reliability independently of congestion, which would be highly desirable; the only way in which this delinking can occur is if there is sufficient fine detail in the specification of link types, so that an innovation can be modelled as substitution of a link type that is inherently more reliable. This in turn requires a deeper understanding of the causal factors contributing to reliability, both on the demand and supply sides.

Traffic incidents and ways of managing and reducing them present a slightly different and more complex problem to traffic control innovations that increase capacity or smooth traffic flow. Traffic incidents involve transient reductions in capacity, of varying duration, with effects that will often increase with demand volume, probability of occurrence that may also increase with demand volume (breakdowns and possibly crashes) and intervention times similarly. There are network effects in the demand response to incidents, with limited access expressways and motorways offering fewer opportunities for diversions than urban arterials.

#### 2.7.5 Reliability in route choice assignments

There are implications for assignment modelling if travel time variability is to be incorporated. Again, there will be a difference between links or routes that have a similar reliability characteristic from day to day and traffic incidents that are unexpected. For day-to-day variation, it is possible that drivers may include reliability in their route choice, although this needs to be demonstrated, whereas for traffic incidents it is arguable that driver routing decisions will not be influenced, unless they have access to some advance warning. The evaluation of advanced warning and route guidance interventions may hinge on routing decisions with and without this prior knowledge and the cost of randomly occurring incidents.

The US Strategic Highway Research Programme prepared a table of treatments and likely effects on reliability, so that reliability affects do not have to align with travel time and congestion effects.

#### 2.7.6 Preferred characteristics of a modelling approach

Clearly it is preferable that modellers are able to work with link and intersection data and build up a realistic model of complete journey time variability from this disaggregate data and that the link and intersection data is able to accommodate all:

- demand induced travel time variability
- systematic supply side changes to reliability from road design and traffic controls
- incident induced travel time variability.

To the extent that different traveller types and trip purposes exhibit different valuations for reliability, each of these groups should be separately represented in the network modelling as they may respond differently in traffic assignment algorithms that include reliability. This will constitute a change in practice for many New Zealand traffic models where individual trip purpose origin/destination matrices tend to be aggregated before the assignment stage.

### 2.7.7 Mean/standard deviation or scheduling approach

Whether travel time variability is incorporated as mean/standard deviation of link travel times with some linearly additive combination for complete journeys, or the scheduling approach taken is currently a matter of investigation in overseas research where both are being investigated. These matters are examined in the literature review in later sections of this report.

## 2.8 Value of time for freight

The value of time as applied in transport modelling and appraisal is a shorthand for the marginal utility of travel time savings (or losses) arising from a transport intervention. The value of time in personal travel combines the marginal value of the in-travel time and the marginal value of the time saved applied to another purpose at the end of the trip. The value of freight time can be decomposed in a similar way for freight as the marginal value of the time spent in transporting the goods and the marginal value of the freight time saved. These concepts have been well explored for personal travel but less for freight.

It was not an objective of this research to investigate the value of freight vehicle time for other than road transport.

### 2.8.1 Marginal value of road freight travel time

The contributions to a value of time during travel for freight transport lie in the freight itself and the use of the system used to carry it:

- The time cost of transporting the goods comprises:
  - the time-variable cost of the vehicle
  - the time-variable costs of vehicle driver/operator and crew.
- The marginal value of the freight time saved comprises:
  - time cost of capital tied up in the value of the goods (the stockholding cost)
  - time-related deterioration in the value of the goods (perishability)
  - time value of earlier receipt of the goods.

In regard to the freight itself, the mode of transport does not influence freight time value; rather the characteristics of the freight including values of time and reliability may influence the choice to transport mode. The five components of freight time value are discussed in sections 2.8.2 to 2.8.6 below.

### 2.8.2 Value of freight vehicle time

The cost of vehicle ownership and operation can be broken down into three components:

- 1 Distance-variable costs, in \$/km, are part of vehicle operating costs, so are excluded from the value of freight vehicle time
- 2 Time-variable costs relating to the number of hours the vehicle is utilised, in \$/h, are closely correlated with distance-variable costs, and may be considered part of vehicle operating cost. However, to the extent time savings release time that may be productively applied to increasing the hours of annual utilisation of the vehicle, there is an associated time value.
- 3 Standing costs arising on a periodical (monthly or annual) basis; savings in travel time that flow through into greater annual hours of utilisation result in a marginal reduction in the standing cost per hour.



A large component of time-variable cost is asset depreciation, expressed in either financial accounting terms or in resource cost terms as real depreciated value, approximated by resale value. Depreciation is a combination of use-related depreciation and age related depreciation. The age-related component can be thought of as a combination of age-related obsolescence and physical deterioration unrelated to use. Again an increase in the annual hours of utilisation spreads the age-related depreciation cost and results in a cost saving.

Repair and maintenance costs are mainly distance-related but may include a time component.

Standing costs include costs of vehicle storage/garaging, fixed overheads and administration and registration and warrant/certificate of fitness costs.

Across a fleet of vehicles, a general increase in annual utilisation may allow the company to reduce the number of vehicles in service and drivers employed. This is in effect an aggregation of the marginal savings described above.

### 2.8.3 Driver/operator and crew time

Cost savings will occur if savings in driver and crew time are able to be redeployed into additional driving (in a similar way to savings in vehicle time being applied to additional vehicle utilisation). The extent to which this occurs will depend on what other constraints and indivisibilities apply.

For drivers and crew different time constraints may apply to those for redeploying vehicle time, such as maximum driver hours and shift timings. In some cases vehicles will be associated exclusively with one driver (particularly sole trader owner/drivers) and in other cases there may be driver shift rotation among vehicles to increase vehicle utilisation in large fleets.

### 2.8.4 Stockholding costs

From the financial viewpoint of the producer/shipper of the goods, the stockholding cost is the opportunity cost (the weighted average cost of capital or WACC) of the difference between the sale price and cost of production (the added value) over the time between production and sale. This time difference may be unaffected by marginal delays in travel, unless the payment is closely linked to the time the goods are received and the incurred costs of production are closely linked to the time the goods are despatched. Except for long haul international freight where delays can be measured in days, internal road transport delays measured in minutes are likely to be insignificant in comparison to the length of the production process and the time delays involved in the goods invoicing and payment processes.

In resource cost terms for economic evaluation, the stockholding cost again applies to value added, although in resource cost terms. Whether there is any effective time saving will depend on the extent to which a travel time delay is buffered by the warehousing time after production and before use at either end of the trip.

### 2.8.5 Physical deterioration and/or maintaining condition

Time-related physical deterioration of the goods will result in a loss of market value, which will fall either on the supplier if this results in a lower sale price or on the buyer if the product has a lower value in use. Fresh produce and flowers are examples of perishable freight.

Perishable goods may also require equipment to maintain condition during transit, primarily climate control, which can be considered as part of the vehicle time cost (the cost of a refrigerated versus general cargo transport) or be associated with the freight value. As with stockholding costs, whether there is any net saving will depend on the warehousing of the goods at each end of the trip, the costs of climate control relative to that in-vehicle, and any net change in the market value.

### 2.8.6 Value of earlier receipt of the goods

The base for measuring changes in freight time is the time between ordering of the goods and the time of receipt. The question is whether a shortening of this ordering-up time through a reliable reduction in travel time has a value to the purchaser of the goods. For some urgent consignments, for example certain documents, critical parts and medical items, the need for the goods may not be anticipated in advance and delay can carry a high cost or risk – examples may be medical emergencies or critical equipment that will remain offline until a repair is made. In such cases it is the costs of non-availability of the goods at the point of receipt rather than the intrinsic value of the goods that gives rise to the value. This is a separate value to that of reliability of freight time which involves the costs of variation from the expected freight delivery time and is discussed below.

## 2.9 Value of travel time reliability for freight

The value of reliability, or cost of unreliability for freight transport is bound up in the scheduling constraints of the particular freight operation and the cost consequences of failure to perform within those constraints.

The following discussion draws on concepts discussed in Fowkes et al (2004; 2006) and McKinnon et al (2008) with some amplification in places.

### 2.9.1 Logistics systems

The scheduling constraints arise from the structure of the production and distribution logistics system with which the freight transport takes place. Information and communications technology (ICT) developments over the last 10 to 20 years have allowed goods production and freight delivery systems to become much more closely integrated. The advantages of doing so are to increase the feasibility of being able to manufacture and distribute to order, avoiding stock surpluses that may have to be later sold at a discount or worse, be unsold, generally known as just-in-time production/delivery. As well as avoiding mismatches between demand and supply of goods, this close linkage reduces the amount of work in progress and the working capital requirements, providing financial benefits for the firms involved.

A parallel change is the development of third party logistics (3PL) by companies who provide warehousing, freight forwarding and freight transport services to originators and receivers of freight. Historically, companies would move goods with their own transport (own-account or first party logistics) or engage directly with a freight transport company (second party logistics). The term fourth party logistics (4PL) has also been coined to describe companies who specialise in facilitation of freight transport, acting as entrepreneurs between customers and suppliers, but outsource all physical operations and own no transport equipment or warehousing. However, there is a lot of debate over the definition of 4PL or whether it actually exists as a fully formed concept. An alternative interpretation of 4PL is a 3PL provider that provides extended services into the customer's operation, for example taking on particular non-core parts of the business such as after-sales parts and repairs and leveraging value by combining such services to a large number of customers each of which would find it more expensive to provide the service directly.

The development of 3PL provides opportunities for consolidation of freight flows, and this in turn has led to more hub-and-spoke operation where 3PL facilities develop at strategic locations where large efficient warehousing can be provided close to main transport routes on land that is relatively cheap and not overly constrained by planning and environmental controls. Line haul over long distances can then be consolidated linking to local pickup and distribution using smaller vehicles appropriate to the consignment size.

As the transport network has become more efficient and reliable, this has allowed increasing specialisation, aggregation into larger units and centralisation to take advantage of scale economies. This is a flow-through

of the benefits of lower transport costs into locational changes and cost reductions for the production system and allows inventories to be centralised and minimised. In a similar way to private transport, this is an induced traffic effect in freight transport, where lower costs stimulate transport demand.

At the retail end of the transport chain, the second half of the last century saw the rise of the supermarket and shopping mall, a reduction in neighbourhood shopping and decline in home deliveries. However, the last decade has seen a swing back towards home and business deliveries using urban courier services, stimulated by internet online purchases. ICT also allows deliveries to be made directly from distribution centre to home, rather than through the intermediate retail store.

### 2.9.2 Scheduling constraints

The scheduling constraints within which the transport system operates arise from factors such as:

- The order period – the time between ordering up the goods and the end delivery which may include part of the manufacturing process, consignment assembly and the transport operation.
- Earliest/latest despatch time and earliest/latest delivery time – which may be influenced by working hours, in turn hinging on labour arrangements, whether shift working or daytime operations, overtime payments etc. Urban planning and traffic regulations may also limit hours of operation for pick-up or delivery to premises near residential areas. Where there is a mode transfer or connecting service such as sea or air this imposes scheduling deadlines.
- For the transport operator, the availability of transport equipment may be constrained by other demands and by driver shift hours and the acceptability of overnight layovers.

The vertical integration of production and distribution industries also influences the scheduling constraints and reflects the market influence of the larger players. For example some larger companies will contract owner/drivers or small transport companies and put adherence to schedules and the responsibility for the reliability onto the contracted service.

### 2.9.3 Nature and cost of consequences

McKinnon et al (2008) note five levels of disruption that can arise when a delivery is delayed:

- Level 1: delays are accommodated within normal operating procedure.
- Level 2: temporary redeployment of staff and equipment at minimal cost.
- Level 3: temporary deployment of additional resources such as overtime working.
- Level 4: delay to the next link in the supply chain – such as an outbound departure.
- Level 5: missed connection – more serious consequences involving the possibility of an out-of-stock situation, loss of sales and under-utilisation of outbound transport.

Fowkes et al (2006) describe the disutility of variation about the optimum departure time:

- earlier than desired departure – could require rushed production and consignment assembly, overtime working etc
- a minimum disutility at the optimum departure time
- a slack time period beyond the optimum departure time where disutility rises slowly
- a point beyond which consequences and costs rise due to the redeployment of resources (corresponding to levels 3 and 4 above)
- a missed connection point beyond which any further delay no longer matters (corresponding to level 5).

The costs of unreliability in these illustrations can occur to an activity or process before despatch, to the transport service (impact on vehicle and fleet utilisation, backloading opportunities etc) and to the subsequent activity or process. Just how these costs are borne by or transferred along the chain depends on the responsibilities and contractual relationships between the parties.

So, in some cases, it would be possible for larger cost consequences to be generated within the distribution system due to a lateness in the schedule, resulting in penalties to one or other party due to their contractual arrangements while, at the original shipper and end customer level the consequences would be relatively minor if a day to two delay in receipt was unimportant. The same could occur in reverse, there could be unacceptable consequences to the end customer from an unreliable delivery but, if the parties responsible for production and transport had passed on the responsibility for accepting the reliability risk to the end customer, they might be indifferent to the delays. The degree of market competition may play a large part in where the responsibility and costs for accepting or managing the reliability risks fall.

## 2.10 Interventions for reducing delays and unreliability

This research was undertaken primarily to inform the transport agencies of central and local government on how they could most cost-effectively intervene to improve the reliability of the transport system for users, including the general travelling public, consignors and transporters of goods and providers of passenger transport services.

There was a question of whether the research should consider only interventions by public sector transport agencies on behalf of users or if it should extend to complementary interventions by the transport users in partnership with the public sector.

Public agencies can intervene to reduce the frequency and consequences of unplanned incidents that disrupt the transport system, or can provide additional capacity and demand management. However, transport users can also play a role – for example in road freight, the importance of journey time reliability can depend on rigidities in opening and closing times of facilities at the start and the end of a delivery trip, or on staff rosters and working hours. The most cost-effective solution to improve the value underlying reliability may in some cases be a mixture of public and private sector interventions – improving the reliability of the transport system.

Our view is that interventions to improve reliability should consider interventions from the infrastructure supplier, transport operator and transport users to get a full picture of reliability and how it can be efficiently mitigated. For example, in some cases it may be more cost effective to supply real-time information to transport users on the current and projected reliability state of the network, if these have a lower ratio of benefit/cost, so that users can plan their travel accordingly rather than to invest in measures designed to increase system reliability.

Interventions to reduce, or limit the impact of, delays and travel time variability can be categorised generally as follows:

- infrastructure capacity enhancement and management – applying to all traffic using the network but with potential for selective prioritisation
- passenger transport operational management
- freight transport operational management.

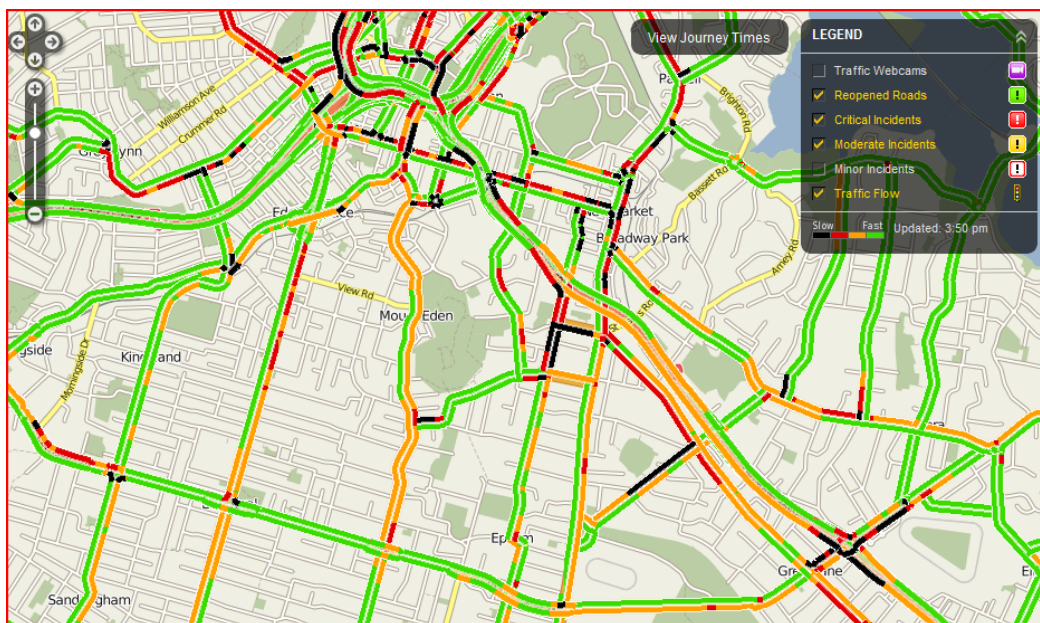
### 2.10.1 Infrastructure capacity enhancement and management

**Transport infrastructure capacity enhancements** – congestion is positively correlated with travel time variability, and increasing system capacity will improve reliability. For roads, the primary method is by adding extra traffic lanes and new links, by enlarging intersections and by grade separating crossing traffic movements, by geometric improvements on tow-lane rural roads and limiting side access. For rail, capacity can be increased by adding additional turning loops to single track rail, double tracking single track sections, improving the track geometry for higher speeds and improving signal controls.

**Active management** – allows the infrastructure to be operated with a higher throughput while maintaining an acceptable level of service. This includes the use of intelligent traffic systems to smooth flow and manage lane speeds and traffic merging so that shock waves of flow instability are minimised, including methods already employed such as motorway ramp metering. Allowing motorway shoulders to be used as auxiliary traffic lanes during high peaks is also practised overseas. On two-lane rural roads congestion and unreliability are frequently a result of lack of passing opportunities, and ways to enhance the capacity of passing lanes through use of speed, lane selection and merge control offer some prospect of reducing delays during high-flow periods.

**Traffic priority** – where it is considered desirable to reduce delays and improve reliability for certain classes of traffic there are techniques such as signal pre-emption, reserved lanes for high-occupancy and/or freight vehicles and ramps and links that are provided solely for specified vehicles. Targeted priority measures may be limited to certain heavily used links or be part of a more organised network of priority public transport and/or freight routes.

**Figure 2.1** Example of AA Geosmart map based on travel time and TREIS-fed incident data



**Incident anticipation and response** – this group of interventions is directed towards mitigating unusual unreliability from traffic incidents such as breakdowns and crashes. They include:

- web and road-based traveller information systems to alert drivers of an incident so that they can consider rerouting or retiming their trip – the Transport Agency already provides a web feed for incident data (Traffic Event Information System (TREIS)) which has been taken up by a number of application developers and has launched an integrated system DYNAC for on-road messaging and

signalling; the NZ Automobile Association also provides map-based data on current travel times based on vehicle-sourced GPS data and TREIS feed (see figure 2.1)

- quick response systems to clear incident blockages as rapidly as possible and provide interim temporary traffic management to reduce the impacts on traffic flow
- ways to harden selected links against incident occurrence that are either more susceptible to incidents or for which the impacts are greater.

**Traveller information and guidance systems** – even if delay and travel time variability cannot be entirely avoided, the impact for travellers can be mitigated by providing accurate real-time information on schedule delays so that travellers have the opportunity to choose alternative routes or departure times. Mobile phone technology will allow applications to be developed that can feed information to travellers based on their routine journeys. In urban traffic networks, active traffic management can now extend to real-time route guidance, so that vehicles are recommended the fastest routes by on-board instrumentation linked to a system monitoring centre fed by ‘crowdsourcing’ data from GPS positioned vehicles.

**Disaster anticipation and response** – this group of interventions is directed towards mitigating the impacts of exceptional unreliability arising from very infrequent and often high-impact events, such as natural disaster. We have taken the view that this is not the intended focus of the reliability research.

## 2.10.2 Passenger transport operational management

**Improved pre-planning of public transport operations** – the configuration of public transport networks can influence the scope for schedule adherence; for example long routes tend to increase the risk of off-schedule running and there will be compromises between route length and numbers of transfers to limit schedule delays. The use of advanced simulation software can assist in testing the susceptibility and resilience of public transport networks and operations to factors that interfere with punctual operation. Close coordination between public transport operators, the public transport authority and road controlling authority and their contractors to develop and implement guidelines for better delivery of punctuality, which may be supplemented with commercial incentives such as bonuses and penalties for high/low achievement of punctuality performance.

**Public transport scheduling management and control** – scheduled urban transit services, particularly buses sharing road space with general traffic are subject to variation in schedule adherence from various factors including traffic congestion and variation in passenger loading times, causing the ‘bunching’ tendency that is often observed. Ways of countering this variability include:

- addition of slack time into the schedule so that there can be extra dwell time at identified heavily used stops to improve punctuality but at the expense of increasing average journey times and peak vehicle demand
- active management using vehicle positioning systems in concert with area traffic control and optimisation software to improve schedule adherence.

**Traveller information and guidance in public transport** – traveller information systems in public transport have the potential to:

- assist users make better choices of transport service to suit their departure and arrival time constraints
- mitigate the impacts of unscheduled delays by forewarning travellers with up-to-date information on expected arrival times.

Traveller information systems include web-based applications that can be accessed before or during travel, information systems at transit stops and in-vehicle. Systems can be information only or interactive giving the traveller the opportunity to rearrange travel before setting out or change services en route. However, while there may be several route and service options combining different modes in large cities, in New Zealand the choices are likely to be fewer and in many cases there will only be one public transport service available.

### 2.10.3 Freight transport operational management

In the following discussion we work from strategic level interventions to tactical and operational interventions.

**National level physical planning** – public policy in New Zealand has been to allow market forces to lead the demand for the national level transport infrastructure of state highways which serve freight and passenger transport jointly, the rail network which is primarily for freight movement apart from the two urban commuter systems, and the ports (mainly freight) and airports (mainly passenger) which were originally public assets but overall still retain a large measure of regional or local public ownership. These transport assets interlink but are also in competition, rail with road, and ports and airports with each other. The ownership structure and cost recovery/pricing arrangements do not necessarily lead to an optimal allocation of resources for transport efficiency, including the reduction in delays, and there has long been a perception of the need for consolidation of port infrastructure with implications for inland freight movement and investments in road and rail. There are also questions of mode neutrality in public policy on cost recovery, pricing, taxation and investment decision making between road, rail and other modes. These are broad policy issues and ones which we judged not to be the focus of this research, so have been taken no further, although they may be one of the main opportunities for improved freight transport efficiency.

**Improved planning for freight distribution centres** – public policy applied to land-use controls that facilitate organisation of freight chains into more efficient configurations, while maintaining environmental standards and not disadvantaging passenger movement. This includes zoning to encourage the development of large blocks of land well connected with the primary transport network as freight hubs that are not restricted by proximity to residential development and are positioned to avoid traffic congestion. This needs to be done with an understanding of industry's current and future development needs and with provisions to ensure that the strategic advantages from the better location are not lost over time by crowding from later development.

**Improved planning for inter-modal freight terminals** – land use and transport network planning to better accommodate inter-modal freight terminals particularly at ports, many of which are constrained by their historic coastal locations close to city centres, but also airport business/industrial parks and road/rail terminals. Again, the objectives will be to allow efficient inter-modal transfers, to avoid the operations being time limited by surrounding development and to secure good connectivity with the main road network and designated freight routes that are less susceptible to congestion-induced delays.

**Improved pre-planning of goods distribution** – in the same way as for public transport there are pre-planning opportunities for freight movement planning, particularly in urban areas, to avoid congested locations and time periods. Close coordination between shippers, freight operators, residents, local authorities and the road controlling authorities in the form of freight forums and partnerships can help each party understand the operational imperatives of others and agree on mutually satisfactory arrangements. These may include scheduling arrangements to move deliveries away from the high traffic peaks, taking account of opening hours and environmental constraints and identification of freight networks and sympathetic traffic management arrangements taking account of all road users' interests. Some urban delivery times are restricted by curfews mainly for noise control; reduction measures for noise from truck engines, truck refrigeration units and goods discharge operations may allow these curfews to be relaxed.

**Goods distribution operational arrangements** – interventions aimed at improving the interface between production transport and consumption – an example of this is where supermarket stocking is linked back to distribution and from there to external ordering so as to deliver goods to the end demand as close as possible to the required time. The interventions lie in better working arrangements between industry and transport in areas such as despatch and delivery working hours, industrial agreements and inter-linked systems. To reduce the impact of delays and variability, introducing flexibility in staff roles to allow them to switch between goods reception/despatch to other warehouse or shop operations in response to varying demands may be considered.

**Improved mode transfers at transport terminals** – while these are just links in the transport supply chain, responsibility often changes at mode transfer points and developing efficient interfaces and inter-operability between modes is one area for delay reduction in the overall journey. This includes intermodal systems whereby two or more modes of transport are used to transport the same unitised package (container, truck etc) in an integrated manner, without loading or unloading, in a transport chain. Improving the efficiency and reducing the cost of inter-modal transfer should make rail more competitive with road where long distance rail transport is reliant on a road pickup or delivery at the trip ends. In turn, as well as reducing rail freight delay, this has the potential to marginally reduce road congestion and improve road reliability.

**Use of ICT in commercial fleet management** – in-vehicle systems vary from hands-off mobile phone communications to GPS tracking to more sophisticated navigation systems that incorporate congestion warning and routing guidance. However, such systems are useful in avoiding congestion only to the extent that there are alternative less congested routes and if fully exploited by all traffic the result will be uniformly congested route options. Tracking truck progress does allow freight operators to give advice to the receiver of the goods on expected arrival times, allowing them to adapt their resources to suit, limit their slack time and provide advice to the end customer. Overall, real-time tracking of the progress of deliveries provides an opportunity for the vehicle fleet to be more effectively managed and improve productivity.

## 2.11 Ways of evaluating impacts and interventions

### 2.11.1 Research objectives

An objective and output of the research is to develop methods for evaluating interventions to improve travel time reliability and, for freight, reducing the incidence and impact of delays. The methods are to be tested and illustrated by a number of worked examples.

A method requires an evaluation framework with objectives, relevant performance criteria for each objective, practical means of measuring and forecasting parameters contributing to the performance criteria, and an agreed method for combining the measures of performance before and after the intervention to allow the selection of a preferred option among mutually exclusive options, or the ranking of projects where independent interventions are being compared one against the other

### 2.11.2 Existing frameworks – the EEM

For New Zealand's economic appraisal process, a cost-benefit analysis framework is already in place through the EEM, and travel time savings and reliability savings are already incorporated as described in chapter 3. The EEM also incorporates many guidelines for the measurement of road traffic parameters and default or typical values, along with worked examples and simplified procedures for common situations. Some of these, for example traffic demand management, may have spin-off benefits in reliability improvement.

There is also provision in the EEM for the economic evaluation of passenger and freight services. In the case of freight the methods are aimed at rail and sea as alternatives to road freight transport. The



procedures demonstrate whether public investment is warranted to cover a project funding gap from transport user benefits not captured in the financial cost-benefit analysis from the freight operator's viewpoint. Procedures for incorporating reliability gains are also set out in the EEM. However, there is no specific provision for incorporating reliability gains for freight, other than in a general 'service quality improvement'.

### 2.11.3 Existing frameworks – evaluation against the *Government policy statement on land transport funding*

The *Government policy statement on land transport funding 2013 – 2021/2022* (MoT 2011b) has become an important statement of the government's public policy objectives for the sector. The GPS indicates the following impact areas for National Land Transport Fund spending:

- Improvements in the provision of infrastructure and services that enhance transport efficiency and lower the cost of transportation through:
  - improvements in journey time reliability
  - easing of severe congestion
  - more efficient freight supply chains
  - better use of existing transport capacity
  - better access to markets, employment and areas that contribute to economic growth
- A secure and resilient transport network
- Reductions in road deaths and serious injuries
- More transport choices, particularly for those with limited access to a car
- Reductions in adverse environmental effects from land transport
- Contributions to positive health outcomes.

The first of these impact areas is directed quite specifically at reliability and freight. The emphasis of the GPS has been changed from the 2008 NZ Transport Strategy and previous policy statements by placing more emphasis on transport to support the productive sectors of the economy.

The framework the government currently uses to assess and prioritise projects for the National Land Transport Programme (NLTP) is set out in the Transport Agency's Planning and Investment Knowledge Base. Projects are rated high, medium or low against the objectives of strategic fit, effectiveness and economic efficiency. In the current guidance on how these three objectives are assessed, the following definitions are relevant when considering how to develop an evaluation framework for interventions:

- **Key routes** are routes providing access to:
  - markets, areas with volume or value of freight greater than 10% of the total volume or value of freight in New Zealand or areas with firms at local authority level greater than 1% of the total firms in New Zealand, or
  - areas of employment greater than 1% of the total employees in New Zealand, or
  - areas of economic growth with either: growth in firms more than 20% above the national average in last five years; or growth in firms in an industry over the last year greater than 20% above the national average for the industry; or growth in employment over the last five years more than 20% above the national average.

- **Freight routes** as defined in the NZ Transport Agency's (2013) *Planning for freight*, are:
  - connections between freight generators and attractors with traffic volumes greater than 800 heavy commercial vehicles (HCVs) per day, including ports, airports, distribution centres and areas with a high concentration of firms, or
  - routes with no freight transport alternative if closed that handle a volume or value of freight greater than 10% above the national total or handles significant volumes of specialised commodities not normally transported on routes.
- **Journey time reliability** – as defined in the EEM as the day-to-day trip time variability, but not including unusual unreliability from traffic incidents which could, however, be interpreted as part of network resilience and security as 'other transport disruptions'.
- **Congestion** – routes where the volume/capacity (v/c) ratio exceeds 80% for five days per week over at least one hour on at least 1.5km of a route.
- **Severe congestion** – routes carrying in excess of 20,000 veh/day where the v/c ratio exceeds 100% for five days per week over at least one hour on at least 3km of a route.
- **Network security** – elimination of risks or effects of a disruption.

These precise definitions provide a good basis for categorising routes and setting targets for reliability and reducing freight delays in a way that integrates with government policy.

#### 2.11.4 Existing frameworks – regional transport planning

The regional land transport plans across the country include policy objectives and in some cases performance criteria and monitoring systems for reliability of journey time for private and public transport. For example the performance of public passenger transport in Auckland is grouped into three levels of local connectors, quality and rapid transport networks with increasing reliability standards in terms of adherence to schedule and lateness.

The various freight strategies developed by regional, district and city councils contain objectives and policies for managing and facilitating freight movement in their geographic areas.

Both of the above provide inputs to a potential framework for assessment of reliability and freight interventions and some synthesis across the country is needed to arrive at a common position.

#### 2.11.5 Framework for assessing reliability and freight interventions

A framework for assessing interventions aimed at improving reliability in the four trip purpose categories and in reducing delays and impacts for freight transport should have regard to the:

- requirements of the EEM, for national viewpoint economic assessment
- funding gap financial analysis for freight services projects seeking a government funding contribution
- objectives, categories and definitions in *Connecting New Zealand* (MoT 2011a)
- policies, performance indicators and monitoring systems used by the regions in their regional land transport plans, which in some cases incorporate freight plans or strategies.

The extent to which frameworks for assessing interventions developed overseas can contribute to this process will be greatly constrained by the differences in government structures and planning and funding processes.

In our proposal we envisaged a way of approaching the evaluation framework could be through a 'toolkit' approach, one that has been usefully employed by agencies such as the World Bank, accompanied by worked examples that illustrate features of the process for identifying delay and reliability issues, analysing the driving factors, developing potential mitigation measures and intervention and then an evaluation process for assessing their effectiveness and efficiency. The toolkit approach typically involves a structured decision framework that guides the user through a process, such as an evaluation, using a series of checklists and examples so that the most appropriate choice of a range of alternatives is made.

We have not undertaken a review of the overseas literature on evaluation methods for freight delay and reliability interventions, though this matter could be examined in future research.

## 2.12 Freight demand elasticities

### 2.12.1 Definitions

The demand elasticity of a product can be defined as the marginal change in demand for that product in response to a unit change in a characteristic of that product (most often the price) or of the consumer (most often the income); hence the price elasticity and income elasticity of demand. As demand usually falls when prices rise, the price elasticity is negative. However, it is quite common for the negative sign to be assumed and omitted. Income elasticity is usually positive, as demand tends to increase with income.

**Elastic and inelastic demand:** demand is elastic when a unit change in the characteristics, usually price, results in a greater than unit change in demand (elasticity of  $-1.0$  or greater negative). Demand is inelastic when a unit change in the characteristic results in less than a unit change in demand (elasticity between  $0.0$  and  $-1.0$ ).

**Demand curve and arc elasticity:** the demand elasticity is measured at a particular point on the demand curve and reflects the curvature of the demand curve at that point, called the arc elasticity of demand.

**Ordinary demand:** the relationship between price and demand on the assumption that other prices and the consumer's budget (or income) is held constant (same as uncompensated or Marshallian demand).

**Compensated demand:** the relationship between the price and demand on the assumption that other prices and the consumer's utility are held constant (Hicksian demand).

**Demand function:** the mathematical relationship between demand, price or income and potentially other characteristics influencing demand

**Demand units:** for freight transport, demand can be expressed as:

- volume of freight – tonnes
- volume of freight transport, tonne-kms
- volume of freight traffic, vehicle-km.

These all measure different characteristics and will be applicable in different circumstances depending on the focus of study.

**Own price and cross elasticities:** own price elasticity is the marginal change in demand for a good for a unit change in the price of that good; the cross-elasticity of demand is the marginal change in the demand for a good for a unit change in the price of another good, for example the cross-elasticity of demand for rail transport with respect to the price of road transport. With many studies focusing on road/rail mode shares, the demand elasticity of rail (or road) with respect to the ratio of the cost of rail to the cost of road has also been another way of expressing demand elasticity.

**Long and short-run elasticities:** the demand response to a price or other change may occur in the short term or may develop over time as systems take time to adjust, for example a price change may in the long run influence the locational decisions of businesses and the siting of transport terminals and consolidation points. Consequently long-run demand elasticities are often found to be more elastic than short-run elasticities as there is less opportunity for adjustment in the short term.

**Demand segmentation:** demand and corresponding demand elasticities can be expressed:

- across all freight commodities and freight forms or for individual commodities or freight forms
- across all transport modes or for specific transport modes such as road, rail, sea and air
- by length of trip/goods market: urban distribution; long distance/inter-regional; international
- for any other segmentation of the freight market, for example between own-account operators, commercial freight transport operators, and freight logistics (3PL) arrangements.

So, examples could be:

- demand for inter-regional coal transport by rail in freight-tonnes
- demand for urban distribution of foods and beverages by road
- demand for international transport of milk powder by land/sea.

This illustrates there is potentially a very wide range of demand elasticities.

**Aggregate and disaggregate demand:** studies of demand elasticity break down into those that use aggregate data on price and demand (typically from official sources and which often result in a wide range of results), and those that study demand for a closely defined example of freight transport decision-making (based on a demand model which is calibrated to observed or hypothetical behaviour and from which demand elasticities are derived). Where based on observed behaviour, there is a need for a sufficient range of variation in the explanatory variables in the model to gain confidence in its structure and yield useful results. The demand models fall into two main classes:

- inventory-based models which attempt to integrate mode choice into goods stockholding decisions
- behavioural models that concentrate on the mode choice decision.

**Non-price factors:** the literature shows a number of transport service factors to be instrumental in mode choice aside from price, including transit time, service reliability (that it will be there when you want it), delivery time punctuality (another form of reliability), security and damage risk to goods. These can all potentially form part of a choice model from which demand elasticities are estimated, and examples are discussed in the subsequent literature review.

## 2.12.2 Application in mode choice and overall freight demand

For freight transport, the most frequent application of elasticity data is in the analysis of mode choice, with the choice between road and rail dominating the literature. A few studies consider the three-way choice between road, rail and coastal shipping, which is also relevant to the New Zealand situation, and some countries have mode choice models that include inland waterway transport, which is not relevant to New Zealand.

As road is the dominant mode, changes in the price and other characteristics of road transport stand to result in changes both to the modal share of rail transport and to freight transport demand as a whole. An example might be response to an increase in road user charges (RUC) without any corresponding change to rail costs. If the road freight prices rise as a result of the increased cost then, where a mode choice exists, rail will be more competitive and increase its mode share. The proportionate change in overall road

freight volume will be much smaller than that for rail, and where there is no rail alternative, there may also be a reduction in demand, over the short and longer run, in response to the price increase. There is, of course, the potential for cost increases to be absorbed or for strategic pricing (under-pricing some parts of the market and over-pricing others where the demand is less elastic) by larger players to be used as a counter to the threat of modal competition, but these matters need to be considered as part of any studies in which demand elasticities are used.

In the case of rail, a change in the price or other characteristic of rail transport will influence the modal shares between road and rail but is less likely to influence overall freight demand. Exceptions could be for particular commodities where road is a particularly unsuitable mode of transport or where there is some legal restriction in place. There used to be rail/road distance competition restrictions in New Zealand before the mid-1980s but these were dismantled and there appears little prospect that they would be re-introduced.

When considering the overall demand for freight transport, income and expenditure effects become important. For example the growth in freight transport is widely found to be linked to GDP and heavy vehicle traffic (veh-km) has been modelled against regional GDP in New Zealand (Mackie et al 2006) and used in forward projections (an 'elasticity' of 1.3 to 1.4). Meanwhile overseas, governments are investigating ways to delink freight demand from economic growth – that is to obtain growth without increasing freight demand, or at least to reduce the rate of growth.

## 3 Existing treatment in New Zealand

The research included the value of time for freight and the reliability of journey time for personal travel and freight. As reliability is a measure of the variation in travel time and is linked directly to the value of time in the Transport Agency's evaluation procedures, a brief discussion of the existing treatment of time values is also needed. Further discussion of reliability theory and methods is contained in chapter 5.

### 3.1 Value of time for travellers

For in-vehicle work time (travelling during the course of paid employment), the Transport Agency procedures use values based on the marginal productivity of labour (MPL), comprising the average hourly earnings for a mix of occupational classes corresponding to the traveller segment plus employers' costs, with adjustments using the Hensher formula (Hensher 1977) for in-vehicle use of time (see Beca Carter Hollings & Ferner Ltd et al ((2002a)) for the basis of derivation).

For non-work time, willingness-to-pay values are used based on SP research carried out in New Zealand with benchmarking to international findings. Separate values are given for car drivers, car passengers and public transport riders with differentiation between work commuting and other trip purposes. HCV driver and passengers are attributed with the same values for non-work time as car drivers and passengers; however, most commercial vehicle driver and crew time is for work purpose derived from the MPL approach. Public transport crowding is acknowledged by different values for seated and standing passengers. Not all of the behavioural variations in the values of time are recognised in the evaluation, implying some averaging and some equity treatment. For example there is no distinction between bus and rail passenger value of time.

Since 2002, the values for savings of person time have been indexed using the Labour Cost Index (salary and ordinary time wage rates) for work time and the Consumer Price Index (all groups) for non-work time.

The values in the EEM are resource costs and do not necessarily reflect travel choice behaviour, particularly in the case of work time. The non-work time values are derived from SP surveys for travel time savings within mode. As the stated choice experiments trade time against monetary savings used to purchase goods on which indirect taxation is levied, an adjustment is made between with WTP costs and resource costs, an adjustment that is largely made up of GST which in New Zealand is applied across almost all consumer purchases.

### 3.2 Value of time for vehicles and freight

The values in the EEM combine a vehicle time value and a freight time value. There has not been a thorough review of these values for many years.

This section sets out the history of development of the values of vehicle and freight time savings as used in the practice manual that would eventually become the EEM, sequentially the National Roads Board (1986) *Economic appraisal manual* (EAM) (Bone 1986), the Transit NZ (1991) and then Transfund NZ (in 1997) *Project evaluation manual* (PEM). The early history is set out in Bone (1999) in a technical note to Transfund NZ as part of a periodic review exercise for economic evaluation parameters which is summarised below together with earlier information from Brown Copeland & Co (1982).

### 3.2.1 Practice up to 1985

Brown, Copeland & Co (1982) describe the early history in New Zealand for attributing values to vehicle and freight time in a commentary on the economic evaluation advice that pre-dated the EAM/PEM/EEM, Ministry of Works Roading Division circular memorandum RD98 (ca 1980) showing that values for vehicle and freight time were in use in New Zealand economic evaluation as far back as Read (1971) but that the values in use ca 1982 were unsatisfactory. Brown, Copeland & Co (1982) estimated a new set of values as shown below in table 3.1.

In this table the conversion factors are the adjustment from financial costs to resource costs that have been applied. The purpose is to remove transfers that do not increase costs from the national viewpoint and to apply any shadow pricing for items where the financial cost does not represent the economic value (because of price control, subsidies or restrictions on foreign exchange). The corrections in this case are solely to remove indirect taxes, apart from interest on capital which is regarded as a transfer from the national viewpoint so is removed entirely. Note that this analysis and table 3.2 pre-date the introduction of GST. Note also that driver wages are included in the value of travel time savings for vehicle occupants.

**Table 3.1 Breakdown of vehicle annual time-related resource costs in the economic evaluation procedures, 1982**

Cost component	Conversion factor	LCV	HCV urban petrol	HCV rural diesel	HCV rural petrol
Time-based depreciation	0.70	403.21	504.14	907.11	509.68
Interest on capital value	0.00	-	-	-	-
Garaging costs	0.90	102.96	205.92	308.88	205.92
Insurance	0.95	154.80	191.76	470.82	197.63
Annual licence fee	1.00	20.20	20.20	40.40	20.20
Accident compensation levy	1.00	12.20	12.20	12.20	12.20
Warrant/cert of fitness	1.00	10.00	26.00	52.00	52.00
Administration fee	0.95	-	4.00	8.00	4.00
<b>Total</b>		<b>695.63</b>	<b>964.02</b>	<b>1,799.21</b>	<b>975.43</b>
Annual hours utilisation		1800	1800	1800	1800
Value of time \$ per vehicle-hour		0.39	0.54	1.00	0.54
Value of freight time \$/h			0.51	1.03	1.03
Vehicle + freight time			1.05	2.03	1.57

Source: Brown, Copeland & Co (1982)

Brown, Copeland & Co (1982) 'in the absence of any other readily accessible data' used a value for freight time of \$0.585 per hour for HCVs, which is taken from a confidential Ministry of Works and Development (1979) internal memorandum as the starting point for estimating a value of freight time in 1982. This figure was derived assuming an average loading of 4.5 tonnes of freight per vehicle, applicable then to a HCV in rural use, with a lower load factor for HCVs in urban use. The time value per tonne of freight is thought to originate even further back in an Australian study in the early 1970s where a value of 5 cents per ton per hour was adopted for use in New Zealand in the absence of firm data. After some further indexing forward to 1982, the resulting values were calculated for freight time of \$0.51 per hour for urban HCVs and \$1.03 per hour for rural HCVs.

There is an implicit assumption in this method for valuing vehicle time that any time savings released can be completely converted to additional vehicle utilisation on productive work. This assumption has continued through to the present day.

### 3.2.2 Practice from 1986 to 1990

The vehicle time values in 1986 were based on analysis by WD Scott DH&S (1986). The time-based costs of each vehicle type were divided by an assumed annual utilisation of 1800 hours, informed by the earlier work of Brown Copeland & Co (1982).

**Table 3.2 Breakdown of vehicle annual time-related resource costs in the economic evaluation procedures, 1986**

Cost component	Conversion factor	LCV	MCV	HCV-I	HCV-II (exc trailer)	Trailer
Time-based depreciation (% time-related)	1.00	488.62 70%	2628.40 80%	8894.04 80%	12,795.66 80%	813.78 33%
Interest on capital value	1.00	501.76	2186.81	6327.45	8979.28	1520.00
Garaging costs	0.90	247.50	556.88	556.88	742.50	742.50
Insurance	0.95	318.25	285.00	703.95	1485.80	771.07
Annual licence fee	1.00	47.20	47.20	47.20	47.20	47.20
Accident compensation levy	1.00	21.55	21.55	21.55	21.55	-
Warrant/certificate of fitness	1.00	12.00	39.00	48.00	57.00	43.50
<b>Total</b>		<b>1638.88</b>	<b>5764.84</b>	<b>16,599.07</b>	<b>24,128.99</b>	<b>3938.05</b>

Source: WD Scott DH&S (1986)

The depreciation costs come from a year-by-year analysis of depreciation, using a declining utilisation with age in kilometres/year, and the age spectrum of the vehicle stock for each vehicle class. Beyond 12 years old vehicles were assumed to have depreciated to 5% of their original value and not to depreciate further. The depreciation relationship itself derives from Bennett and Dunn (1985) as does the breakdown into time and distance related components: 70% time-related for light commercial vehicles (LCVs), 80% for medium commercial vehicles (MCVs) and HCVs and 33% for trailers.

The insurance costs derive from the annual publication by the Ministry of Transport at the time of car and truck operating costs.

The interest cost represents the opportunity cost of the capital invested in the vehicle fleet if deployed elsewhere and is based on an age-weighted depreciated value of the vehicles in each class and an interest rate, for which 10% was used. Inclusion of interest costs was a departure from the previous practice, where interest was treated as a transfer payment (Brown, Copeland & Co 1982).

Garaging costs were based on those used by the Ministry of Transport (1986) together with assumptions regarding the percentage of the fleet in each vehicle class that is garaged. These assumptions were 50% for LCVs and 75% for MCVs and HCVs.

No values for freight time were included in the 1986 EAM. No record of why this was so has been located, but a probable reason is that the existing basis was by that time completely unsatisfactory and it was suspected that value of freight time was relatively small in comparison with the value of vehicle time, which itself was subject to some estimation uncertainty, particularly around the allocation of depreciation between age and utilisation.



### 3.2.3 Practice from 1991 onwards

In the 1991 version of the Transit NZ *Project evaluation manual* (PEM), the values of vehicle time were updated, apparently by cost indexing rather than a full review. At the same time some very approximate freight time values were added, varying from 10 cents per hour for LCVs +up to \$1.50 per hour for HCV-II. These added no more than 10% to the values of vehicle time.

How these values were arrived at is described in Beca Carter Hollings & Ferner (1991):

*Inclusion of the value of freight time savings involves a knowledge of the commodities and quantities being carried and the cost of delays per unit. Delay costs for freight may include:*

- *Deterioration of perishable cargoes, resulting in lower market value.*
- *More rapid delivery may allow in-transit packaging and environment control of cargo to be less demanding and cheaper. Alternatively, cooling has to be provided for less time.*
- *The need to maintain a larger stock of product between the points of production and consumption, with the attendant opportunity cost of this extra stock.*

*Although for any particular goods delivery, such savings may appear inconsequential or unlikely, accumulated time savings will allow changes to be made over time and, more importantly will be taken advantage of in the location and organisation of warehousing and distribution.*

*It should be noted that the cost of freight vehicle time is already incorporated in the values currently in use, it is only the cargo time value that is at issue here. Also, cargo deterioration may result from rough handling which is a separate issue from the value of freight time saving.*

*Data requirements for the analysis of cargo time value are:*

- *Load factors and commodities carried*
- *Rate of value loss on perishable commodities*
- *Market value of commodities at point of production*

*A classification of commodities for which there is some recent statistical data on relative quantities carried is the MoT Commercial Road Transport Monitoring Report 1986-87, August 1989. Unfortunately the categories do not distinguish commodities very effectively, being a mixture of load type and service type descriptions. Some categories, such as "heavy haulage" are vague.*

*A more useful classification was provided by the Ministry of Works Commodity Surveys. Unfortunately, the number of such surveys has declined in recent years.*

*The value of cargo can be broadly summarised into low, medium and high value corresponding to under \$1000/tonne, \$1,000 - \$10,000/tonne and over \$10,000/tonne. For a medium value commodity of say \$5,000/tonne, the opportunity cost of capital involved in production, assuming this is related to the marginal selling price at the factory gate, at say 10% per annum equates to approximately 6 cents/tonne/hour. For a truck carrying 25 tonnes, this is \$1.50/h compared with \$22.7/h vehicle time. This component of cargo time value will thus be low on average, although for certain high value cargoes it will be much more significant. For light commercial vehicles, a proportion will be engaged on courier and mail services, for which time values will be much higher than the average.*

*The cost of time savings on perishable produce carried without refrigeration can be related to the rate of value loss in transit. For fruit and vegetables assuming \$1000/tonne wholesale value and a shelf life when in transit without special cooling of 40 hours, the value of time saving is \$25/tonne/h. However this will only apply to a relatively small proportion of road freight. More frequently, the cost of refrigerated transport will be the determining factor, and the cost of providing refrigerated storage, assuming 15 tonnes of produce in a 20 ft reefer ISO container, is about \$0.1/tonne/h. The above estimates are very approximate and the subject requires more investigation. However as an interim allowance, the following costs of freight time are suggested:*

<b>Vehicle type</b>	<b>Freight time cost \$/veh/h 1991</b>
<i>Light commercial</i>	0.10
<i>Medium commercial</i>	0.40
<i>Heavy commercial -I</i>	0.75
<i>Heavy commercial - II</i>	1.50

*Note: the above costs are for vehicle in the traffic stream; an allowance has been made for empty running”*

Text describing these values was suggested to accompany the tables in the PEM, although this was not included in the final publication:

*Vehicle Time: Savings in commercial vehicle time allow the vehicle to be used for additional travel, spreading the fixed annual costs of operation over a greater annual hourly utilisation. There are other ways in which reduced vehicle time can lead to a user response, by reorganisation of travel patterns, rescheduling of maintenance tasks, reduction in the number of vehicles employed and changes to depot location and operating methods.*

*Although there are various ways in which the time savings of commercial vehicles can be utilised by their operators, there will be some situations that occur in project evaluation where fixed services are being considered and extra time will not lead to extra utilisation. ... It may also be reasonable to discount vehicle time savings for long distance commercial vehicles on rural roads, although the task of identifying this traffic may be difficult in practice. ... The value of vehicle time per hour has been calculated from the resource costs of annual standing charges divided by the estimated annual hourly utilisation, which is a continuation of previous practice.*

*Freight Time: Savings in travel time for freight have a value arising from: reduction in stock holdings between the points of production and consumption and perishable cargo either being delivered in better condition, with higher market value, or requiring less cost in environmental control and packaging during transit.*

The vehicle and freight time values continued to be indexed year by year. The subject was again reviewed in Symonds Travers Morgan et al (1997). The conclusion of that work, after noting the paucity of overseas research evidence, was that for goods vehicles the present assumption of all time savings being converted to increased vehicle utilisation should be reviewed, with the expectation that a series of reduction factors would need to be applied. That review also identified two components for the value of freight time: the mean value of stockholdings related to the time saved and the losses to perishable goods or failure to

meet just-in-time schedules, related to travel time reliability although no new estimates were made for these costs.

The values for vehicle and freight time appear to have been indexed right through to the present day and there has been no subsequent research or in-depth review. However in 2002, there was a full review of the value of travel time savings, along with a number of other parameter values (Beca et al 2002b). As part of this, values of time for freight transport operators were elicited using a SP questionnaire and separately were calculated using the marginal productivity of labour approach. The SP surveys were of despatchers, or drivers in the case of small owner/driver firms. Overall the value of time savings traded off against direct costs of the trip was estimated to be \$70/hour. No significant differences were found between owner/drivers, large freight companies and own account transport. An increase in the value of time with distance was detected, varying from \$42/hour for under 20 km to \$108/hour for long distances (over 700 km). Part of this effect was related to slowness (associated with shorter more urban trips) and part to distance. The inclusion of value of time in the SP was primarily to assist in eliciting a value for reliability, expressed as unanticipated delay time. The value of saving unexpected delay time was roughly equal to that of saving in expected travel time.

The MPL derived values, on which the EEM travel time values for the working time of goods vehicle drivers are based, were obtained from Statistics NZ surveys of wages by occupational groups together with estimates of employers' overhead costs comprising paid leave and fringe benefit payments, Accident Compensation Corporation levies, workplace accommodation, equipment and overhead costs. The report also compared practice in several other countries, all of which used a similar approach although with differing degrees of rigour in the estimation of employers' on-costs. The resulting values for LCV and HCV driver work time saving were \$22.9 and \$19.1/h respectively (2001 values) before any correction from financial to economic costs.

The NZ Vehicle Operating Cost (NZVOC) model was developed by WD Scott-DH&S (1986) based on the calibration of the World Bank HDM-4 model for New Zealand conditions (Bennett and Dunn 1985) to provide a framework for estimating changes in vehicle operating costs for the purposes of project economic evaluation. The latest update to the NZVOC model is described in Data Collection Ltd (2003). This attributes 15% of depreciation to vehicle use (distance-based) and the remaining 85% to time for light and heavy goods vehicles and trailers. The annual utilisation of each vehicle sub-class was separately identified, varying from 13,300km for a LCV up to 60,000km for a heavy articulated truck.

### 3.3 Value of reliability

The EEM provides for the evaluation of journey time reliability in private road vehicle trips using the reliability ratio, the ratio of the value of one standard deviation in travel time to the value of travel time. The value of an improvement in reliability is evaluated from the change in standard deviation of variability, the value of time and the reliability ratio. The EEM currently does not provide for the evaluation of reliability in public transport services or for commercial vehicles and freight.

The value of the reliability ratio averaged over an urban arterial traffic mix is advised as 0.9 in the EEM. For other situations the advice is to use values of the reliability ratio of 0.8 for cars and 1.2 for commercial vehicles. These values are again based on findings in Beca Carter Hollings & Ferner Ltd et al (2002a) and separate the WTP for improved reliability from the WTP to avoid congested traffic.

This background to the reliability analysis procedure in the EEM is discussed in Beca Carter Hollings & Ferner Ltd et al (2002b) and has been based on analysis of the day-to-day flow variation on different types of road for each time period and relationships between flow and delay. For all road links apart from two

lane rural highways, the volume/flow relationships developed by Akçelik (1991) are used as the basis of establishing a relationship between travel time variability and degree of saturation for road links. For rural two-lane highways, speed/flow relationships including passing sight distance are used, originally deriving from the *Highway capacity manual* adapted for Australian/NZ use in Austroads (1988). The relationships between travel time variability and period traffic volume were developed by curve fitting to the theoretically derived variation in delay using the empirical data on flow variation. This resulted in the relationship for the standard deviation of travel time:

$$SD(TT) = s_o + \frac{(s - s_o)}{1 + e^{b\left(\frac{v}{c} - a\right)}} \quad (\text{Equation 3.1})$$

where:

S = maximum level of the standard deviation of travel time (at an oversaturated flow condition)

So = base uncongested level of the standard deviation of travel time (free flow)

a = v/c at the midpoint of the curve (calibrated to the empirical data)

b = constant which describes the steepness of the curve (calibrated to the empirical data)

The coefficients used in equation 3.1, are summarised in table 3.3 (as defined in the EEM (table A4.5)).

**Table 3.3 Equation 3.1 coefficients**

Context	S	b	a	So
Motorway/multi-lane highway (70–100km/h)	0.90	-52	1	0.083
Urban arterial	0.89	-28	1	0.117
Urban retail	0.87	-16	1	0.150
Urban other (50km/h)	1.17	-19	1	0.050
Rural highway (70km/h–100km/h) (two lanes in direction of travel)	1.03	-22	1	0.033
Signalised intersection	1.25	-32	1	0.120
Unsignalised intersection	1.20	-22	1	0.017

This was recognised as a second-best method for comprehensive measurement of travel time variability against traffic volume and degree of saturation to establish empirical relationships, but one which retained consistency with other parts of the project evaluation procedures. However, one result of this approach is that congestion and reliability are always linked, so there is no basis for evaluating interventions that rely on reducing travel time variability while the degree of saturation remains constant.

The procedures note that this formula for estimating standard deviation of travel time applies to ‘normal’ variability experienced day to day in congested traffic; it does not allow for variability from traffic incidents.

### 3.4 Evaluation of reliability from network model output

For situations where reliability is estimated for more than a single road link or intersection movement, the present procedure assumes that the standard deviation of the travel time variability over a journey comprising several links and turning movements can be approximated by the square route of the sum of the variances for each movement. As indicated in section 3.7.3, this introduces an assumption that reliability on consecutive links is not correlated, whereas some research indicates a reduction in the CoV for whole journey reliability compared with journey sections. However, a brief analysis of a few sample vehicle runs

from the Auckland congestion surveys undertaken for this review showed the variance of the whole journey quite closely corresponded to the combined variances of the sections, though the results might be due to the limitations of the experiment performed. This issue therefore needs further theoretical and empirical consideration before a conclusion is drawn on whether the existing procedure is adequate.

Where part of the journey is outside the study area boundary, then modifying factors are applied to scale down the degree of improvement in journey time variability achieved by the project being evaluated.

For network models using origin-destination matrix data, the overall change in reliability is estimated by performing this calculation for each origin-destination pair and aggregating the results. This process is suited to traditional static staged network models where each flow period (AM, inter-peak, PM) is modelled individually and the results combined. It is not suited to dynamic models where unsatisfied demand is allowed to cascade between flow periods (such as SATURN modelling) or for micro-simulation modelling.

For small networks where origin-destination data is unknown, then some form of matrix estimation is required before the procedure can be applied. This issue is discussed in more detail in sections 5.3 and 5.4.

### 3.5 Freight demand elasticities

The EEM volume 2 includes appendix A15 which gives travel demand elasticities in relation to road/rail mode choice as follows:

*Table A51.1: Elasticities for freight commodities*

<b>Commodity</b>	<b>Range</b>
<i>Food and kindred products</i>	<i>-1.04 to -2.58</i>
<i>Lumber and wood products</i>	<i>-0.05 to -1.97</i>
<i>Paper products</i>	<i>-0.17 to -1.85</i>
<i>Machinery</i>	<i>-0.16 to -2.27</i>

*Elasticity depends on the level of inter-modal competition. The values in the table above are indicative only and represent the percentage change in rail volume with respect to the percentage change in rail to road price.*

*Transit time (generally used as a proxy for distance) appears to be a significant determinant of mode choice. The greater the distance, the less likely truck transport will be chosen. In New Zealand, where inter-modal competition is likely to be significant, it is considered that freight price elasticities would more likely be at the higher end of the ranges identified above.*

*However, it should be noted that other factors may influence a shipper's decision."*

The origin of these demand elasticities is a report by Symonds Travers Morgan (1996) which provided a meta-analysis of overseas studies, in particular Oum et al (1992) and Luk and Hepburn (1993). The review notes that most published elasticity estimates at that time were from aggregate mode choice studies and did not refer to ordinary (within mode) demand elasticities. As well as the price elasticities in the EEM table, the review considered non-price factors such as service level, transit time and loss/damage, concluding that these were significant influences on freight mode choice, in particular:

- Price and reliability were of greatest importance in determining mode choice by shippers of manufactured goods.
- Price was most important for non-manufactured goods.

- For forwarders, avoidance of loss or theft and availability of capacity when required were seen as the important factors.

The only New Zealand study identified in this previous review was by Guria (1988) on rail freight demand elasticity estimates with respect to the road/rail cost ratio against tonnes and tonne-km for bulk commodities (coal, fertiliser, pulp and paper), meat and dairy. The study was conducted just after the deregulation of road/rail competition. The values are reproduced below for completeness:

**Table 3.4 Rail freight demand elasticities wrt road/rail cost ratio**

Commodity	Rail tonne-km demand elasticity	Rail tonnage demand elasticity
Coal	-1.04	-0.14
Dairy products	+0.10	+0.10
Fertilisers	-1.04	-0.02
Meat	-0.02	-0.27
Milled timber	-0.05	-0.05
Pulp and paper	-0.67	-0.36

Source: Symonds Travers Morgan (1996) citing Guria (1988)

There appears not to have been any subsequent work on freight demand elasticities in New Zealand either within mode or in mode choice contexts. The *Surface transport costs and charges study: cost model* (Booz Allen Hamilton 2005) and the subsequent update undertaken by Booz Allen Hamilton (2008) do not appear to have examined this area.

## 4 Market segmentation

In this section we discuss segmentation of transport in relation to the focus trip purposes of the research: commuting, tourism, other personal travel (section 4.1) and freight (section 4.2).

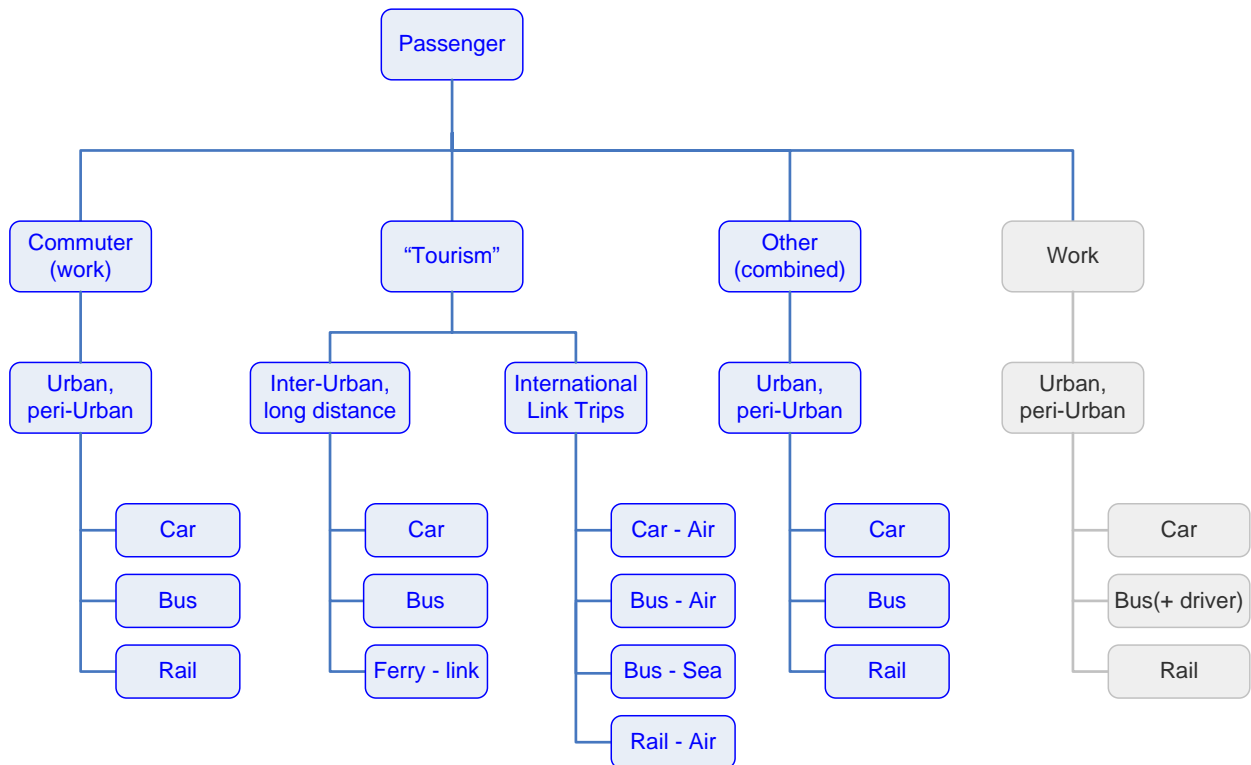
For each of the identified trip purpose segments and, where applicable sub-segments, there is also the segmentation applying to factors influencing trip reliability (supply and demand-side factors) and how these align with the three frequency/consequence degrees of reliability identified (day-to-day, unusual incidents and exceptional events).

### 4.1 Market segmentation for personal transport

#### 4.1.1 Broad segmentation at the inception stage

The inception stage gave an initial view on the important market segments for reliability in passenger transport. These are shown in the diagram below in blue, noting that bus-sea was added, at the inception stage project steering group meeting, for tourism bus trips linking to cruise ships. It was also noted at the meeting that work travel should be separated from 'other' travel for consistency with the EEM procedures. This is shown in grey as it was not specifically within the project scope.

Figure 4.1 Broad market segmentation, personal transport



For urban car travel, commuting accounts for 15% of travel purpose, work for a further 15% and other purposes for the 70% remainder (EEM, table A2.4).

## 4.1.2 Work commuting

The important market segment for reliability in personal travel for work commuting trip purpose was identified as trips within an urban commuting radius, either within urban areas or on roads leading into urban areas. While there is commuting in rural areas, it is little studied, is relatively small as a percentage of the total work commuting market segment, and is less subject to congestion and reliability concerns. The urban commuter market segment is composed mainly of private vehicle (mainly car) trips and trips on urban/suburban public transport modes of bus and rail in Auckland and Wellington, and bus only in Christchurch, Dunedin and a few other urban centres.

There is a small amount of commuter travel by harbour ferry, mainly in Auckland (various inner harbour and Hauraki Gulf services) and a little in Wellington (Seatoun/Days Bay ferry). While reliability is certainly a consideration for ferry services, which are prone to weather delays and cancellations, this is a relatively small segment for which no separate evaluation currently exists on the value of travel time, so we did not recommend including it in this research.

## 4.1.3 Tourism

### 4.1.3.1 Segmentation of the tourism market

Efficient movement on state highways and local roads is recognised in MoT (2011b) as being 'essential' to New Zealand's tourism industry, which directly and indirectly contributed more than \$15 billion to GDP in the year ended March 2010 (Statistics NZ 2010).

Tourism New Zealand is the main source of data on tourism activity and divides the tourism market into domestic travellers, outbound travel by New Zealanders and international travellers (being visitors to New Zealand from overseas). The 2011 Domestic Travel Survey (DTS)<sup>2</sup> indicated domestic tourism expenditure was estimated to be \$8.9 billion for the year ended June 2011, which was 58% greater than the estimated \$5.6 billion<sup>3</sup> expended by international visitors during the same period. It should be noted that since this research was undertaken more recent data has been published.

According to the DTS, domestic tourism involves 'people spending money on activities and accommodation outside of their normal routine and contributing to local economies'. In this context, domestic travel includes both daytrips and longer stays for holidays, visiting friends and relations, business travel and other purposes (including education, attending sporting or recreational events etc). A more precise definition of a domestic visitor or traveller can be taken from the DTS<sup>4</sup>: 'persons residing in a country, who travel to a place within that country outside their usual environment for a period not exceeding 12 months, and whose main purpose of visit is other than the exercise of an activity remunerated from within the place visited'. Domestic travellers can either make overnight trips, that is a 'trip made in New Zealand, but outside the area in which the respondent usually lives or works day-to-day, which involves a minimum of one night away from home' or day trips, 'a trip made within one day, outside the area in which the person usually lives or works day to day, involving travel of at least 40km one way from home, or travel by aeroplane or ferry service'.

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<sup>2</sup> [www.med.govt.nz/sectors-industries/tourism/tourism-research-data/domestic-tourism](http://www.med.govt.nz/sectors-industries/tourism/tourism-research-data/domestic-tourism)

<sup>3</sup> International Visitor Survey (IVS) 2011; [www.med.govt.nz/sectors-industries/tourism/tourism-research-data/international-visitor-survey](http://www.med.govt.nz/sectors-industries/tourism/tourism-research-data/international-visitor-survey)

<sup>4</sup> The definitions of international and domestic visitors are based on the internationally accepted definitions provided by the World Tourism Organisation (2008).



Inbound international tourists or visitors are defined as 'persons travelling to a country other than that in which they have their residence for a period not exceeding 12 months and whose main purpose of a visit is other than the exercise of an activity remunerated from within the country visited'. As for domestic tourists, this definition includes business travel, provided the remuneration is from outside of the area in which the visit takes place.

Outbound New Zealand resident departure data is captured from port and airport departure cards, where a departing resident indicates they are travelling overseas for a trip less than 12 months. While not specifically described as tourists (in that their overseas trip is not contributing to New Zealand's economy), outbound New Zealand residents are of potential interest to this research as, together with international visitors, they comprise a portion of surface access trips to and from the international airports and, to a much lesser extent, through ports on cruise ships.

There is an issue of how, or whether, to align the trip purpose of tourism used by the tourism industry with trip categories used in transport and traffic planning.

#### **4.1.3.2 Domestic tourism**

Under the definitions of tourism discussed in section 2.2, domestic tourists are either on daytrips of more than 40km not as part of their regular travel pattern, or are away for at least one night from their home base. Land transport associated with domestic tourism will be composed mainly of inter-urban and other long-distance trips to and from tourism destinations and local travel in urban or rural areas by visitors staying in the area, either with friends and relations or in tourist accommodation. Where a domestic trip includes air travel within New Zealand, linked trips between the airport and home and between the airport and accommodation in the destination fall within the definition of tourism travel. Land transport travel modes can vary between private motor vehicle (car), bus and rail and may include trips on the inter-island ferry. The most common mode of travel for domestic travellers is private motor vehicle.

In the NZ Household Travel Survey (NZHTS), the activity categories that include domestic tourism, as defined here, are 'social visits/entertainment'<sup>5</sup> and 'recreational', but it is likely that the majority of travel in these trip purpose categories are unrelated to tourism, so the NZHTS data is probably of little use for this research. International tourism is specifically excluded, as only people who are 'normally' resident in a household answer the survey and people in guesthouses, motels, hotels, etc are excluded from the survey. Note also that only two days of travel per household are recorded, so the data collected is geared towards short trips that do not involve overnight stays away from home.

#### **4.1.3.3 Inbound international tourism**

From the *Government policy statement on land transport funding* (MoT 2011b) and state highway classification system, it is clear that the market segment of particular concern to the government is inbound international tourism and, within this, the holiday travel sub-segment and the reliability of travel on inland routes that they frequent.

The inbound tourism segment comprises people visiting friends and relations, holiday, participation in or attendance at educational, sporting or recreational activities, attending other occasions, events, conferences, and/or conventions and so on. Visitors may stay in private residences or tourism

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<sup>5</sup> Interviewers are trained to code the following trips as social visits/entertainment: visiting friends and family, entertainment (including eating out, going to movies, concerts, music lessons, picnics, etc), religious meetings, going on holiday, other hobby-related pastimes (including social groups such as scouts, sewing classes, etc). Recreational trips include going for a walk/cycle/drive as well as travelling to participate in sporting events (source: Povey, Ministry of Transport, pers comm, August 2010).

accommodation and under travel arrangements varying from independent travel to full package holidays with all transport provided. Travel for this segment includes link trips to and from international airports, cruise ship berths and the inter-island ferry (between Wellington and Picton), local sightseeing travel around urban and rural areas, longer-distance travel to other tourism regions and longer-distance day tours (such as Auckland-Rotorua, or Auckland-Waitomo).

Travel modes for this sector vary from car and campervan hire, associated with independent travellers, to casually booked excursion bus and rail, local bus tours and fully packaged tour bus travel. Different perceptions and values of reliability may apply to these sub-segments, on one hand to self-drive travellers many of whom will have little or no prior experience of routes and travel times, and on the other hand, tour buses operating to a planned schedule with time constraints around meal stops, and pre-arranged arrival times at attractions and return to base. In the former case there may be no clear expectation of journey time, unless this has been conveyed to tourists from visitor information sources. In the latter case, the demand for reliability and perception of an expected travel time will arise with the tour operators, rather than with the visitors, at least in the first instance.

#### **4.1.3.4 Outbound international tourism**

Land transport trips by outbound New Zealand residents are mainly from home to airport or seaport, and the return trip from airport/seaport to home. Trips to international airports may have a higher value on reliability than airport arrivals, because of the consequences of missing a flight. On the other hand international air trips now have large inbuilt time buffers due to extended reporting times for security purposes which may temper the aversion to late arrival.

#### **4.1.3.5 International and domestic visitors traveling for business purposes**

Both the DTS and the international visitor data (both inbound and outbound) include business travellers as part of the data collected and reported. Domestic business travellers are identified as 'firm's business' or 'work purpose' in the EEM procedures and have values of travel time saving and reliability that can be expected to differ from other visitor categories of visiting friends and relations and holiday travel.

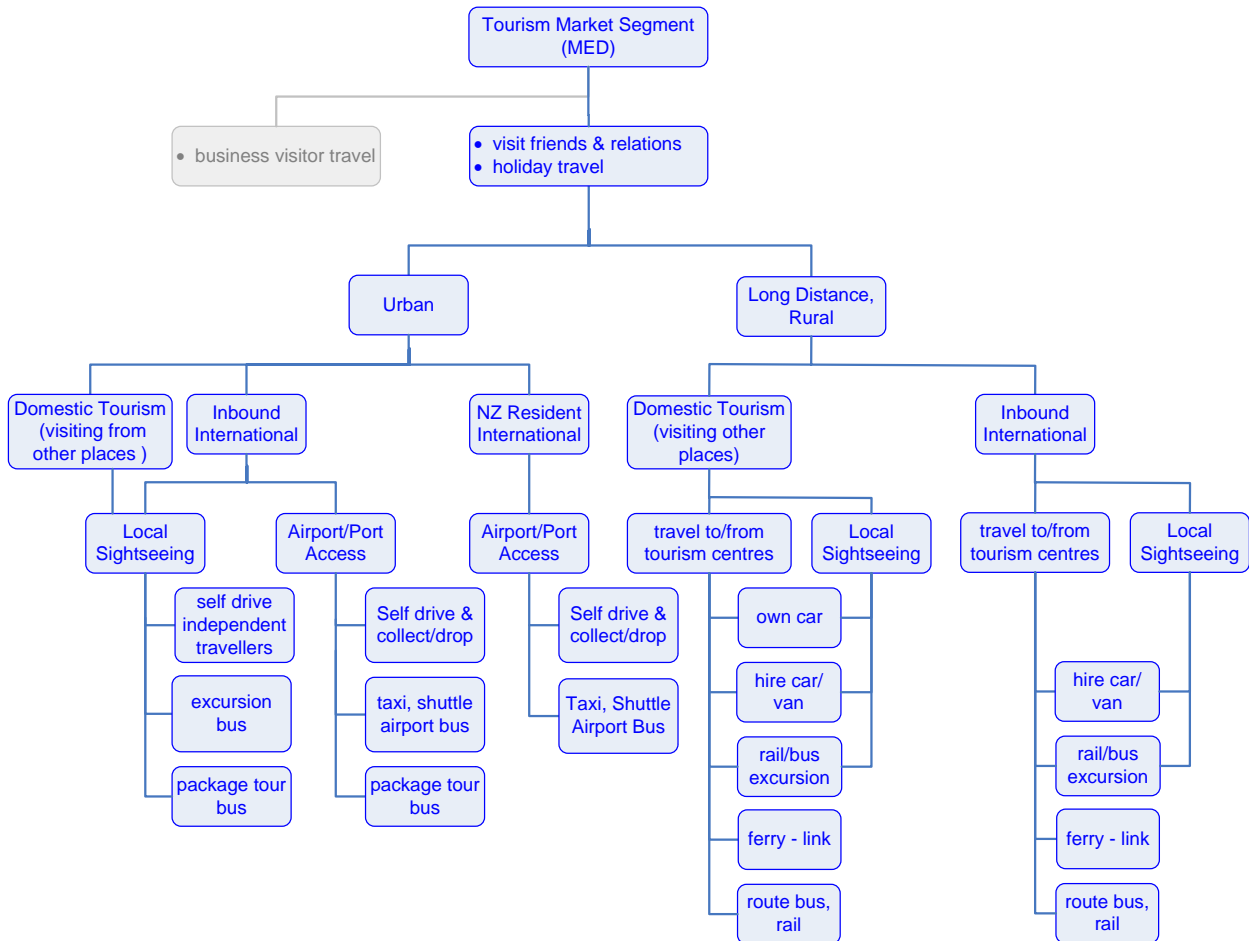
We propose to exclude these business traveller categories from the tourism definition. As noted earlier, work trip purpose is not specifically a target of this research, but we would not expect there to be marked differences between international and domestic business travellers in respect to issues around reliability.

#### **4.1.3.6 Breakdown of the tourism segment**

The combinations of travel purpose, urban/long-distance/rural trips, domestic/international visitors, sightseeing/tourism centre access/airport access and mode of travel are shown in figure 4.2. All business visitors, domestic and international (inbound and outbound) are reassigned as work travel (travel during paid employment).

Within urban areas, domestic visitors (from other places in New Zealand), international visitors and outbound New Zealand resident tourists feature, the latter only for airport access trips.

Figure 4.2 Breakdown of the tourism segment



Finally the travel modes that may be involved are:

- own car for New Zealand residents
- serve-passenger drop-off/pick-up at airports for people collecting or delivering international visitors, New Zealand residents travelling overseas and New Zealand domestic tourists travelling internally by air
- self-drive hire car/van for both international and New Zealand tourists on airport access, urban and rural local sightseeing and trips to tourism centres
- taxi, shuttle or airport bus to/from airports (stage bus is very little used and serves mainly airport workers)
- excursion bus and a few tourist rail services for local and longer distance sightseeing (eg Transalpine)
- inter-regional route bus and inter-city rail (eg Overlander, Transcoastal) services for which tickets are usually purchased separately from other travel arrangements
- the Cook Strait ferry services (Bluebridge, Interislander) as links in longer car/ferry, bus/ferry and rail/ferry tourism trips
- buses provided as part of package tours either for airport/seaport access, for local or longer distance sightseeing and for access to tourism centres.

There is clearly a large number of combinations of sub-groups within the tourism category and it would be useful to reduce the numbers to manageable smaller categories with similar characteristics in relation to travel time reliability and ignore some of the minor sub-groups.

There is a probable division to be made between:

- the self-drive group who assume all responsibility for lateness
- the scheduled transport services (airport buses, route buses) where the operator bears no ultimate responsibility for lateness apart from reputational damage and loss of business if the service is unreliable and those risks have to be gauged by the travellers
- tour bus services as part of a pre-arranged package where the operator bears responsibility for adhering to the schedule and provides an implicit guarantee of making connections with air, boat services or destination activities – the start time of the connecting service will in most cases be delayed if a large number of people are involved.

Within the self-drive group there may be different perceptions and expectations of the trip between travellers familiar with the journey driving their own vehicle and those who are unfamiliar as well as driving a hire vehicle. This gives a basic division of four sub-groups within the tourism segment.

Some initial market research is needed to better define issues and perceptions through exploratory interviews with providers of transport services used by tourists, with tourism operators and with travellers. Also some rough estimates of market size are needed so that research is concentrated in the areas likely to be most productive and useful. This is readily obtained through the DTS and the International Visitor Survey (IVS).

#### 4.1.4 Other trip purpose

The 'other' trip purpose group is a catch-all once commuting and work-purpose are removed. The main sub-purposes are education, shopping, personal business, social and recreational. Urban transport studies may separately capture data on some or all of these sub-purposes as well as identifying person-trips made to collect or deliver passengers (serve passenger trips). As noted earlier, social and recreational trips by definition include tourism travel and the social and recreational trip category account for quite a large proportion of 'other trips'. The proportion of trips by each trip purpose corresponding to 'others' varies between travel modes – for example public transport carries a relatively high proportion of education trips. Urban transport studies will also often separate home-based and non-home-based trip making, which can have different characteristics.

As urban transport studies capture data primarily on trip making by residents through household surveys, international visitor travel in urban areas may not be excluded from the primary data sources.

The 'other' trip purpose breakdown differs between travel on urban roads and rural highways and local roads, these differences being reflected in the standard traffic compositions used in the EEM. Compared with urban trip-making, there is relatively little survey data on trip purpose composition on rural highways and other roads, particularly detailed breakdowns below the three categories of commuting, work and other and the data on which the EEM advice is provided is now probably quite old.

Within the 'other' trip purpose category, there are factors that are known to be indicative of higher or lower values of travel time and by extension, to the value of reliability. For example, the behavioural value of time for students and retired persons are known to be lower than for working adults, reflecting activity schedule constraints and these differences are likely to be reflected in values of journey time reliability. Some groups are known to have difficult scheduling constraints that lead to higher values of time and

reliability, for example working parents with primary age children. However, surveys seldom capture data such 'life-cycle' information, even though it may be important to a full understanding of travel motivations and behavioural values.

The question arises whether this research should attempt to subdivide the 'other' trip purpose category into 'tourism' and 'non-tourism'. Overall, tourism is likely to form a small component of 'other' purpose with the possible exceptions where tourism travel is concentrated on particular routes, times of day and seasonally. For example the 'high tourism' routes in the new state highway classification of greater than 60,000 tourist trips per year for a highway carrying, say, 10,000 vehicles/day, implies a tourism component of less than 2% on average.

The obvious course is to accept that the 'other' category includes a small proportion of tourist travel and not to try to sub-divide this category in the EEM but to identify routes with significant tourism flows and apply some standard expectations of reliability appropriate to the value of reliability to the tourism sector – either to the travellers themselves or to the tour operators. However, because tourism flows are so relatively small a component of total travel, it will need to be determined whether reliability expectations are greatly different from other trip purposes and so warrant special treatment in relation to other possible uses of scarce funding.

For application of values of reliability for tourism for road or service improvements there will need to be direct survey data on trip purpose composition on the route in question or some indirect way of estimating the tourist trips as a component of the total flow, together with research-based data on the value of reliability to tourists. It may also be observed that a value for reliability almost inevitably involves also researching information on the value of time savings, for which there is also little or no data for the tourism segment.

## 4.2 Market segmentation for freight

### 4.2.1 Requirements of the market segmentation

The segmentation of the freight market has to satisfy the four research themes of freight delays and impacts, freight travel time reliability, freight values of time (vehicle and freight carried) and freight demand elasticities. There are also practical matters of data availability and achieving research outputs that can be practically applied, meaning that the freight segments need to be observable for the areas of application. This could be a challenge as the scheduling constraints for freight extend beyond the trip into the activities at the trip ends and there are complexities of freight (de)consolidation, intermediate storage and transfers between modes.

Possible dimensions of the freight market segments are:

- transport mode – road and rail for inland transport, possibly extending to coastal shipping to satisfy the three-way choices between road, rail and coastal shipping when determining modal cross-elasticities, incorporating Cook Strait as parts of the road or rail trip for roll-on roll-off (RoRo) cargo, and separately identifying freight deliveries/collections from export ports/airports
- sub-mode – for road, in particular for the values of time and reliability in appraisal, there is a need to conform with the vehicle categories used for standard traffic mixes in the EEM, that is light, medium heavy-I and heavy-II commercial vehicles and possibly, for analysis of vehicle time, a further division into the 18 or so categories used in the NZVOC model
- commodity – a breakdown into commodity groups will be needed and these will have to be identifiable from existing data or will require market surveys to establish. The commodity groups should have

relevance to the impacts and costs of delays and travel time reliability and desirably should correspond to standard statistical classifications to enable market survey data to be expanded to national level

- freight form – bulk, break bulk/loose goods, palletised, containerised – this will have some correlation with commodities, and it needs to be determined whether freight form is in fact needed, and whether it can stand as an observable proxy for commodity (for example in visual traffic surveys)
- trip length and urban/rural area for road freight – the need for differentiation by trip length is because of differences in delay factors and impacts between long and short trips found in overseas studies; also the need to conform with the EEM traffic mixes which separate urban from rural
- form of logistics arrangements – differences in the perceptions of, and responses to, delay and reliability can be anticipated according to the form of logistics arrangement – own account transport operations, commercial carrier, third party logistics provider
- freight trip purpose - differences in the perceptions of, and responses to, delay and reliability can be anticipated for freight trip purposes, such as raw materials to processing facility, manufactured products to wholesaler, retail distribution, export goods delivery to port/airport
- ordering/delivery timeframe – the tightness of the timeframe between order time and required delivery time can be expected to influence the costs of delays and reliability – lower costs can be anticipated in traditional ‘push’ product supply systems with undifferentiated goods produced to an inventory stock from which buyers make purchases – higher costs can be anticipated in modern ‘pull’ product supply systems where goods are manufactured/assembled to order on a tight timeframe, with customisation to buyer choices. Certain delivery situations can be expected to generate higher costs of delay/reliability – where there are narrow delivery time windows (eg to supermarkets), to ports/airports where there are high cost consequences of missing a service connection.

These are explored further below.

## 4.2.2 The nature of freight movement

A brief discussion of freight movements may assist in developing the market segmentation. A general diagram is shown in figure 4.3.

### 4.2.2.1 Primary production

Starting with primary production, much of New Zealand’s freight originates in areas of rural industry, in particular agriculture, forestry, mining and quarrying. Fishing is the other primary industry and takes place in New Zealand’s economic zone.

Rural primary industry involves freight movement of the raw materials to processing plants which are also rurally based in a geographically favourable location. The location decision is based on many factors, such as being near the centre of gravity of the raw material inputs, good transport connections, well priced developable land and proximity of a workforce.

The main primary industries and their transport connections are:

- coal, other mineral mining and quarrying – the initial processing is usually close to the point of extraction, sometimes with transport on internal roads or using other dedicated transport means (conveyor, slurry pipeline, aerial ropeway); the outputs are either exported (coal, china clay, iron sand, copper/gold ore concentrates), or distributed on the domestic market (quarry aggregates to construction, coal to power stations, ironsand to steel manufacture)

- forestry - logs are cut and trimmed in the forest, then transported to export in various grades and lengths, or inland to chip mills, pulp and paper mills, various types of board mills (panels, veneers etc.) and sawmills for supply of framing and fencing timber and furniture production
- livestock farming - livestock movements among farms and to saleyards and meat works; dairy farming involves raw milk collections to dairy factories, and some inter-factory movements of cream
- fresh fruit (mainly pipfruit, citrus and kiwifruit) and vegetables to pack houses for fresh/chilled supply and to freezing and canning plants
- grapes to wineries, with some intermediate movements of grape juice in bulk
- grain to flour and feed mills and to dry goods manufacturing, and hops and barley to breweries.

Primary production also relies to a greater or lesser extent on freight inputs. In most cases these are relatively small and confined to plant and equipment supply, the notable exception being fertiliser inputs to agriculture (see below). Raw primary materials are among the larger users of rail, in particular coal, logs and some other wood products moving by rail where services are available and competitive. Special rail wagons are used for coal (hopper, bottom dumping), logs (open forked wagons) and woodchip (side-discharging hopper wagons).

#### 4.2.2.2 Large scale and heavy manufacturing

Large scale and heavy manufacturing industry processes raw materials into intermediate and finished products and is also a large generator of freight in raw and semi-processed form. The industry size is large and location is governed by the location of inputs so tends to be rural based. Heavy manufacturing is a significant user of rail and includes:

- steel production – at Glenbrook, using ironsand which is moved to the plant by slurry pipeline, inputs of coal and outputs of steel coil and bar, mainly exported; Glenbrook has a dedicated rail line used for coal and steel
- aluminium production – at the Bluff smelter, with bulk imports of bauxite from Australia and outputs of aluminium ingots for export and domestic production
- cement manufacture – Golden Bay Cement at Portland near Whangarei and Holcim at Westport, with inputs of limestone and clay at the site, coal or other fuel for firing the kilns, and outputs of bulk and bagged cement; the bulk cement is transported by coastal bulk carrier and by road, although there is also potential to move cement by rail
- petroleum refining – at Refining NZ, Marsden Point, which imports crude oil and oil products by bulk tanker and distributes product through its oil products pipeline to South Auckland and coastally by oil tanker; inland, most oil products are distributed to service stations by road tanker
- fertiliser manufacture – the raw materials (dolomite lime, rock phosphate, sulphur etc) are quarried locally or imported by sea; the fertilisers are manufactured at various plants around New Zealand and then distributed in bulk or bagged form either direct to farms or via farm suppliers
- dairy factories – receive raw milk inputs by road tanker from farms and produce a variety of milk products and by-products including town milk supply, butter and cheese, milk powder, casein, whey and various specialist products; the bulk of production is for export markets and is transported by rail and road
- meat works – receive livestock for slaughter by road and produce chilled and frozen meat in various forms, mainly for export but also for the local market; transport for export is by both road and rail; also smaller abattoirs contribute to local meat supply

- breweries, distilleries and other mass production beverage industries – receive mainly hops and barley for beer making, sugar and other inputs for distilling, and distribute product by tanker, and in cask, cans and bottles
- fruit and vegetable processing – receive fresh produce inputs and produce canned, preserved, dried and frozen consumer fruit and vegetable products for local distribution and export.

#### **4.2.2.3 General manufacturing**

General manufacturing industry produces finished goods using raw and processed intermediate inputs from primary industry and heavy manufacturing, including imported materials. Outputs are finished products for the local market and export. General manufacturing is not as closely tied to raw material supply as heavy industry and is generally urban based to take advantage of utility services.

General manufacturing outputs are more likely to use road than rail, and to be palletised and containerised rather than transported in bulk or loose form.

#### **4.2.2.4 Wholesale and retail distribution**

Much of the wholesale distribution sector is based upon import franchises for finished goods and distribution to one or more of:

- retail outlets
- direct selling through discount stores/warehouses
- mail order/internet sales.

Depending on the market scale, product origin and sea shipping arrangements, distribution centres may be nationally or regionally based. Transport is primarily by road but rail may be used over longer distances where cost competitive and suitable to the products carried.

Various wholesaling business structures can be identified:

- Wholesale distribution warehousing may be dedicated to a specific manufacturing brand group, for example where there is vertical integration between overseas-contracted or locally based manufacturing and sales distribution to independent or owned retail outlets.
- Alternatively, wholesalers may hold a number of franchises for a range of product lines, or parallel import, and act as a true intermediary ‘middleman’ in the ownership and distribution chain.
- A third type is where the main business is product retailing through large chains, the retail stores either owned or franchised, where the warehousing is a regional point for receiving, storing and cross-docking goods between the original suppliers and the retail stores. The two main supermarket chains are examples of this type, also many well-known clothing, footwear and other chain stores.

There is a cross-over between wholesale distribution and 3PL logistics warehousing, where the distribution centres are also used as points for freight (de)consolidation. The essential difference between the wholesaler and 3PL warehouse lies in the ownership of the goods and the exclusivity or not to particular products.

Wholesale and retail distribution accounts for a large percentage of freight movement but, being made up of thousands of large to small firms is difficult to track other than in broad terms.

#### **4.2.2.5 Service industry**

Service industry includes professional, business, financial, personal, household and government services. The hospitality industry (restaurants, accommodation and entertainment) can also be counted in this



group. Freight inputs are relatively low and sourced from wholesalers and specialist suppliers and almost exclusively by road transport, often in small but frequent consignments. This sector is also a large user of mail and courier services. The freight, courier and mail movements are mainly urban and inter-urban, with some overseas flows. The service industry also generates demand for secure freight services (security vehicle deliveries and couriers).

House and business removals are a specific service industry which is a significant freight generator of road, sea and air cargo. Maintenance and repair services, such as automotive garages and other equipment repairs (other than returns – or reverse logistics), generate a freight demand for urgent supply of spare parts as well as maintaining an inventory of spares and consumables.

#### 4.2.2.6 Wastes and recycling

At the end of product life cycle, the waste removal and recycling industry is a large freight generator. The waste stream commences with household roadside collections, business waste removals, transfer stations and freight of baled waste to landfill sites or incineration. Recycling is increasingly important, with separation of the waste stream into paper and card, glass, ferrous and various non-ferrous metals, recyclable plastics. The sorted waste streams then become inputs to industry examples being steel scrap to Pacific Steel, and some glass cullet to Owens-Illinois. In recent years some of the recycling outlets in New Zealand have closed and much of the sorted waste is now exported. The movement of waste to landfill can be over long distances in provincial parts of New Zealand.

#### 4.2.2.7 Illustration of freight movements

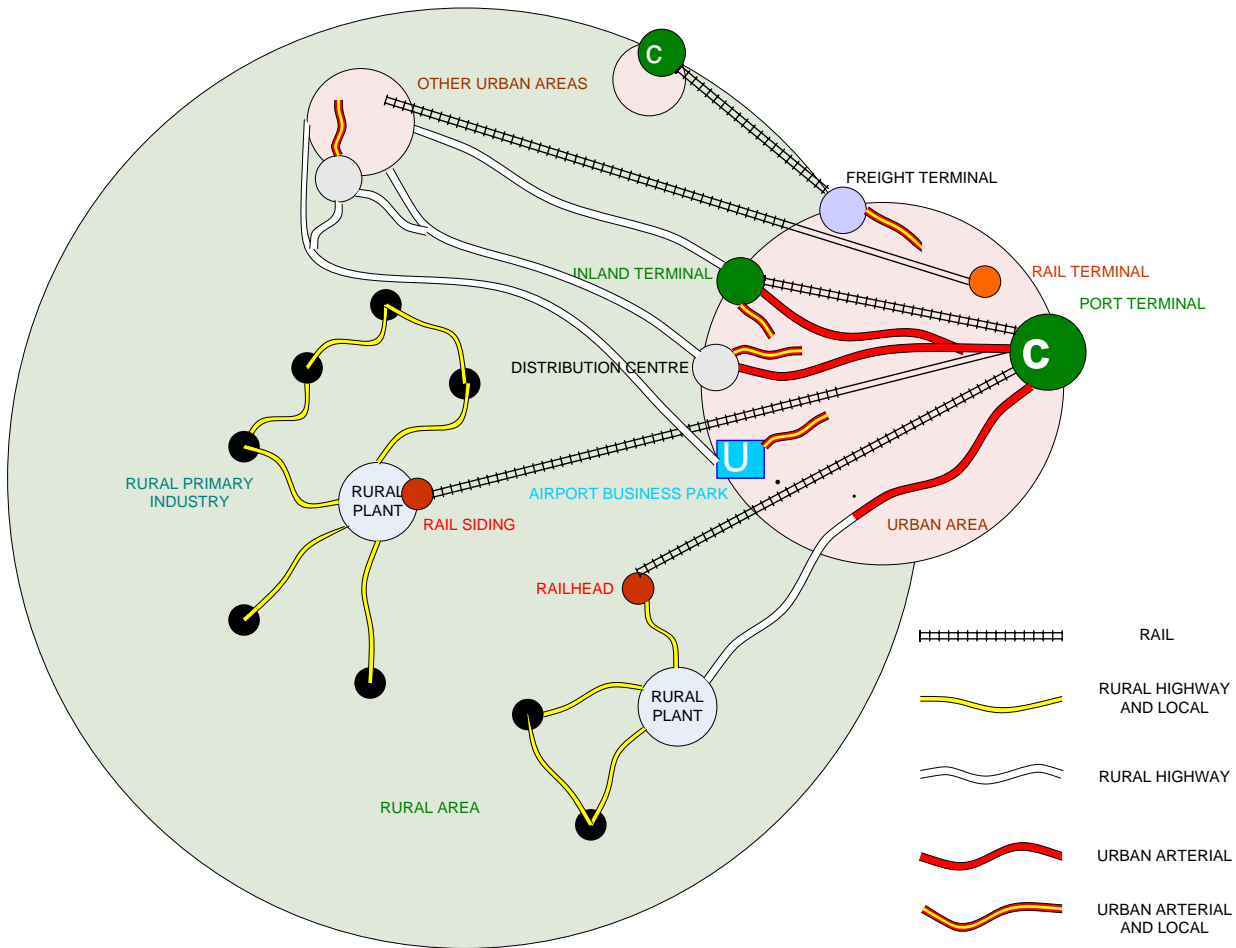
Figure 4.3 shows freight movements diagrammatically.

**Rural production** – in rural areas, inputs to and outputs from rural industry are the main movements, either on a collection/distribution route (milk, fuel etc) or as full loads/empty returns between the product source and processing plant. From the processing plant, onward transport is either to an export port, to further processing or to inland distribution. This is longer haul and mainly on rural highways and on urban arterials for port access, as almost all New Zealand ports are located within main urban areas. Some rural processing sites have direct rail access and feed to port rail grids, while in some cases there is road delivery to a railhead and then onward movement by rail.

**Seaport terminals** – to counter the expansion and landside access constraints New Zealand ports, notably Auckland, are looking to inland ports, either road or rail fed, as a way of easing distribution pressures, particularly for imported general cargo. These are located towards the urban periphery. Tauranga has gone so far as to create an inland port in South Auckland to increase its hinterland trade.

Apart from inland terminals established by the port companies, shipping companies and transport logistics companies have also established their own yards for import/export cargo, mainly Internal Standards Organisation (ISO) containers, partly to avoid demurrage charges and to provide space for vanning/devanning less than container loads (LCLs) (container packing and unpacking).

Figure 4.3 Diagram of freight movements



**Airports** – while catering for a much smaller cargo volume by comparison to sea freight, there has been a tendency for freight forwarders and transport logistics companies to set up warehousing and transit facilities in close proximity to airports, with Auckland again being the prime example. Having the freight terminals close to the airport allows a close connection with delivery and collection of goods from flights, attention to customs and quarantine etc. It also reduces the risks of delays by ensuring that outgoing air cargo is assembled at the airport in advance of the flight, rather than at some remote point. Airport companies have encouraged the growth of business parks on airport owned land as revenue generators.

**Inland rail transport** – is linked to most ports, but for domestic goods carriage delivery has to be made to rail freight terminals located within the urban area equipped to handle container cargo, located either at the original central station site or on industrial land away from the city centre. Movements are from terminal to terminal with road collection at each end, apart from the relatively few, mainly rurally sited, customers who operate industrial sidings. The need for road access and a cargo transfer process at one or both ends of the rail trip works to the competitive disadvantage of rail unless the transfers can be made seamlessly and without adding delay or cargo damage risk.

**Inter-urban road transport** – inter-urban haulage is a mixture of 1PL, 2PL and 3PL operations. Increasingly, 3PL operators are establishing warehousing, freight consolidation and cross-docking facilities at the periphery of urban areas on accessible suitably zoned flat land and at other strategic locations to suit their national transport operations. Shipments are either collected from the customer’s premises or

delivered to the freight consolidation centre and moved inter-regionally in maximum size loads by road or rail, with deconsolidation and urban distribution at the other end of the trip.

**Intra-urban pickup and delivery** – intra-urban point-to-point transport is a mixture of own-account transport provided as part of household, personal and business supplies and services, small owner-operator road transport services often attached to a particular group of clients, and courier services for small irregular consignments. At the bottom end, the use of personal vehicles for goods purchases and collection as an alternative to home deliveries is also technically part of the freight chain. The development of car-based shopping malls, supermarkets and discount hardware stores could only have occurred with the individual purchasers being able to self-carry goods, thereby transferring some transport costs away from the supplier to the customer and at the same time undercutting traditional high street shopping and home delivery services. However, this is a dynamic area, with internet goods ordering direct from the domestic supplier and from overseas (Amazon etc) marking a swing back to home delivery for some purchases.

### 4.2.3 Standard classification systems

There are three main candidates for aligning a breakdown of freight commodities with recognised statistical classifications used in national surveys by Statistics NZ. These are the:

- New Zealand Harmonised Classification (NZHC) system 2007
- New Zealand Standard Classification by Broad Economic Categories (NZBEC)
- Australia and New Zealand Standard Industrial Classification (ANZSIC) 2006.

The merits of each are described below.

**New Zealand Harmonised Classification (NZHC) 2007** is used by Statistics NZ and the NZ Customs Service as the basis for classifying freight commodities, and is a tiered system providing a good level of detail. It was the starting point for the national freight matrix study (Bolland et al 2005) but was subsequently discounted. We have reviewed the NZHC and also find it to be of little use for this research.

The main section category groups are based on one or more raw or base material and include all products made from that material. So each section category includes everything from low-value raw materials through to highly worked and refined products of high value. There are also some odd categories that seem to be historic survivals (eg section X11 'Footwear, headgear, umbrellas, sun umbrellas, walking-sticks, seat-sticks, whips, riding-crops and parts thereof; prepared feathers and articles made thereof; article flowers; articles of human hair'). It would be possible to link a more rational commodity grouping back to the NZHC but this would often have to be at one of the more detailed levels (there are 13,800 at the finest level) and would not be readily correlated against any statistical reporting using the NZHC at its section or chapter levels.

**New Zealand Standard Classification by Broad Economic Categories (NZBEC)** appears to be a more useful framework and 'is designed to convert data compiled on the Standard International Trade Classification Revision 3 (SITC Rev 3), to meaningful aggregates of the end-use of goods, based on the System of National Accounts (SNA) concepts. An objective of the NZBEC is to provide categories which can be aligned with the basic classes of the SNA; capital goods, intermediate goods and consumer goods'. The NZBEC classification is aligned to industry and consumption sectors and better fits with the scale of freight transport from bulk movement of raw materials through to inputs to manufacturing and then to wholesale and retail with a generally increasing freight value, smaller consignments and mixed loads.

**Australia and New Zealand Standard Industrial Classification (ANZSIC) 2006:** This, as its name implies, is organised around industry sectors. This classification also has the advantage of being aligned with the system of national accounts, described in the supply and use tables which show how commodities are linked with industries. The ANZSIC06 classification is also more widely used in Statistics NZ surveys of economic sectors which include financial data on sales and stockholdings of raw and finished goods. Another important advantage of ANZSIC06 is that data on enterprises (businesses), geographic units (separate business locations) and employee numbers are available in the business demography statistics and are searchable on a geographic basis.

Overall, we conclude that ANZSIC06 offers the best available statistical system for aligning freight market segment data with official statistics.

#### 4.2.4 Freight segmentation from prior studies

*Development of a New Zealand national freight matrix* (Bolland et al 2005) was the first attempt for many years to construct a comprehensive picture of the inter-regional and import/export movements of freight nationally.

Initially this study attempted to use the NZHC system at the second tier level with 98 categories. However this was subsequently reduced to 16 groups to reduce complexity and to better match the main commodity flows, because of data gaps and data confidentiality issues. This reduced classification included an ‘other’ category, for commodities not falling within a main group and including ‘general freight, wholesale and retail supply, furniture removal and construction movements’. As this comprised over 60% of the inter-regional freight tonne-kms by road, it meant that a large portion of the freight matrix was a mix of goods with widely varying values and time sensitivity.

*National freight demands study* (Richard Paling Consulting et al 2008) set out with four broad commodity classes of agricultural, basic minerals, basic manufactured products and consumer goods and 26 sub-categories in all. These were later reduced to 17 categories for similar reasons as the national freight matrix work.

The emphasis of both these studies was on identifying the main freight movements by road, rail and coastal shipping, inter-regional and port linkages in terms of freight tonnes, tonne-km and vehicle traffic demand.

These existing sources of data on the freight market unfortunately tend to concentrate on those easily identifiable commodities that make up New Zealand’s main exports, plus some bulk imports. The more time/reliability-sensitive commodities are smaller in volume, lumped in with general freight categories and so are less visible in available statistics.

**Table 4.5 Commodities identified in prior studies**

National freight matrix	National freight demands	From	To	M tonnes 2006/07	% of total
Logs, woodchips	Logs	Forest	Mill, export	19.7	8.7
Sawn timber	Sawn timber	Mill	Export, local C	6.0	2.6
Pulp, paper, panel	Pulp and paper	Factory	Export, local C	1.8	0.8
Wood products	Other timber products	Factory	Export, local C	2.6	1.1
Liquid milk	Liquid milk	Farm	Processing	17.2	7.6
Dairy products	Dairy products	Processing	Export, local C	5.9	2.6
Livestock	Animals and products	Farm	Processing, export	3.6	1.6
Meat		Processing	Export, local C	0.9	0.4

National freight matrix	National freight demands	From	To	M tonnes 2006/07	% of total
Wool		Farm Scourer	Scourer Processing, export		
Petroleum products	Petroleum products	Refinery	Wholesale, retail, export	9.0	4.0
		Import	Refinery		
Lime, marble, other minerals from quarry	Limestone, fertiliser, cement and concrete	Extraction Import	Export, processing Processing	20.8	9.2
Fertilisers		Factory	Local C		
Cement		Plant Import P	Local C Local C		
Coal	Coal	Mine	Export, local C	6.4	2.8
		Import	Local C		
Unprocessed fruit, vegetables, grains	Horticultural and grain unprocessed	Farm	Export, processing, local C	4.2	1.9
	Processed	Factory	Export, local C		
	Horticultural and grain	Import P	Local C		
	Aggregates (sand, gravel, crushed stone)	Quarry Stockpile	Construction, Stockpile Construction	40.2	17.7
Steel and aluminium	Steel and aluminium	Mill	Export, local C	1.9	0.8
Other	Food retail products	Processing	Local C	7.4	3.3
	Other retail products	Processing	Local C	6.6	2.9
	Courier	Origin	Destination	0.4	0.2
Total identified				152.8	67.4
Other	Other			74.0	32.6
Total				226.8	100.0

#### 4.2.5 Freight commodity sensitivity to delay and travel time variability

The observations in section 2.8 indicate there are many possible dimensions for segmenting the freight market and that, for example, attempting to segment into detailed commodities is unlikely to be useful even though some studies on freight demand elasticities have taken this approach. It is also fairly evident that the cost impacts of freight delays for many relatively low-value bulk commodities will be quite low and that it will be the more time-sensitive, perishable, climate-controlled, non-substitutable, high-value freight that will contribute most to the costs of delays and journey time variability, viz:

- are high value in relation to bulk (\$/tonne) – working capital is required to finance work in progress; to the extent that delays add to the time between production and sale of the goods, there is an increase in the capital tied up in unsold stockholding and this capital has an opportunity cost
- are perishable (lose condition and value rapidly with time) and/or require specialised in-transit storage (such as climate control for chilled goods and atmospheric control for certain produce) to retain condition that adds cost

- are customised and not substitutable as opposed to being commonly available and replaceable – less likelihood that demand can be satisfied from stockholdings at the delivery end and that lateness will result in costs from non-availability
- require specialised transport, eg cannot be carried in a standard 20' ISO container on a flat-bed truck; examples are cement trucks/rail wagons, bottom or side dumping hopper trucks/wagons for coal, fertiliser, wood chip; ready-mix concrete trucks; milk and petrol tank trucks/wagons; as well as often being higher-cost containment than for general goods, the inability to easily substitute vehicles will lead to either a higher risk of an unplanned delay having consequential delays in fleet scheduling or requirement to have a larger vehicle fleet holding to meet peaks relative to the average vehicles in use
- are time sensitive – lose their intrinsic value or their value in use if a delivery schedule is missed, examples are urgent courier items which by the chosen form of carriage are likely to be highly time sensitive; also highly tuned just-in-time ordering/delivery arrangements.

Having said this, the sheer volume of the lower value bulk commodities will have a relatively high weight in the traffic stream and this will dilute the cost contribution of the high time/reliability value freight to the weighted mean.

We therefore adopt the position, unless or until demonstrated otherwise, that the research should aim for a composite attribute which we shall call 'freight sensitivity' that combines these various characteristics of freight commodities.

Table 4.1 shows the approximate value per tonne of a range of freight commodities, the values based where possible on New Zealand sources from government ministries and industry group publications. Information on the higher value commodities is limited and varies along the distribution chain. However, a suitable breakdown into three groups of freight value is suggested as:

- low value – under \$1,000 /tonne
- medium – \$1,000 to \$10,000/tonne
- high value – over \$10,000/tonne.

Overseas studies have found a systematic difference in the value of freight by transport mode, with air transport averaging over \$100,000/tonne, road transport accounting for the bulk of freight movement being represented by the average value of freight, then sea transport slightly lower, reflecting the split between sea and air for international freight movements, with rail the lowest freight value reflecting its suitability to bulk commodities.

However, for New Zealand, comparing the commodity mix transported by rail from the National Freight Demand Study with the value of freight as a whole, there appears to be little difference between the average commodity value between rail and inland transport in general. An overall mean value of freight appears to be around \$2500/tonne (net of packaging).

Table 4.1 Freight commodities values and sensitivity to delay and journey time reliability

Commodity	Approximate value in \$/tonne	Stock value per tonne, H/M/L	Perishable losing value over time	Require climate or atmospheric control	Specialised containment	Customised non-substitutable, H/M/L	On-time delivery sensitive, H/M/L
<b>High commodity value &gt; \$10,000/tonne</b>							
Emergency medical supplies		H	S	S	S	H	H
Emergency replacement parts						H	H
Urgent courier items							H
Consumer electronic equipment	100,000	H					
Fish, shellfish fresh exports by air	75,000	H	H	H	H	M	H
Consumer mechanical/electrical equipment	50,000	H					
Cut flowers	25,000	H	Y	Y		M	H
Newspapers	20,000	M				H	H
Supermarket products (exc fresh fruit/veg)		H					
<b>Medium commodity value \$1000 – \$10,000/tonne</b>							
Chilled/frozen meat exports	7000	M	Y	Y		M	M
Butter, cheese milk powder exports	5500	M				M	M
Fish, frozen exports	4300	M	Y			M	
Aluminium ingots	3000	M				L	
Petrol and diesel fuel	2500	M			Y	L	L
Fresh fruit and vegetables	1-3000	M	Y	Y		M	M
Rolled steel coil	1000	M				L	
Timber products		M				L	
<b>Low commodity value under \$1000/tonne</b>							
Raw milk, farm collections	500	L	Y	Y	Y	L	L
Woodchips, export	400	L					
Bulk fertilisers	200-500	L			Y	L	L
Readymix concrete	400	L	H				M
Bagged cement	375			Y			
Steel scrap	300	L				L	L
Bulk cement	150			Y	Y		
Coal	100-200	L			Y	L	L
Export logs	100-150	L				L	L
Waste paper/card	100	L				L	L
Pulp logs	50					L	L
Lignite	30	L				L	L
Construction aggregates	15-45	L					

Key: H - high, M - medium, L - low; Y - yes, S - some

## 4.2.6 Consignment size, cargo form, logistic arrangements and trip length

These four characteristics are each potential dimensions for segmenting the freight market. However, we believe that they are somewhat correlated and that a combined segmentation capturing all of these features together may be the best way forward. We discuss each in turn and then consider how they fit into an overall market segmentation.

### 4.2.6.1 Cargo form

The different cargo forms are:

- Dry bulk – commodities such as bulk grain, fertilisers, aggregates, quarried materials, coal and mineral ores, wood chips, lime and cement. These have the characteristics of being carried in relatively large loads, often in purpose-built truck bodies, rail wagons or bulk ship carriers. The pattern is often full in one direction and empty return giving a 50% load factor. They tend to either import/export commodities or raw materials supply to industrial processing. The transport is more likely to be in the shipper's own vehicle fleet or closely controlled through contract transport arrangements up to the point of on-sale.
- Liquid bulk – commodities such as raw milk, petroleum fuels, imported vegetable oils, industrial chemicals. These have similar characteristics to dry bulks.
- Rough cargo – cargo that does not require particular sensitivity in packaging and handling or weather protection and may be stockpiled in loose form – logs, steel scrap, steel coil. These have similar characteristics to bulks.
- Live animals – mainly the movement of livestock to meat works and inter-farm; also national and international carriage of breeding stock, racehorses and pets.
- Loose freight/breakbulk – cargo that is neither bulk or unitised (container cargo, palletised cargo), typically bagged, boxed, baled, crated – needing individual handling at transshipment points. Loose cargo is nowadays mainly confined to the end delivery of small consignments and the collection and delivery of mail and parcels; for inter-regional and international transport small loads will be consolidated, either palletised or in containers.
- Palletised cargo – cargo strapped and/or shrink wrapped onto standard cargo pallets, traditionally wooden but also plastic and metal, with slots for various forms of handling equipment (pallet, scissor, fork lifts, reach/turret stackers, stockpickers, conveyors etc). Cargo will often be palletised before loading into containers.
- Container cargo – normally refers to ISO shipping containers, basic unit of 20' x 8' x 8', twenty-foot equivalent unit, also 40' length is common in New Zealand for shipping dairy and meat exports, 10' length less common and special containers complying with ISO configuration such as tank containers; also 9' 6" high containers (hi-cube) are increasingly used. Containers are either dry or refrigerated (reefer) using single or dual integrated cooling units with external power connections. Containers provide advantages for inter-modal transport between road, rail and sea and international freight has become increasingly containerised. Smaller standard container sizes are used for air freight to fit aircraft holds and automated loading systems.
- RoRo cargo – arrangement in which cargo is driven on and off cargo vessels equipped with bow or quarter ramps. In New Zealand RoRo is used mainly for drive-on/off car carriers and road trucks and rail wagons moving across Cook Strait.



#### 4.2.6.2 Consignment size

The main differentiation is between consignment sizes that are a full container load (FCL for a single consignee or consignor (or both), and smaller consignment sizes that are consolidated to fill a container (less than container load (LCL)) or truckload and have to be packed and unpacked at freight terminals or other premises points along the way.

At the larger end are bulk movements, where consignments are more than truckload and may be full train or ship load in scale. They tend to be regular, with a fixed pattern of origins and destinations and so justify investment in special handling arrangements at each end and dedicated transport. They cater for relatively low value time insensitive freight.

Mail, parcel and courier services are for the smallest consignment sizes and are generally operated as specialised services by NZ Post and other mail and courier businesses rather than as part of general freight carrier operations (and certain of the large freight companies also operate courier services). They also differ from the general run of freight operations in that they deal directly with the general public as well as the business sector. There is an increasing market for courier operations and various specialisations for direct store to customer delivery such as document, medical, high-value security items, florists, fast food, animals etc.

#### 4.2.6.3 Trip length and area

Freight movements can be described as:

- regional transport from rural industry either direct to export or via processing plant; and reverse of import port to processing/distribution to rural industry supply (eg logs, coal, fertiliser, dairy products, meat); the transport is generally to/from the nearest port, although this depends on the shipping service, for example in the north of the North Island the export port could be Auckland, Tauranga or Northport; *medium to long distance travel, mainly rural apart from port access which tends to involve travel through an urban centre; by road and rail – this is the main group of transport movements that use rail*
- rural-based industry to processing plant and then national distribution to urban sales distribution centres; *medium to long distance travel; users of road and some rail*
- finished (or partially finished) imported goods from import port (to final processing) to regional sales distribution centres; *short to medium distance transport; mainly by road*
- sales distribution warehousing (generally one per greater urban area) to chain retail stores and/or direct customer delivery – generally urban based; includes supermarket and discount store deliveries as well as to smaller franchise speciality stores; includes just-in-time supply to order to minimise retail outlet stockholding; *short distance mainly intra-urban travel by road*
- point-to-point courier, parcel and mail delivery, generally but not exclusively small consignments, mainly urban by road and inter-urban by road and air or rail depending on service requirements and availability.

For road freight, the longer the journey, the fewer trips that can be made in a day and the greater the potential for constraints such as driver hours to reduce vehicle productivity, for example there will be a distance/time threshold beyond which a return trip cannot be made in one day. Driving hour rules effectively limit this to a six-hour outward and return trip or, at an average speed of 80 km/h, 480km. This can be limiting for certain inter-urban movements, and unexpected traffic incidents such as road closures for accidents or flooding/icing can result in the need for drivers to overnight at the destination.

For shorter distance around-town deliveries, there is more flexibility to fit a number of trips into the working day and the main concern is general urban congestion that increases travel times and introduces variability.

The possible variation in the value of reliability with trip length is analogous to the findings of variation in the value of time with trip length and with the length of time saving, noting that larger time savings are more possible on longer journeys. Market research on traveller perceptions (see for example Mackie et al 2003; Hague Consulting Group et al 1996) consistently finds that larger time savings are worth more per minute than smaller time savings (and similarly for time losses, with losses being valued more than gains); also that unit values of time saving increase with trip duration, which is strongly correlated with trip distance. Mackie et al (2003) conclude for example that for car drivers in the UK the elasticity of the value of time to distance is around 0.3.

However, while these research findings are well established, they are not commonly applied in modelling for practical reasons and certainly not in evaluation. The application where value of time variation with trip distance is potentially of significance is for toll modelling where the segmentation of values of time may be as important as the mean. There are also some confounding issues such as the cost numeraire used in behavioural studies and how the perception of the vehicle operating cost may vary between short/long and slow/fast trips, and also whether driver fatigue affects the elicited values of time on longer journeys and if so, how this should be interpreted.

The research base for freight transport is not as extensive as for personal travel, but we may anticipate that there could be variation in the value of freight time with trip duration/distance for reasons of trip scheduling noted above. This has been found internationally and is discussed later in the report. If there turns out to be a willingness to incorporate trip length differences into modelling and evaluation practice for freight, then this would immediately beg the question why not also for private vehicle travel.

#### **4.2.6.4 Form of logistics arrangement**

The different forms of logistics arrangement, from first to fourth party logistics are:

- 1st party logistics (1PL), own-account or ancillary operations – the transport is supplied and managed by the shipper as an ancillary function to the business; generally this is road transport (although there are some cases of special purpose rail wagons and shunting locos owned by rural-based extractive industries, although the mainline rail haulage is provided by others); the reverse arrangement is where the end purchaser self-collects the goods from the supplier, which applies to personal shopping goods collections and some business purchases.
- 2nd party logistics (2PL) – the shipper engages a transport operator to provide services; this includes owner/drivers contracting to the shipper, with the shipper managing the transport operation which is an extension of 1PL, or a commercial contract with a common carrier, where the carrier bears full responsibility for performance of the service.
- 3rd party logistics (3PL) – the shipper engages the 3PL operator to arrange for the provision of an integrated service that includes transport, but also may extend to full distribution management including contract warehousing, cross-docking, consignment tracking, inter-modal and international freight forwarding services; the 3PL operator may directly provide some or all of these services with strategically placed warehousing/distribution centres generally being the focal points; there are a number of these companies in New Zealand.
- 4th party logistics (4PL) – is a term that has been coined for management consulting and transport companies that act as ‘non-asset based’ designers and facilitators of transport logistics arrangements for their clients, which may include engaging and organising other parties in the logistics chain to provide the physical services.

The most widely used forms of logistics arrangements are 2nd party using owner/drivers under dedicated or transport companies and, increasingly, 3rd party logistics. 3PL services are offered by all of the larger freight companies (Mainfreight, Toll, etc) and the main ports also claim to offer 3PL by virtue of their yard and inland port storage facilities. There are also freight load matching IT services aimed at the smaller owner/operator with one or a few trucks that exist to help operators increase backloads and overall load factor (Freightfinder, Findatruckload).

Zhang (2009) undertook market research on the extent and nature of 3PL usage in New Zealand, sampling 170 companies from the Chartered Institute of Logistics and Transport database, but excluding 3PL firms and logistics consultants/4PL. The sampling was not random and seems more likely to have captured companies with significant transport logistics needs. Both large and small companies were captured. Some of the findings from this survey were:

- About half of respondents over half (57%) used 3PL services and of these about half (46%) for both international and domestic transport, and 23% and 31% respectively for just international or just domestic operations. This use of 3PL put New Zealand higher than Western Europe and America but lower than Australia. There was little difference in usage between smaller and larger companies (a small company was defined as turnover under \$25million).
- The use of 3PL was well entrenched, with over half of companies having used 3PL providers for more than five years.
- The most frequently used 3PL services were in descending order: domestic transportation; freight forwarding; warehousing, international transportation; customs clearance and freight brokerage (all near or over 50%). The least used were 4PL services, fleet management and operations closer to the business process (customer service, IT, repairs and returns, ordering (under 20%. In the middle (20-50%) were services such as selecting carriers, cross-docking, shipment consolidation, inventory management, packaging and assembling. This usage of services pattern correlated with the satisfaction of businesses with 3PL services.
- Most users of 3PL services used more than one 3PL company, typically three for smaller companies and four for larger companies; the reasons appear to be related to the spread of markets (particularly international) and the coverage provided by individual 3PL firms and different areas of specialisation.
- The importance of service factors showed speed of delivery as highest out of 14 factors, slightly ahead of quality, price, flexibility, skills and experience. Speed of delivery as a service factor was rated 70% very important and 26% important; unfortunately for the current research questions of reliability of delivery time were not asked. According to the survey, in none of the factors considered important were 3PL providers rated by the companies surveyed as performing up to the standard desired; although the performance gaps were not great, speed of delivery was the largest.

#### **4.2.6.5 Contractual agreements for delivery on time**

Associated with the form of logistics arrangement is the contractual agreement between the shipper, the freight logistics supplier and the customer and any provisions regarding delivery to a particular schedule. How these contractual agreements are expressed and the penalties for lateness will influence how the impacts of lateness on the consignee of the freight and on the transport operator (through loss in operational efficiency) are transferred between the parties.

The contractual situations that can occur are:

- Where goods are collected by the customer, any delivery schedule risks are internalised with the customer; so if carrying out a market survey to gauge risk perception and value, the customer/transport provider would be the interview subject.
- Where transport is provided by the supplier of the goods (1PL), responsibility for meeting any contractual conditions for on-time delivery lies with the shipper/transport operator.
- Where there is a transport operator as intermediary between the shipper and customer (2PL), there are two contracts, one between the shipper and the customer and another between the shipper and the transport operator, either or both of which may impose a cost for late delivery.
- Where there are several parties in the transport chain, then the number of inter-party contracts increases; for example in overseas exports there will be one or more surface freight movements to the export port/airport, some cargo handling and storage responsibility lying with the port company and the stevedore/cargo handle, the responsibility of the shipping line/airline, and similarly a chain of responsibility at the delivery end to the final consignee; the inclusion of freight forwarders will simplify the number of contracts seen by the shipper.
- Where these more complex transport and storage arrangements are undertaken by a 3PL company, then the shipper sees just two contracts, one with the customer and one with the 3PL provider.

The contractual provisions for on-time delivery vary widely. In many contracts, for example most mail and courier services, while there may be an expected time to delivery published, companies do not guarantee the delivery time and so do not carry any of the delay costs of the shipper or consignee of the goods; any costs to the carrier in these circumstances are only in reputational damage. Even in this case there are a variety of possible causes of delay that the carrier can cite as being outside of its control.

In general, freight contracts have to specifically include clauses to impose obligations for on-time delivery and penalties for late performance. Even so, there will usually be some limitation of liability, such as to the cost of that portion of the carriage that was late.

Within New Zealand, contracts for freight fall under the Carriage of Goods Act 1979 but this act has no force beyond the national borders and the corresponding legislative provisions within the destination or transit countries will apply.

For international shipping arrangements, the contract will use the International Chamber of Commerce *Incoterms 2010*, to describe the responsibilities for shipping arrangements and which party bears the risks and costs at each stage (noting that the burden of risk does not always transfer with the custody of the goods).

For completeness these are listed below. Where insurance is not specifically mentioned in the terms, the risk to the goods and responsibility for insurance pass with the transfer of ownership of the goods, at whichever point that may be.

- EXW (ex works) – the seller makes the goods available at his premises, the buyer responsible for collection, transport and all associated risks.
- FCA (free carrier) – the seller hands over the goods, cleared for export, into the custody of the first carrier (named by the buyer) at a named place (suitable for general/multimodal transport and international maritime container transport).
- FAS (free alongside ship) – the seller undertakes to clear the goods for export and deliver them alongside the ship at the named port (for maritime transport excluding containers).

- FOB (free on board) – the seller undertakes to clear the goods for export, deliver to port and load the goods on board the ship nominated by the buyer (for maritime transport excluding containers).
- CFR (cost and freight) – the seller pays all costs for freight delivery to the named port of destination, but risk and responsibility for insurance is transferred to the buyer once the goods are loaded on the ship.
- CIF (cost, insurance and freight) – as CFR except the seller pays for insurance on behalf of for the buyer.
- CPT (carriage paid to) – The seller pays for carriage to the named destination point, but the risk and insurance responsibility transfers to the buyer when the goods are handed over to the first carrier.
- CIP (carriage and insurance paid) – the seller pays for carriage and insurance to the named destination point to a named destination; but risk passes to the buyer once the goods are handed over to the first carrier.
- DAP (delivered at place) – the seller pays for carriage to the named place, except for costs related to import clearance, and assumes all risks prior to the point that the goods are ready for unloading by the buyer.
- DAT (delivered at terminal) – the seller pays for carriage to the destination terminal, except for costs related to import clearance, and assumes all risks up to the point that the goods are unloaded at the terminal.
- DDP (delivered duty paid) – the seller pays for carriage to the named destination point including inland freight at each end, and for all costs including goods clearance at point of export and import, but excluding insurance.

An examination of the published conditions of carriage of several road, air and sea carriers show contractual obligations tend to be restricted to delivery of the goods to the required destination in the contract and that most of the responsibility for the risks of loss, damage and delay and the respective insurance costs lie with the shipper or consignee, whoever has ownership responsibility of the goods at the time.

In fact, contract conditions are often worded to protect the carrier or freight forwarder from delays arising from actions or non-actions by the shipper, such as failing to present or load goods within a certain time upon arrival of the truck, or failure to promptly accept a delivery, rather than applying a liability to the carrier for delays to the transport service provided.

This insulation of delay responsibility between the carrier and the shipper leads us to the conclusion that both viewpoints need to be considered separately and, to a large extent independently, in any market study of the impacts, costs and mitigation of freight delays.

A consequence of this separation is that shippers and buyers of goods exercise limited influence over the operation of the transport system and services that connect them. For example, the response of the shipping industry to rising fuel costs and the global financial crisis by ‘slow steaming’ illustrates that the maritime transport industry is incentivised by its own cost structure and that the timely delivery requirements of its customers (particularly smaller ones) have limited impact. Slow steaming adds days or even weeks to transit times, so time savings at the supply and final delivery ends of the chain pale into relative insignificance.

So one line of study should be on the shipper/buyer relationship and the impacts and costs of delays, where the significance of a delay rises where ordering is on a just-in-time basis and the stock-out risk is high, and when the goods are valuable and/or perishable. The second line of study should be on the impact of delays on the carrier’s operation, as there is a strong commercial incentive for the carrier to operate equipment and staff resources as efficiently and productively as possible.

#### 4.2.6.6 Just-in-time production and delivery windows

In the last section we drew a distinction between the shipper/buyer's delivery time and punctuality requirements and the concerns of the transport operator for a cost-efficient and predictable operation, noting that contracts for carriage often place all time risk onto the shipper/buyer, insulating the carrier from the shipper/buyer concerns about speed of delivery and reliability.

A possible 'special case' is just-in-time supply, which has the objective of minimising inventory and work in progress to reduce cost. It is also referred to as 'stockless production' and various associated (mainly Japanese industry derived) terms such as Kaizen (continuous improvement), 'lean manufacturing' and pull-manufacturing or supply. In pull-supply, the goods are ordered and possibly paid for before production, and the method relies on an ability to rapidly respond to the demand. This distinguishes just in time from the traditional 'push' production where stockholdings are produced ahead of any certainty of sales, resulting in inventory and storage costs and increased requirement for working capital.

Overall, these techniques are known as competitive manufacturing and there are government and industry supported initiatives, in conjunction with Australia, to introduce practices into, in particular, New Zealand export industries<sup>6</sup>. While many of the improvements are internal to the manufacturing process, the transport part of the supply chain also has a part to play and unresponsive or unpredictable transport links stand to downgrade and dilute the improvements made within the industrial processes.

Just-in-time operations rely on goods delivery within a narrow window to avoid running out of stock or missing onward connections at freight terminals, intermediate warehousing and retail premises. Delivery windows can also be constrained by staff working hours, opening/closing times and environmental management curfews.

#### 4.2.7 Interim conclusions on freight market segmentation

Our interim conclusions on market segmentation focus on the two probable sources of cost of delays and unreliability:

- 1 Costs to the transport provider
- 2 Costs to the shipper and consignee of the freight.

We have discussed how the transport provider may or may not be sensitive to the costs of the shipper/consignee through the conditions of carriage. The same applies in reverse, the shipper and consignee may not be sensitive to the costs of the transport provider.

The different implications of delay and reliability to the shippers and transporters of freight will affect the approach to market segments. For shippers and consignees, the main issues will be overall speed and dependability of the transport service, which will increase with the value, perishability and uniqueness of the freight, the tightness of the timeframe between ordering and delivery and with the requirement to deliver within a tight time window. These factors will influence the shipper and consignee willingness-to-pay for service quality, with the main emphasis being on the shipper to respond to the consignee/buyer's requirements. For the transport supplier, the main emphasis will be on operating a lean and efficient service, with high utilisation of staff and equipment; delays and journey time unreliability will adversely affect these business objectives almost as much for low value as for high-value freight. In fact, the cost of transport for a low-value commodity will be a greater proportion of the market price than for a higher

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<sup>6</sup> See [www.cmi.org.nz/index.asp](http://www.cmi.org.nz/index.asp)

value and more time-sensitive one so, while the value of journey time reliability may be relatively low for a low value commodity, the value of delay may be relatively high.

An interim conclusion on market segmentation is therefore that a dual approach is needed, one which is mode/equipment/operator focused when considering the freight transport logistics operation and the other is focused on freight value/sensitivity when considering the impacts on shippers, consignees and markets. These are elaborated below.

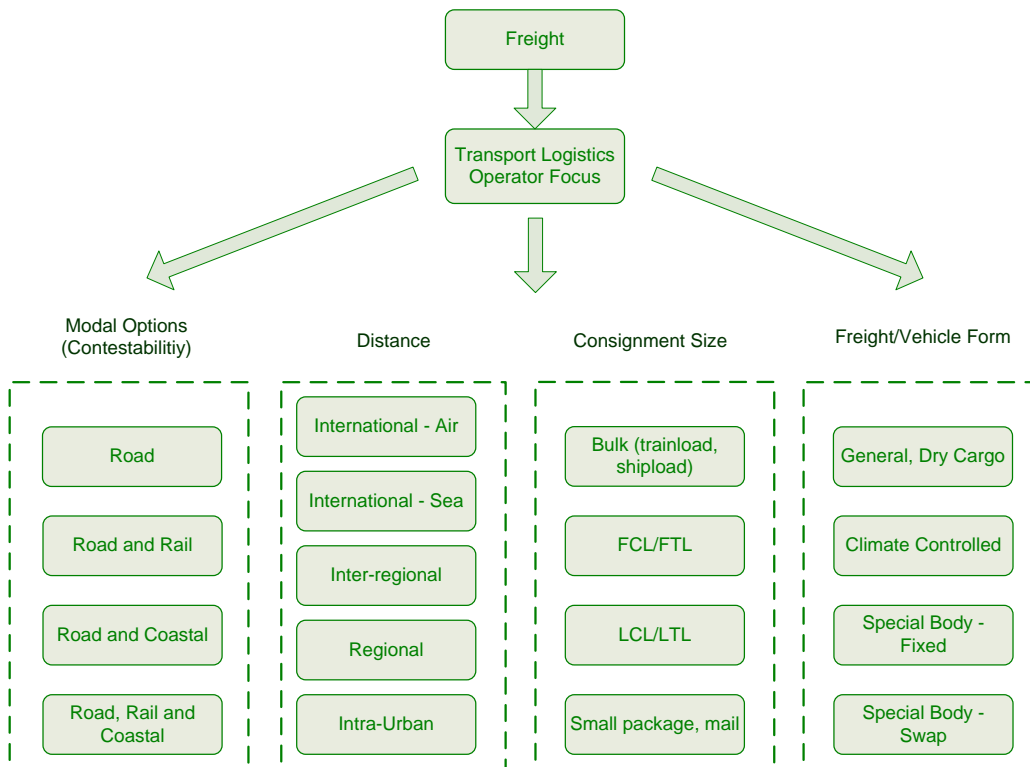
#### **4.2.7.1 Transport logistics operator factors**

Costs to the transport chain stem from the loss in utilisation of the transport equipment and associated staff time and overhead cost impacts, and any consequent losses in the intermediate storage and handling processes. Influencing factors are anticipated to be:

- Transport mode – clearly the modal options of road and rail freight have different cost characteristics, with rail services all being operated by KiwiRail. An important application of the research results are in the area of modal choice, so we propose that modal contestability be one segmentation factor. Road is always an option and in most cases is part of the transport chain even if the main mode is rail or coastal shipping. The terms of reference for the research exclude coastal shipping except that there is a possible desire to include coastal when considering freight demand elasticities. For this reason we have shown four segments for modal contestability:
  - captive to road
  - road or rail (rail either on its own or with a road access trip at one or both ends)
  - road and coastal shipping (similar road access trips as for rail)
  - road, rail and coastal all available as options. We note again that the Cook Strait Ferry is considered as a part of an inter-regional road or rail trip, although it will have some special scheduling characteristics and reliability aspects that may need to be investigated as the research proceeds.
- Trip distance – we suggest a segmentation:
  - international – air, that is the land transport link to international air cargo or mail, which may require some further subdivision into export and import freight
  - international – sea, similarly, in both air and sea the link trips by land are likely to be regional rather than inter-regional although this will not always be the case
  - inter-regional (domestic) freight
  - regional (domestic) freight
  - intra-urban freight.
- Consignment size – has an obvious influence on the need or possibilities for consolidation. We have suggested four segments:
  - cargo in consignment sizes much greater than truck or container load, measured in hundreds of tonnes, such as trainload or shipload
  - full container load (FCL) or full truck load (FTL) cargo, where ‘full’ refers to a single shipper and consignee with no need for freight consolidation
  - less than container load (LCL) or less than truckload (LTL) consignments where consolidation of different consignments is a possibility, or else a lower load factor is accepted

- smaller mail and courier consignments.
- Vehicle type/freight form – this is to distinguish characteristics that vary the cost of the vehicle and its ability to be used among differing freight commodities. So where a special vehicle body type is required, an example might be a fuel tanker or bulk cement carrier, there is no opportunity to use the vehicle for any other cargo form. The suggested segments are:
  - general dry cargo which has least demands on the vehicle and body form
  - climate controlled cargo, primarily chilled and frozen but also controlled atmosphere cargo, where there are significant costs in maintaining the climate control
  - cargo requiring special containment which makes the vehicle unsuitable for other commodities so limiting its alternative use
  - swap bodies, where the containment is special but able to be demounted and swapped between road chassis, storage and other modes.

**Figure 4.4 Market segmentation from transport logistics operator viewpoint**



#### 4.2.7.2 Shipper/consignee factors

For the shipper/buyer viewpoint, the segmentation needs to focus on the features of whether the goods are undifferentiated substitutable products, through to highly customised products and the value and perishability of the product, with an emphasis on the higher cost and more perishable end as this is where the cost implications of delay are greater. It also seems likely that segmentation by urgency of delivery may be needed to identify those situations where a tight delivery timeframe is imposed by market forces.

Costs to the shipper and consignees stem from having to hold excess inventory, from loss in value of the freight with time and perishability, and from the business consequences of stock-outs. Unreliability in the

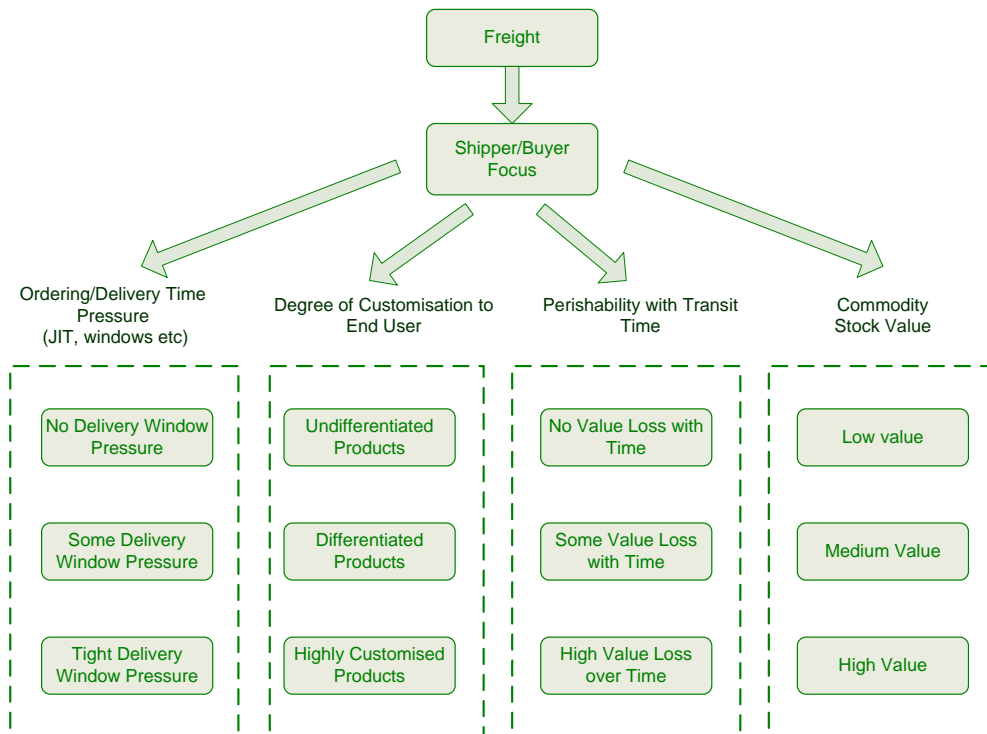


system magnifies the costs of delays by the need to provide buffer time and resources to avoid the worst consequences of unplanned delay and by the probably higher costs of exceptional delays.

So our interim selection of market segments is:

- ordering/delivery time pressures – segmentation according to the tightness of the time available for delivery, that is the required order servicing time deducting the order processing time, and any constraint on the delivery window (earliest, latest delivery)
- degree of product customisation – from undifferentiated products to supply a market on the traditional push-production stockholding approach to highly customised products using the pull-production, lean or zero stocking approach
- loss of product value with time – it is assumed that any required climate control or special packaging is provided and may be a cost, but that the value of the freight deteriorates over time either because of physical deterioration or because lateness reduces its value in use
- commodity stock value – the basic stock holding value of the commodity, represented by the opportunity cost of working capital per tonne or other appropriate unit.

**Figure 4.5 Suggested market segmentation from shipper/buyer viewpoint**



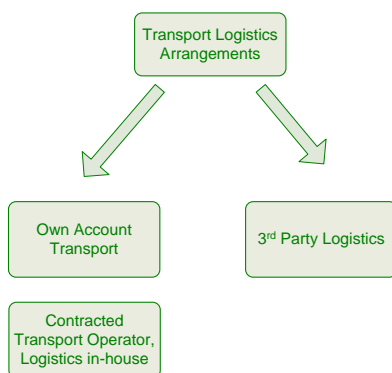
**4.2.7.3 Form of logistics arrangements**

Just how important it is to differentiate the market by 1PL, 2PL and 3PL logistics arrangements is not immediately clear. The decision whether to operate transport as an ancillary part of the business, whether to hire a carrier but control the remaining logistics or whether to outsource to a logistic provider, particularly for more complex freight management decisions, is one made on the balance of commercial advantage and with a view to the availability of commercial transport logistic services. For any particular freight commodity and market, the basic drivers remain the same whether the transport is in-house or contracted. In both cases there will be a desire to operate the transport side cost efficiently, and the shipper will face the same imperatives from the market being supplied irrespective of the transport

arrangements. There are perhaps some differences in the opportunities that a 3PL organisation has to optimise its services by setting up distribution centres for warehousing and cross-docking, compared with in-house transport where such opportunities are likely to be more limited. So from this viewpoint, the market segments should take account of the logistic arrangements. Also, while there is a reasonably clear distinction between own-account transport and 3PL, the operations of transport logistics companies are complex and developing and include various alliances, including with infrastructure providers and operators (port companies, KiwiRail).

At this point we suggest that the logistics arrangements be considered as an additional overlay on the basic transport and shipper segmentation, with a main division between transport and associated storage operations that are primarily controlled in-house even if the actual transport service is contracted, and those where the responsibility for freight forwarding and delivery including decisions on transport mode are handed over to a logistics company at the factory door. In the case of a 3PL arrangement these two viewpoints exist side-by-side possibly with limited interaction. From the in-house viewpoint, the drivers to operate an efficient transport operation sit alongside the drivers for speedy and reliable delivery to service customer requirements.

**Figure 4.6 Freight segmentation by logistics arrangements**



### 4.3 Segmentation by factors causing unreliability

As noted in section 2.3, transport networks are subject to both supply- and demand-side influences that may affect reliability. Supply-side influences have been the primary focus of research to date, with most studies investigating the effect of service disruptions, such as roads being fully or partly closed or public transport services being disrupted or cancelled, on the performance of the network.

As well as the potential segmentation by supply and demand factors, unreliability can be categorised according to the frequency of occurrence and the extent of the delay caused.

As introduced in section 2.4.2, travel time unreliability has been defined as the *unpredictable variation* in journey times; see for example Arup (2003). Predictable variations in travel time for a particular journey relating to varying levels of demand by time of day, day of week, and seasonal effects are by definition excluded. Arup (2003) considered day-to-day variability to comprise two components:

- 1 Variations due to random and unpredictable variations in demand
- 2 Variations due to random and unpredictable fluctuations in capacity. They also separately distinguished between day-to-day variability and incident-related variability.

The two classifications are not inconsistent. For instance, Nicholson and Du (1997) suggested there are two sources of trip time variability, namely variations in demand and variations in supply. Incident-related variability invariably involves reductions in capacity (or supply) whereas day-to-day variability is largely the result of fluctuations in the pattern of demand.

In reality, both demand and supply variations can occur separately or together, and it is not always easy to identify the separate effects of each type of variation. For instance, if a crash occurs during the early part of a peak period and results in a road being partly blocked, it may well be difficult to separate the effect of the capacity reduction and the increasing traffic flow. In major urban areas, where the networks are typically dense and congested, both supply and demand variations occur. While such variations are typically of relatively short duration, the social and economic impacts can be substantial (Nicholson 2007). In rural areas, however, where the networks are typically sparse and uncongested, demand variations are generally not important, but supply variations, which can well be of relatively long duration, can have substantial social and economic impacts (Nicholson 2007).

Bates et al (1987) and Hollander (2007) suggest that travel time variability can be due to 'inter-vehicle variability' (variation in the travel times by different vehicles making similar journeys at the same time), 'inter-period variability' (within-day variation or variation in the travel times for similar trips at different times on the same day), and 'day-to-day variability' (inter-day variation or variation in the travel times for similar trips at similar times on different days). Travel time variability is defined differently in different studies, causing confusion when comparing the results of different studies. As noted by Hollander (2007), this confusion is also exacerbated by some studies not clearly defining what is meant by travel time variability.

From a practical point of view, inter-period variability appears best considered as predictable variation. Transport studies invariably segment into different volume bands, generally AM, PM peak and off-peak, identifying flow variations between weekdays and weekends and also seasonal factors, particularly for rural roads where studies may consider the numbers of hours per year for each of several flow bands.

Inter-vehicle variability is an expression of differing vehicle performance, including different types of vehicle (cars, buses, trucks, etc), different power/mass characteristics within each vehicle class and differing driving behaviour. Travel time surveys generally aim to sample the average speed and journey time of vehicles in the traffic stream. While random fluctuation in the mix of vehicle types, performance and drivers can lead to day-to-day variability, there is no obvious gain in attempting to segment the market in this way.

This leaves day-to-day variability related to small changes mainly in demand factors as one focus of interest. Incident-related variability involving abnormal factors that interfere with supply are separable reliability effects that are less frequent and generally have greater consequences. Then there are the exceptional variations caused by very infrequent and generally larger scale events which it is proposed not be a focus of the research.

Where transport modes share the same road space and do not enjoy any special priority (such as dedicated lanes, intersection control pre-emption etc), then the road and traffic factors influencing travel time variability will apply across the board to cars, buses and trucks alike. Passenger transport modes enjoying dedicated right of way (suburban rail and busways) will be subject to their system-specific reliability influences, and there will be a halfway house where a class of vehicle is given priority. Public passenger transport will also be subject to some additional demand and supply effects, such as varying boarding demand (and the bunching effect) and matters relating to fleet and crew scheduling and positioning.

## 4.4 Conclusions of research into market segmentation

The research brief sought reliability values for commuting, tourism, other personal trip purposes (combined) and for freight. Commuting is well defined in transport planning practice, refers to work commuting and is dominated by daily home to/from workplace travel in urban areas by public and private transport. 'Other', however, covers a range of trip purposes and, as recognised in the EEM procedures, is all other trip purposes apart from work commuting and work travel. The 'other' category includes social and recreational trip purposes, so implicitly incorporates 'tourism' although this does not have a recognised definition in transport demand and infrastructure planning. It should be noted that the research brief did not seek reliability values for shopping or education trips.

National statistics on international visitor arrivals and domestic visitor surveys provide the available data on the tourism sector, but the term 'visitor' can include business, holiday and visiting friends and relations. What constitutes a visitor trip is also influenced by day-trips versus overnight or longer, inter-versus intra-regional travel, and New Zealand resident versus overseas visitor. Government policy appears to focus on international holiday visitors as 'tourists' in its classification of state highway traffic.

The value of travel time has not been separately quantified for tourism or social/recreational travel, and any quantitative investigation of the value of travel time reliability for this market segment should also include the value of time. We have concluded that research should concentrate on three components of the 'tourism' sector where either the transport operator or the traveller can be expected to place a relatively high value on reliability, namely: departing air passenger ground access trips; tour and excursion bus trips where ability to maintain a schedule is important; and travel on congested outlets to main urban centres at holiday peaks.

The market segmentation for freight is particularly complex. We have explored the data sources for freight volumes and freight movement and find that these are not well aligned to factors likely to influence freight value of time and reliability. The perceived costs of off-schedule delivery are expected to differ between the transport operator and the freight shipper, unless these are one and the same. Often, freight forwarders and transport operators specifically insulate themselves from delivery time risks in their contracts of carriage. It is the shipper's value of time saving and reliability of delivery that is most likely to reflect economic value, whereas the transport operator's perceptions will be reflective of the costs of vehicle and driver time and schedule adherence.

Factors contributing to high value or time and reliability from the shipper's viewpoint are anticipated to be:

- ordering/delivery time pressures
- degree of product customisation
- loss of product value with time
- commodity stock value (see figure 4.5).

We suggest that a high/medium/low categorisation of these factors should form the basis for market segmentation as shown in figure 4.5. The tight delivery window/highly customised/high value loss with time/high stock value group is likely to be a very small part of the freight market in volume terms, with the low delivery time pressure/undifferentiated product/no value loss with time/low stock value contributes a large percentage of the market by volume as well as being the category for which statistics are most likely to be available.

## 5 Reliability theory and methods

In this section we review the literature on the theory and modelling of reliability, including how reliability is incorporated into microeconomic theory, and drawing attention to how existing overseas theory and practice compares with that in New Zealand (as discussed in chapter 3), including:

- concepts of travel reliability, including journey time, departure and arrival time reliability and how reliability is perceived and understood by the transport user in different travel contexts
- mathematical and statistical methodologies that have been used or proposed for measuring and modelling reliability and their respective merits and practicality in application
- the subject of travel time reliability in transport networks including modelling theoretical and methodological issues, and implications for how reliability is measured and monitored
- primary studies of transport user preferences and perceptions of reliability, from structured studies of SP and RP and from less structured focus group and other market surveys, and the results obtained for behavioural values of reliability and their connection to values of time and related parameters
- a review of how behavioural values of reliability have been incorporated into practice for transport planning and for economic evaluation.

### 5.1 Concepts and perceptions of reliability

#### 5.1.1 Introduction

Transport reliability has been of interest for many years. For instance, Garrison (1960) used graph theory concepts to assess the connectivity of the US interstate highway system and the accessibility of major urban areas to the system. This study and subsequent studies of network connectivity (eg Wakabayashi and Iida 1992) focused upon whether a location could be accessed, with little or no regard for the time taken. Such studies are particularly important when considering the impacts of natural hazards, and the ability of civil defence authorities to rescue injured people and facilitate restoration of essential service. More recently, however, there has been an increasing interest in the predictability of the time taken to make a trip.

In basic terms, a facility is 'reliable' if the expectations of users are almost always met, and the reliability increases as the frequency and/or consequence of failing to meet user expectations decreases.

Expectations can vary considerably between users, some having expectations that are much higher than others, and can also vary over time for a particular user under different circumstances. As noted by Nicholson et al (2003), the spread of the just-in-time philosophy has been accompanied by an increase in the expectations of users of the transport system. This philosophy has entailed a greater reliance on the predictability of travel/delivery times, especially for freight. Various studies have shown that travel time reliability (or predictability) is important for personal travel, whether by private transport (Parkhurst et al 1992) or public transport (Chapman 1976).

#### 5.1.2 Reliability in personal private transport

Parkhurst et al (1992) found that while the quality of service embraces a wide range of service attributes one of the most important is reliability, with travellers commonly mentioning unreliability and the consequent variability and unpredictability of travel times as a negative service attribute.

Unreliability in travel time is commonly considered to be directly related to increasing travel congestion, with Goodwin (1992a) suggesting that transport planners 'should deliberately allow for spare capacity' by

upgrading or constructing links in road networks, to improve network reliability. Noland and Polak (2002) noted, however, that travel time variability is somewhat independent of congestion effects, with travel times being high but consistently so in some highly congested networks and being very variable in some networks with little congestion.

The response of users faced with congestion and/or unreliability can take various forms, including:

- cancelling their trip (change in trip generation)
- postponing their trip (change in the temporal distribution of trips)
- choosing another destination (change in the spatial distribution of trips)
- travelling by another mode (change mode split)
- choosing a different route (change in the traffic assignment)
- do nothing.

The wide variety of potential responses, along with the uncertainty regarding the proportion of users choosing each, increases the difficulty associated with identifying the economic consequences of reliability. However, it is expected that the higher the level of user knowledge (eg advance warning of service disruptions, knowledge of the network and alternative paths), the lesser the impact of service disruptions (Polydoropoulou et al 1994; Nicholson et al 2003). These have acted to increase the opportunities for advance action by the traveller to mitigate the impact of unexpected delays and for the impacts of delays that do occur to be contained. Against these positive influences, traffic congestion has increased, leading to more opportunities for flow breakdown and unreliability, and expectations of reliable travel times have increased.

### 5.1.3 Reliability in public passenger transport

Most studies of travel time variability have focused on trips by private vehicles (cars and trucks), with fewer studies (eg Hollander 2007) of public transport trips and little (if any) research on travel time variability for cycling and walking trips. Hollander (2007) investigated the willingness-to-pay of bus users for improvements in the reliability of public transport services, finding that the willingness-to-pay to reduce the lateness of arrival is much larger than the willingness-to-pay to reduce the mean travel time or the earliness of arrival. Van Oort (2011) gives a comprehensive theoretical analysis of various planning instruments, and demonstrated that passenger waiting time may possibly be extended up to 600% due to service variability.

Wallis (2011) has recently reported to the Transport Agency on bus reliability with the main audience being the bus sector (bus operators and the public agencies planning and contracting services). The report aim was to examine bus service reliability issues and, as a consequence, inform issues and good practice. It concentrated on reliability as perceived by the bus user. The following discussion draws on that work and other sources.

In public transport, there are generally three parties to the delivery of reliable service – the traveller, the public transport operator and the network provider, whereas there are only two parties for private transport. In the following discussion the references are to bus mode but can equally be applied to passenger rail.

The perception of reliability as it relates to passenger transport varies between the three parties. For the passenger, it is the departure of the expected service and arrival at the destination at the advertised times that constitutes the perceived reliability of the service. For operators and passenger transport authorities, reliability is often used to mean whether a particular service runs at all whereas punctuality is used as the measure of arrival on time; both have operational implications and may be used as performance indicators in service contracts. Passengers, however, are not really concerned whether a bus that arrives later than

expected is in fact the 'next' bus running early or the 'last' bus running late and is a result of dropping a service or just late running.

In many cities overseas, timetables are not published for the peak periods where frequent services are instead advertised by headway (eg a bus on average every seven minutes); however, in New Zealand up to now it has been practice to publish a full timetable, even on high-frequency bus routes. Nevertheless on main public transport corridors where several routes converge, passengers are less likely to time their arrival at the bus stop to meet a timetabled service than to arrive with a general expectation, from experience, of not having to wait more than a certain time.

Any differences in passenger perception of reliability between headway and timetable modes of running may also be influenced by modern departure display systems at bus stops which in effect update the timetable, although at a point where the decision on trip timing has already been made. Systems that inform the passenger before the trip is started, such as through texting or other hand-held device real-time applications, have the advantage of updating the schedule before making the access trip to the bus stop so stand to reduce the impact of off-schedule running.

As the headway between services increases, which is the case on the outskirts of the urban area where there is only a single public transport route serving an area and in the off-peak and at weekends, then the published timetable becomes a more important point of reference for the traveller and he/she is more likely to time arrival at the bus stop to catch a particular service. Timetabled running imposes some constraints on the operator that are not present in headway running as it is less acceptable for a service to leave earlier than scheduled even though this may be useful in some situations to even out headways.

The third party in delivering reliability, the road or rail network manager (local authority or the Transport Agency for roads and KiwiRail), is removed from the interface between the operator and the passenger. The operator relies on the network manager providing conditions conducive to operating a reliable service. This division of responsibility provides opportunity for the responsibility for reliability shortcomings to be disputed between the two parties. Ways of encouraging a cooperative approach to reliability performance by the service and infrastructure providers occupies a good deal of the literature on public transport reliability interventions. When the network provider and service operator are the same, this gets over the problems of responsibility for service unreliability, particularly where there is dedicated right-of-way, but this is not a current model of operation in New Zealand.

So the public transport traveller has to contend with both the uncertainty of the service departure time and the uncertainty of the service arrival time in meeting the PAT at the ultimate destination. For a timetabled and less frequent service, the risk of delay at the departure point is mainly from late departure of the service; the traveller may allow a small time buffer for unexpected delay in the access trip to the bus stop and/or for earlier than timetable departure of the service. The decision of which service to catch will have been made with a view to how well the timetabled arrival fits with the PAT. Where there is a high perceived cost of lateness, the traveller is likely to build in a larger time buffer, and this buffer will also depend on the traveller's inherent risk aversion and any foreknowledge of service reliability from past experience.

#### 5.1.4 Reliability in tourism travel

Most of the discussion about the concept of 'reliability' in tourism-related literature is focused on the dependability of service or product quality (eg tourism operator or accommodation provider and the accommodation or rental vehicles themselves), rather than journey time reliability.

For example, Dickinson and Robbins (2009) investigated attitudes of residents, overnight and day visitors in Purbeck, UK towards different modes of transport through their responses to a transport and mobility attribute checklist. Respondents were asked to indicate whether a series of statements, including 'a mode

of transport you consider reliable’, applied to car, bus, cycle, walk or none of these. In another study, Kelly et al (2007) considered issues around travel time such as frequency, travel/wait time for bus and train, convenience and flexibility, but did not include reliability or variability of travel time.

Visitor satisfaction with core elements of their trip is commonly measured, including the catch-all term ‘transport’, as satisfaction is considered an important determinant of whether or not a tourist becomes a repeat visitor (Reisinger and Turner 2000). In New Zealand, the Visitor Experience Monitor<sup>7</sup> administered by Tourism NZ asks respondents to rate ‘reliability’ of transport on a scale of 1 to 10.

On the other hand, bottlenecks and congestion associated with tourism destinations are acknowledged in the literature, although little effort is expended to determine how much of an issue this is for the tourists themselves (Yigitcanlar et al 2008; Dickinson 2006; American Highway Users Alliance 2005; European Commission 2003). Traffic congestion and resulting delays have been identified as concerns around different tourism destination in New Zealand, for example the Lincoln University (2008) report on Akaroa and the Environment Bay of Plenty (2002) baseline and issues report on transport in Bay of Plenty. As far back as 1993, the New Zealand government set up a task force (Transit NZ and Ministry of Commerce 1994) to investigate the future tourism demands on road transport, in part, because of tourism areas experiencing congestion.

Dickinson (2006) questioned 830 visitors arriving by car to Purbeck, UK, and found that many were concerned about congestion, but few (10%) identified undertaking any ‘coping mechanism’ (usually finding an alternative route) to address it. Forty-one percent of visitors just accepted the congestion as part of the holiday destination and did nothing to avoid it. Dickinson did note that Purbeck is a rural destination, and while crowded, may be so at a lower level than the urban locations that visitors actually live in.

A study by Shailes et al (2001) of visitors arriving by car in Cornwall UK found that 55% of respondents took ‘evasive behaviour’ (implying that 45% did not, a figure similar to that of Dickinson’s), primarily by choosing a time and day of travel to avoid congestion. A few undertook ‘route diversion’, either on its own or in conjunction with the aforesaid ‘time diversion’. In the binary logit model developed following the 200+ interviews, anticipation of (unexpected) delays or congestion did not feature as significant, although a priority to avoid congestion in pre-journey preparation did. The authors hypothesise that an awareness of congestion results in greater acceptance than does experiencing unexpected delay.

The American Highway Users Alliance (2005) stresses the importance of tourism to many local and national economies, and speculates that bottlenecks could have a negative impact on income and employment at the destination if tourists were to avoid travelling there. Similarly, the European Commission (2003) surveyed nearly 4000 tourism operators and businesses across the European Union who offered opinions such as traffic congestion or delays may cause tourists to think carefully before choosing where to travel; and ‘delays and congestion are commonplace and are likely to act as a barrier to continued growth in the future.’ Such opinions undoubtedly have some basis in reality as anecdotal evidence, but their true significance is unknown.

Quarmby (2006) observed that the pattern and concentration of tourism trips on the transport network is very different from day-to-day trips by local residents. Tourism trips tend to be a significant proportion of rail journeys of more than one hour long and most of the scheduled inter-city coach journeys. They also are ‘relatively insignificant on urban and regional roads, except for departing and arriving at the beginning and end of holiday periods and weekends’ and may be a ‘significant’ proportion of road traffic on certain parts of the highway network at certain times, most notably at the beginning and end of weekends and holiday periods. Even then, Quarmby states that local traffic, vans, and heavy goods vehicles will form the

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<sup>7</sup> [www.tourismnewzealand.com/markets-and-stats/research/visitor-experience-monitor-201112/](http://www.tourismnewzealand.com/markets-and-stats/research/visitor-experience-monitor-201112/)



major portion of the traffic stream. 'Travel around the destination' may encounter delays and/or congestion, for both visitors and local day-to-day travel.

There is much speculation as to how tourists view the issue of travel time reliability. For example, Beecroft et al (2003) in preparing one of several 'vision' documents for the UK Department of Transport, stated that tourists making a trip once or twice in a life time are not 'even going to know if it's reliable'. However, they also observed that the increasing road congestion in developed countries means that average road speeds are slower now than a century earlier in some locations, with the effect that local travel can take as long as long-distance travel. In New Zealand, this could be true for holiday periods and could affect both overseas and domestic tourists. The advent of low-cost air services in New Zealand may mean residents can trade off a local road-based holiday with one in Australia. Indeed, a Ministry of Tourism (2009) report, based on DTS data, stated that 'there is evidence that outbound tourism is being substituted for domestic tourism' as between 2004 and 2008, the total domestic nights by New Zealand residents fell by 6%, while the outbound nights increased by 13%. Overall, the total number of nights spent away from home, either domestically or overseas, remained unchanged. At this stage, the reasons for the substitution are unexplored, and they may not include reliability concerns, although the results of a separate survey, *Mood of the New Zealand traveller* (Tourism Industry Association 2012) indicate that traffic is a 'source of frustration' for 13% of New Zealand travellers in the Christmas/New Year holiday period.

Koo et al (2009) explored the substitutability of low-fare air services and other (land-based) mode alternatives in the New South Wales travel corridor. In the modelling, journey time reliability was only included for air services, as a percentage of 'on time arrival'. The reliability attribute was omitted for the coach and train alternatives because of limited data on the actual levels. No reliability attribute was assigned to rental/private car. In any case, none of the time-related variables (in-vehicle time, out of vehicle time, door-to-door time, frequency, reliability, and scheduling) were significant at the 5% level. In-vehicle, out-of-vehicle and door-to-door time attributes varied by up to four hours. The authors speculated that the lack of significance could be due to the fact that attributes varied specifically for the mode and cross effects were not estimated. The two most relevant factors in mode choice for the experiment were the trip 'context' (ie single or multiple destinations) and low airfare costs.

McDonald and Murphy (2008) examined constraints surrounding 'short-break' vacations (defined as a trip taken for one to three days and up to two nights) through focus groups involving regional residents travelling to Melbourne. While 'time' was raised as a constraint, this was in the context of a shortage of time due to work and/or family commitments, the lack of time available for a short break, and/or the time of year. Reliability, variability in travel time and/or delays were not raised, although some participants commented that they favoured 'closer, less congested, alternative destinations' to Melbourne and/or wanted 'less congested' state roads.

Older travellers are perceived as being time rich (having more time) and, therefore have less concern about travel time reliability (Patterson 2006; Horneman et al 2002).

Oxford Economic Research Associates (OXERA) and Mott Macdonald (2003) examined the impact of poor rail performance on the tourist industry in the UK<sup>8</sup>. Poor rail performance was related to lateness and/or cancellation of services. Disutility of poor rail performance was estimated by using the 'perfect-running counterfactual' (perfect punctuality and reliability) to show the total amount of disutility attributable to poor

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<sup>8</sup> More recently, Ruggles-Brise (2009) reported on a Transport for London survey of visitors' perceptions of London's public transport services. Some respondents commented that they had experienced service delays and suspensions, which were sufficient to put them off using the service, although whether or not it would put them off travelling to/within London was unclear.

rail performance and by comparing the performance for the best-year with the other years where the service had not repeated its best performance levels. OXERA posited that most passengers have a PAT and if, due to scheduling or unreliable information, they arrive too early or too late, particularly for a flight, they may experience additional disutility. OXERA modelled the effect of the overall disutility (translated into a generalised cost), taking into account the proportion of travellers that leave rail and do not travel at all (other options include: travel by another mode to same destination, travel overseas, travel by rail to another destination), the overall expenditures by international and domestic tourists, They estimate that the loss is 0.04% (approximately £11 million) of total tourist spending in 2002, some of it to rail operators and other to 'third parties'. They note that resident non-trip makers will still spend money in the economy, albeit at a lower rate. While the volume of rail travel in New Zealand is too low to repeat such a study here, the overall methodology may be useful in discerning the effects of delays on domestic tourism in New Zealand, where the alternatives may be to not travel at all or to travel overseas.

In areas where there are a lot of tourists, the effects of journey time unreliability, delays and/or congestion will be experienced by both visitors and local residents. Residents may adopt 'coping mechanisms' to deal with busy tourism periods, such as reorganising daily activities (changing times and/or locations of activities) and/or retreat from normal life (stopping/ avoiding certain activities and/or planning ahead to avoid the need to go out) (Dickinson 2006).

## 5.2 Mathematical and statistical methodologies

### 5.2.1 The mean - dispersion and schedule delay approaches

There are two basic approaches to assessing travel time reliability in the literature. The first and more common is the mean - dispersion approach, which assumes that there is a direct trade-off between changes in the mean travel time and some measure of variation in travel times, such as the variance or standard deviation, with utility being defined to be a linear combination of the mean travel time mean and the standard deviation (or variance) of travel time.

The second is the 'schedule delay' or 'scheduling' approach, in which travellers are assumed to have a target schedule expressed as a PAT, or an arrival time window, at their destination. They are then theorised to trade off change in the mean travel time against factors such as the chance of early or late arrival relative to their PAT at the destination. Again, the trade-off is typically represented through a linear combination of the involved factors each with an attached utility. In both approaches the value of reducing variation in travel time is combined in an expected utility model with the value of saving travel time, so the value of travel time variability is directly linked to the value of travel time saving.

### 5.2.2 The mean – dispersion approach

In the mean - dispersion approach, expected utility theory (see section 2.6.2) is used to produce a formulation for traveller's expected utility as a linear combination of expected (mean) travel time and standard deviation of travel time with generalised cost coefficients against each. Dividing the cost coefficient against the standard deviation of travel time by that for travel time gives what is referred to as the 'reliability ratio', the ratio of the value of reliability improvement to the value of time saving.

$$\text{expected utility} \quad E[U] = \alpha T + \lambda \sigma \quad (\text{Equation 5.1})$$

$$\text{reliability ratio} \quad \rho = \lambda/\alpha \quad (\text{Equation 5.2})$$

While standard deviation is used in most modelling as the single statistic for measuring of variability it does not describe the degree of skew in the distribution of travel time variation. In most cases the

distribution will show a long tail of relatively large but infrequent delays and a greater probability of relatively small delays, with the mean variation larger than the median.

Other possible statistics are a measure of the positive skew (various indicators are possible) or percentile measurements, concentrating on those that describe the higher end of the distribution and which have some relevance to thresholds in the cost of being late. Percentile measurements may be easier to link with policy on achieving reliability performance in an understandable way than standard deviation.

### 5.2.3 The scheduling approach

Introduced in section 2.5, the scheduling approach is based on schedule delay about a PAT. The standard model formulation for this approach is

$$\text{utility} \quad U = \alpha. T + \beta. SDE + \gamma. SDL + \delta. L \quad (\text{Equation 5.3})$$

Where SDE is schedule delay early, SDL is schedule delay late and L is a dummy variable for being late set to 1 (late) or zero (not late). The coefficients  $\alpha$ ,  $\beta$ ,  $\gamma$  and  $\delta$  are respectively the disutilities (values) per minute of travel time savings/losses, the values per minute of early and late arrival on schedule and the value of arriving late. This model can be extended to an expected utility maximising model with formulation:

$$\text{expected utility} \quad E[U] = \alpha. E[T] + \beta. E[SDE] + \gamma. E[SDL] + \delta. E[L] \quad (\text{Equation 5.4})$$

The disutility of arriving early, per minute, is hypothesised to be different from (and less than) the disutility of arriving late. This has been borne out in empirical research (see for example Bates et al 2001). It is further hypothesised that there may be a disutility associated with being late (L), irrespective of the late time. The approach derives from Small (1992) and Noland and Small (1995) and is well described in Hollander (2007). The 'being late' per se attribute was not included in the original scheduling work by Vickery and is also absent from many empirical studies. It was introduced later by Small et al (1999).

### 5.2.4 Suitability of the two approaches to private and public transport

#### 5.2.4.1 Private transport and general traffic

The mean-dispersion approach is the more readily applied to reliability of journey times in general road traffic, as both mean travel time and variability can be measured using techniques such as floating car surveys, GPS tracking or other individual vehicle detection methods. However, this ease of measurement is at the expense of some theoretical shortcomings discussed in sections 5.2.5 and 5.3.

For vehicles in the general traffic stream it is not possible to have any direct information on the occupants' PATs and earliness or lateness on schedule, which makes the schedule delay approach harder to apply unless some linkage is made between measured travel time variability and the probability distribution of early/late arrival arrived at by other means.

#### 5.2.4.2 Public transport

The schedule delay approach is intuitively more suited to public transport, particularly to timetabled services where it is possible, at least in principle, to measure off-schedule running. However, again there is the problem that the traveller's PAT is not directly measurable. So, for practical reasons, application of reliability to scheduled public transport has usually conflated the scheduled arrival time of the public transport service with the PAT of the traveller and the variability around this timetabled arrival with the schedule delay around the PAT.

The passenger's choice of service will certainly have regard to the access time at the destination and PAT, particularly for infrequent services. Also the traveller will in some cases be able to choose the PAT to suit the public transport timetable. There has also been the suggestion in the literature that service schedules are

broadly designed to fit the PATs of travellers (Fosgerau and Hjorth 2008) which lends further support to using the variability of the PT service as a proxy for the variability around the PAT from the traveller's viewpoint. Bates et al (2001), for long distance passenger rail in the UK found that the value coefficient on delay relative to timetable was of similar magnitude to late schedule delay relative to PAT, both around 2.5.

The trip components of service departure time (or headway for frequent non-timetabled services), in-vehicle journey time, service arrival time and destination arrival time, will each have their own pattern of variability and intuitively it seems likely that these will be to some extent correlated. Rather than try to unpack each trip component, models have focused on the schedule delay on the PAT as the main object of interest to the traveller.

A potential problem in equating the adherence to schedule of a public transport service with reliability from the viewpoint of the traveller can be appreciated where bus operators accept an overall increase in journey time in return for better schedule adherence by requiring services to wait at particular stops along the route if running ahead of schedule. While this can improve the timekeeping of the service, and may be driven by a performance requirement on the operator, it may not reflect the time/reliability trade-off that the public transport user would have made.

Also relevant is the work of Fosgerau and Karlström (2010) who showed equivalence (under certain assumptions) between the scheduling approach and an approach using the mean and the standard deviation of travel time.

### 5.2.5 Travel choice behaviour comparison of the two approaches

Another key distinction between the approaches lies in the factors involved in the linear trade-offs made between the components of utility.

The mean–dispersion approach has some intuitive appeal, in the sense that when comparing two alternatives (A and B, say) with a similar mean journey time, the alternative (A) with smaller variance will generally be preferred (see figure 5.1).

However, consider the example of a traveller who has already been delayed in commencing a trip for which there is a high cost penalty for lateness, say to the extent that there is a less than 50/50 chance that the destination will be reached in time. In this example, a rational traveller should choose route B with the larger travel time variation, to improve their (albeit low) chance of arriving on time. That is, the lower variance option is not always the better option (Nicholson et al 2003). However, if the consequences of being late are relatively small and it is the amount of lateness that governs the rational decision, then alternative A should be chosen.

The traveller's inherent risk-taking behaviour may also influence the choice made – the habitual risk taker gambling on a less than even chance of being on time and the risk averse aiming to minimise their lateness. This inherent behaviour may of course influence the time allowed for the journey at the outset, with the risk-averse leaving earlier to better cover any chance of late arrival.

This example demonstrates a drawback to the mean–dispersion approach to travel time variance in that it may lack a behavioural foundation, in the sense that it is unlikely to be something directly perceived by drivers. The structure of the schedule delay model appears better for capturing this behavioural response. Indeed, Bonsall (2000) noted that when users of transport systems are confronted with an unpredictable situation, they appear to adopt strategies that cannot be explained in terms of the variance of the performance measure.

The components in the scheduling approach to travel time reliability thus have a better behavioural basis, but the resulting definition of utility is a rather more complex function of the travel time probability

distribution, and would lead to a more computationally burdensome implementation in a traffic assignment model. The scheduling approach does, however, allow testing of options such as increased flexibility in work start times, but this is not possible with the ‘direct trade-off’ approach, which does not include such policy variables.

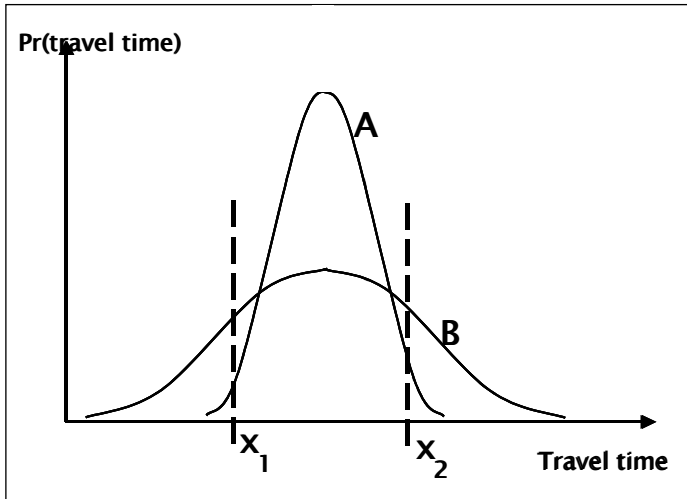


Figure 5.1 Choosing between options with different variabilities

### 5.3 Aggregation of trip segments

Economic appraisal procedures allow for travel time savings on a segment of a trip by equating the time saving for the trip to the time saving for the segment of the trip. This is both convenient and scientifically sound, as the trip time ( $\mu_T$ ) is simply the sum of the times ( $\mu_i$ ),  $i = 1, 2, \dots, n$  for the trip segments, i.e.

$$\mu_T = \sum_{i=1}^n \mu_i \tag{Equation 5.5}$$

One can place a value on a reduction in the mean travel time for one segment of a trip, without knowledge of the mean travel times for the other segments, only because segment travel times are additive.

Such a simple and convenient relationship does not exist for the standard deviation of the trip travel time ( $\sigma_T$ ) and the standard deviations of the segment travel times ( $\sigma_i$ ),  $i = 1, 2, \dots, n$ , as the standard deviation of the trip time does not equal the sum of the standard deviations of the segment travel times. It can be shown from statistical theory that if the segment travel times are not correlated, then:

$$\sigma_T^2 = \sum_{i=1}^n \sigma_i^2 \tag{Equation 5.6}$$

and the standard deviation of the trip travel time is the square root of the sum of the variances of the segment travel times, i.e.

$$\sigma_T = \sqrt{(\sigma_1)^2 + (\sigma_2)^2 + \dots + (\sigma_n)^2} \tag{Equation 5.7}$$

One cannot identify the effect of a reduction in the standard deviation of the travel time for one segment of a trip (e.g. changing the form of control at an intersection) on the standard deviation of the trip time, without knowledge of the variability of travel times for the other segments, because the standard deviations of segment travel times are not additive.

As noted by Nicholson (2007) it can be shown that:

$$\sqrt{(\sigma_1)^2 + (\sigma_2)^2 + \dots + (\sigma_n)^2} < \sigma_1 + \sigma_2 + \dots + \sigma_n \quad (\text{Equation 5.8})$$

i.e. the standard deviation of the trip travel time is less than the sum of the standard deviations of the segment travel times, and the discrepancy between the two quantities increases as the number of segments with unpredictable travel time increases. Hence an x% reduction in the standard deviation for one segment will mean a smaller than x% reduction in the standard deviation for the complete trip (ie the change in trip travel time reliability will be over-estimated), and the degree of over-estimation will increase as the number of segments (ie the trip length) increases.

If the segment travel times are not independent (i.e. they are correlated), the variance of the total trip time is:

$$\sigma_T^2 = \sum_{i=1}^n \sigma_i^2 + 2 \sum_{i=1}^{n-1} \sum_{j=i+1}^n \rho_{ij} \sigma_i \sigma_j \quad (\text{Equation 5.9})$$

where  $\rho_{ij}$  is the correlation coefficient of the travel times for the  $i^{\text{th}}$  and  $j^{\text{th}}$  segments.

It is likely that the travel time for all segments will be greater than the mean value (based on average traffic conditions) at times when the road network is fairly uniformly congested (ie the travel times for the segments will be positively correlated). For a road network which is subject to congestion at particular locations only (eg bottlenecks), the correlations between the travel times for the segments on opposite sides of the bottlenecks might be negatively correlated.

It can be seen that allowing for correlation of segment travel times results in a much less simple expression for the variance of the trip time, which comprises two terms:

- the sum of the variances of the segment travel times (the ‘variance term’)
- the sum of the products of the correlation and standard deviations (the ‘correlation term’).

The effect of allowing for correlation is to exacerbate the non-additive characteristic of the standard deviations of segment travel times.

The ‘correlation term’ can be ignored if and only if:

- the correlations of the travel times for the segments are all zero (ie the segment travel times are independent), or
- the standard deviations of the segment travel times are all zero (ie there is no variation in the segment travel times), or
- there are positive and negative correlations of such magnitudes that the sum of the products of the correlations and standard deviations is close to zero.

As noted by Nicholson (2009), it is very unlikely that any of these three conditions will be satisfied in networks with substantial congestion.

Approximate expressions for the standard deviation of the trip travel time ( $\sigma_T$ ), such that  $\sigma_T$  can be estimated in the same manner as the trip time (ie simply adding the values for the trip segments), have been developed (Mott MacDonald, 2000a). More recently, Engelson and Fosgerau (2011) have proposed an additive relationship, but they have not allowed for correlation between link journey times.

As noted later (in section 6.5), an investigation has found that the approximate and additive relationships do not result in accurate estimates of the standard deviation of the trip time, resulting in inaccurate estimates of the flows in links (Mott MacDonald 2003). It is worth noting that Arup (2003) identified ‘the

need to allow for the correlation between link journey times' as being the 'key issue' in estimating trip time variability.

## 5.4 Travel time reliability in traffic networks

Estimating the effect of supply and/or demand variations on travel time in a network can be done using a standard 'equilibrium approach', provided the change in the supply and/or demand is sustained for a sufficient time for equilibrium to be achieved. If the supply and/or demand variations are of short duration, then it is unlikely that there will be time for traffic conditions within the network to stabilise, and one is unlikely to get an accurate estimate of the effect of the such variations by using a standard 'equilibrium approach'. The use of a micro-simulation approach can handle such situations better.

A study of the effect of short reductions in road capacity (Berdica et al 2003) involved comparing the results of using the equilibrium and micro-simulation approaches. It showed that the micro-simulation results are more sensitive to short-term capacity reductions than are the results obtained using an equilibrium approach. It was concluded that the micro-simulation approach is more realistic, as it allows for users changing paths after starting their trips, to avoid congestion they encounter, while with equilibrium-based models, the status of the road network is assumed to be known beforehand and route choice does not change en-route.

It should be noted that neither approach is currently able to take account of travel time variability as a factor in route choice, as they both rely upon the goal of users (when choosing routes) being able to be defined in a form that is additive, just as travel times for segments of a trip can be added to get the time for the trip.

## 5.5 Studies of transport user preferences

Identification of the importance attached to travel time predictability by users, and hence the value that should be placed upon improvements in the predictability of travel time, is very difficult if using RP techniques, which examine the choices travellers have actually made in observed situations, because it is extremely hard to find such situations (Bates et al 2001). SP surveys are generally the only realistic option, despite the challenges in the design and conduct of such surveys (Hollander 2007; Tseng et al 2009).

Tseng et al (2009) noted that while travel time reliability is an important factor in travel decisions (especially, which mode and route to take), and the benefit of reliability improvement should be included in economic appraisals, it is difficult to identify the effect of travel time reliability using the classical SP survey method. They noted that there is considerable variation between studies in the way that travel time reliability is presented to survey participants. They undertook a survey, in which respondents were asked to consider four types of trip (by car or public transport, with or without trip timing being important), with reliability information presented in eight different ways. The presentation formats were assessed by asking respondents about their subjective preferences, and asking questions that could be tested objectively to see if respondents perceived unreliability in a consistent and logical way. They concluded that respondents find some formats much more difficult to understand than others, with the format involving a verbal description (without any graph) of five possible travel times, each with equal probability, being understood best.

It appears that obtaining accurate information regarding how users perceive and value increasing the predictability of travel time is rather more difficult than obtaining similar perceptions and values about savings in the mean travel time.

User behaviour might not reflect the actual probabilities and consequences of events occurring (eg users might overreact to low-probability events), a situation for which ‘prospect theory’ is well suited (Kahneman and Tversky 1979). This approach has recently been applied to the problem of predicting traveller response to adverse weather conditions (Zhang and Chen 2009), as well as to other applications (see Hensher et al 2011; Hensher et al 2012; Koster and Verhoef 2012).

A more detailed review of methods and studies undertaken for eliciting information on transport user preferences involving reliability should be undertaken at the next stage in the research, once the need for and focus of market research needs are better formulated.

## 5.6 Incorporation of reliability into transport planning

Much of the research has focused upon how to incorporate improvements in travel time reliability in project economic appraisal. There is another problem of how to allow for changes in travel time reliability during the transportation planning phase which precedes the economic appraisal phase, and how the two phases are linked. If travel time reliability is not taken into account during the transport planning phase, then traffic flow predictions might be inaccurate, resulting in inaccurate estimates of the benefits of the project.

Some research has been done on how to allow for travel time reliability during the trip assignment stage such as allowing for users to prefer a longer but more predictable route over a shorter but less reliable one. If travel time reliability is allowed for in trip assignment, it should then be possible to allow for travel time reliability to be taken into account in the preceding stages of the transport planning process (mode split, trip distribution and trip generation) by the use of ‘feedback loops’ within a four-stage transport modelling approach.

Current trip assignment methods rely upon the generalised cost of travel for a trip (or route) being the sum of the generalised costs for the segments of that trip (or route). This additivity requirement is not met if the generalised cost of travel is extended to include travel time reliability (in addition to travel time and vehicle operating costs), whether the travel time reliability is included via the mean - dispersion approach (as in the current EEM) or the alternative ‘schedule utility’ approach.

A study for the UK Department for Transport (Mott MacDonald 2000a) has investigated options for allowing for travel time reliability in trip assignment, using the mean - dispersion approach, which has the advantage of greater simplicity compared with the ‘schedule utility’ approach (Batley et al 2008). Mott MacDonald considered a generalised cost (GC) function for a route that includes variability, as follows:

$$GC_{route} = time_{route} + [k \times f(\mu_{route}, \sigma_{route})] \quad (\text{Equation 5.10})$$

where  $\mu_{route}$  and  $\sigma_{route}$  are the mean and standard deviation of the route travel time,  $k$  is a measure of the cost of variability relative to the mean time (the ‘reliability ratio’) and  $f$  is some function of the mean and standard deviation of the route travel time (the ‘variability function’). Note that other cost components (eg vehicle operating costs) can readily be converted to equivalent travel time costs and added to the travel time component.

If the ‘variability function’ is simply the standard deviation of the route travel time, as in the current EEM, the generalised cost function is:

$$GC_{route} = time_{route} + [k \times \sigma_{route}] \quad (\text{Equation 5.11})$$

Mott MacDonald investigated two approaches for dealing with the non-additivity problem. The first approach involved changing the algorithm for finding the minimum-cost route, one using path



enumeration and one modifying the D'Esopo/Moore/Dijkstra algorithms), and the second involved changing the generalised cost function using an approximate cost function that is additive.

Mott MacDonald (2000a) refer to evidence that that the travel times between adjacent links are positively correlated, with the correlation coefficient typically lying in the range 0.2 to 0.4, which is consistent with the correlations obtained by Nicholson and Munakata (2009). They also note that such correlation between link travel times is an additional cause of non-additivity in the generalised cost function (ie non-additivity exists when there is no correlation, and is greater when there is correlation).

A subsequent study (Mott MacDonald 2003) involved implementing each of the three methods for a very simple network with only four links and three nodes, and three routes through the network. They found that only one method (path enumeration) can be relied upon to give the correct results, and that is only if the set of enumerated paths includes the optimal path. In a typical network, with many more links and nodes, the computational effort associated with the enumeration method would be extremely high. While this computational effort would be reduced by enumerating only a sub-set of the possible paths, it would be at the expense of an increase in the probability that the enumerated paths does not include the optimal path (ie at the expense of an increased probability of getting an incorrect result). Nevertheless, they found that the other two methods produced sufficiently inaccurate results that enumeration was deemed to be the only method worth pursuing.

There is currently no evidence in the literature that an effective and efficient method has yet been found for accurately estimating traffic flows within a large network using commercially available software, such as is invariably involved in typical transport planning studies, while allowing for travel time variability. However, there has been a good deal of recent work published on solving network problems with non-additive path costs, although these have yet to find their way into commercial software. It is expected that work on overcoming this issue, which is a substantial impediment to developing a sound method for accurately estimating the benefit of projects aimed at improving travel time reliability, is continuing.

## 5.7 Incorporation into economic evaluation

The UK is one of the few jurisdictions that formally incorporate reliability into project economic appraisal. Reliability is not included as a matter of course in Australian project assessment, but some advice is contained in Austroads, This section therefore concentrates on the situation in the UK and Australasia.

### 5.7.1 United Kingdom

Current UK guidance is provided in Webtag (Department for Transport, UK, Tag Unit 5.7, the Reliability Sub-Objective<sup>9</sup>).

For private vehicle travel, the UK currently adopts the mean - dispersion approach giving an advisory value for the reliability ratio of 0.8, without any distinction by travel purpose.

For private vehicle travel, application of the reliability values differs for the three cases of inter-urban motorway and dual carriageway roads, urban road networks and other roads.

- For motorways and other multi-lane divided roads incident delays are modelled using the INCA software developed for the purpose (Mott MacDonald 2008a; 2008b); other day-to-day journey time variation is assumed to be negligible, based on earlier research by Arup et al (2004).

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<sup>9</sup> [www.dft.gov.uk/webtag/documents/expert/pdf/unit3.5.7.pdf](http://www.dft.gov.uk/webtag/documents/expert/pdf/unit3.5.7.pdf)

- For urban networks, a model was developed to predict the standard deviation in journey time from journey time and trip length (distance) using relationships derived from the ITIS/CJAM (Congestion and Journey-time Acquisition and Monitoring System) which sampled trip data over 10 representative urban areas (Hyder Consulting et al 2007; 2008). Local validation of the model is recommended where data is available and local conditions indicate that the default relationships may be improved upon. (Note that this approach avoids the issue of aggregating reliability from a series of journey segments, as is done in current New Zealand practice in the EEM. It may also be possible to develop a similar procedure for New Zealand using the congestion monitoring data collected by the Transport Agency).
- For other roads, an assessment of reliability is substituted with a value of congestion ‘stress’, (equivalent to the New Zealand congestion values), recognising that reliability and congestion are linked phenomena with the assumption in this case that the WTP to avoid congestion implicitly includes a journey time reliability component.

For public transport, reliability is incorporated as a value for lateness on a published arrival schedule at a rate ‘broadly the same as the value of time waiting for public transport, that is 2.5 times the value of in-vehicle time’. The advice applies only to rail passenger transport for timetabled services and has been developed to suit the performance monitoring applied to UK rail passenger services. There is no specific advice for urban bus or underground services, where services are mainly headway-based apart from the low flow periods.

The UK values work time (DfT 2011) using the MPL approach, similarly to New Zealand, for commercial vehicle drivers and all other occupational groups. The composite values of time per vehicle are weighted values taking account of work/non-work split and occupancies but exclude the component of vehicle standing charges divided by annual utilisation as done in New Zealand practice. Instead, all vehicle costs form part of a set of simple vehicle operating cost functions of the form  $a + b/V$  per kilometre, where  $a$  is the distance-variable part of cost (oil, tyres, maintenance and distance-related depreciation) and  $b$  is a parameter to represent the change in productivity of commercial vehicles in working time, and  $V$  is the average speed in km/h. In the UK, studies indicated that depreciation could be considered entirely a time-related cost for all apart from LCVs and in these cases it would not form part of either parameter in the NZVOC model (note – New Zealand studies showed depreciation to be part-distance and part-time related). Details of the derivation of the parameter values dates back to 1991 or earlier (DoT 1991).

## 5.7.2 Australia

In its review of current practice Austroads (2011) concludes ‘there appear to be a number of methodological and measurement challenges before the concept of travel reliability becomes standard in project appraisal’.

Reliability is not included as a matter of course in Australian project assessment, although suggestions have been made on how this might be done (Taylor 2009).

The Austroads advice on economic evaluation of road projects includes travel time variability as a user cost in presenting an assessment framework (Austroads 2005) both for passengers and freight, but reliability is not included in the advice on parameter values. It is included only qualitatively as part of multi-criteria analysis in guidelines to evaluation of projects to improve incident management.

Austroads (2003) derived values of freight time from an SP survey of shippers. This gave A\$1.50 per hour of delay per pallet for inter-state capital full trucks loads and A\$0.80 per hour for intra-city freight. For less than full loads intra-city, a value of A\$2.2 was obtained. This was over a variety of goods types. This study forms the basis for parameter values included in the Austroads (2008) guidance which gives values of freight time on a vehicle type basis for urban and non-urban travel. The values incorporate conversion from per pallet to

per truck using unreported conversion and load factors. Freight vehicle time costs appear to be included in vehicle operating costs on a per kilometre basis, although the derivation is not clear.

In New Zealand, the EEM separates vehicle operating costs into distance and time based components using methodology based on the World Bank HDM4 model. The time-based component of vehicle costs includes part of depreciation costs and all annual standing charges.

## 6 Sources, interventions and evaluation methods

### 6.1 Introduction

In this section we review the international and New Zealand literature on:

- the sources of travel time variability for personal travel – an understanding of the sources of variability is needed before interventions can be suggested and evaluated
- interventions with possible potential for improving the reliability of journey times. Identification of the forms of intervention that improve journey time reliability or reduce the impact of unreliability and their effectiveness, considering interventions that aim to target demand fluctuations and those targeted on capacity fluctuations; and note that some interventions discussed in this section are general in their nature affecting both passenger and freight traffic together
- methods for evaluating interventions.

**Delay and reliability** - we include reductions in delay as well as improvements in reliability when considering sources, interventions and evaluation methods for road traffic. Although reductions in delay are not the target of the research for personal travel, they are within scope for road freight transport. Demand management measures that either reduce personal travel demand by road, increase passenger vehicle occupancy or both so as to reduce peak road congestion will have benefits for road freight transport journey time reduction and improved reliability as well as for those remaining users of private personal transport. In chapter 7 we discuss reductions in delay that are targeted specifically at road freight.

We also address:

- demand-related (fluctuations in traffic volume and other operating speed and schedule influences) sources of variability and supply-related (variations in infrastructure capacity of transport links and nodes) making a distinction between planned and unplanned reductions in capacity
- day-to-day variation and unusual variation (traffic incidents) as discussed in section 2.4.2, including a position on the dividing line between traffic incidents and larger scale but rarer exceptional delays from natural hazards
- travel mode and location – general road traffic in urban traffic networks and on inter-urban highways, scheduled urban bus services and suburban rail services. Urban and highway road and traffic conditions differ sufficiently in the sources of variability and possible solutions to require separate consideration. Suburban rail clearly requires separate consideration as the sources of variability will be system related. Urban bus is exposed to the same traffic congestion pressures as the general traffic stream but there are timetable punctuality requirements that do not apply to private transport, plus the need to enter and leave the traffic stream at bus stops, and the bunching phenomenon.

**Travel purpose** is not, of itself, a factor in journey time variability. All travellers are equally affected, except that the time of day and location of travel may make one group more disposed to travel time variability than another. So, as commuters travel in the peak periods which are more congested their exposure to more variable journey times is greater. The impact will be taken into account in evaluation through the values for time and reliability in the standard traffic mixes and time periods which weight for trip purpose. It may become clear that the standard traffic mixes do not adequately provide for differences in the value of trip reliability, airport access trips being a case in point. The obvious solution is to create

other traffic mix categories and to provide practical ways of easily entering different mixes of trip purpose into the evaluation procedures.

## 6.2 Sources of journey time variation

### 6.2.1 Sources of demand-side variation in general traffic flow

#### 6.2.1.1 Sources of day-to-day road traffic congestion, delay and variability

Traffic delay can be divided into vehicle interaction, with delay increasing as the v/c ratio rises and bottleneck delay, where a point in the network becomes over-saturated and queues from upstream and dissipate only when the demand volume falls sufficiently to clear the queue. When considering travel time and variability over a complete trip, whether the source of unreliability is from vehicle interaction or a bottleneck does not matter for purposes of measurement, but may be important when considering possible interventions.

In urban road networks, intersection capacity is generally the governing factor, and variability in intersection delay time can arise from random variation in the traffic arrival pattern at the arms of the intersection, the gap acceptance behaviour and acceleration profile of individual vehicles at priority junctions and the individual signal control or area-wide traffic control settings for signalised intersections. For multi-lane arterials, link and intersection delays are both significant while, for motorways, link congestion and delay dominate.

Other factors that contribute towards day-to-day congestion delay and variability for a particular route and flow period are the effects of weather and light, which influence driver behaviour, and demand variation within the recognised flow periods from influences such as school holidays and special events. The day-to-day variability in the origin-destination trip matrix is another issue and has attracted recent attention from various authors.

#### 6.2.1.2 Flow profile and congestion monitoring

When describing day-to-day journey time variation, there has to be a standard for comparing like with like. This requires the traffic flow profile to be broken down into periods of similar levels of congestion corresponding with the same daily time periods, as this will correspond to the experience of regular travellers and will form the basis of the expected delay around which variability is measured.

The congestion profile varies between motorways, multi-lane arterials, urban roads and rural two-lane roads. Typically, the flow is divided into characteristic periods of morning (AM), afternoon (PM), inter-peak and low flow, using procedures set down in the EEM for identifying each flow period (section A3.14) and default peak period definitions (section A2.4). The Transport Agency's traffic profiles also recognise evening/night-time and weekend periods. Public holiday peaks on rural highways where there are concentrated recreational flows are also included in travel time and reliability analysis.

Congestion monitoring surveys carried out for the Transport Agency and for some regional and district councils are the only controlled data collection on road traffic congestion. The surveys are carried out for the main urban centres and with extension outward from some of the main centres to capture congestion on some rural highways. For example these include State Highway 1 (SH1) from Auckland north to Wellsford, SH1B bypassing Hamilton from Taupiri to Cambridge, the Tauranga Eastern Arterial, and SH1 north of Wellington to Levin. Routes are chosen to analyse congestion trends on various classes of route, including the central urban area, urban/suburban commuter routes and some surveys (in Auckland) have focused on freight routes.

The routes and segments of routes are sampled for AM, PM and inter-peak periods using floating car observers with the data collected electronically. These surveys exclude significant traffic incidents where

they occur on the route, but minor incidents and restrictions to normal flow from road works are not excluded (on the grounds that there are too many of them). Planned flow restrictions such as road works are noted in the survey logs. This protocol for the congestion monitoring data will need to be borne in mind when drawing conclusions from the surveys.

A report by Beca Infrastructure Ltd (2010) analysed sample data from the congestion monitoring surveys and found CoVs (standard deviation/mean) for journey time of around 33% for the peak direction in morning and afternoon peaks and around 20% for the inter-peak, for links typically between 0.25km and 3km in length on a mixture of motorway and arterial roads in Auckland.

For typical cross-town urban journeys which include a mixture of local road, arterial and motorway running, the day-to-day travel time variability reduces as the route length increases so, typically the CoV of travel time in the Auckland AM peak reduces with distance from around 25% for trips of 5km to 10% for trips of 15km.

The chance of the travel time being greater than one standard deviation (assuming a normal distribution) greater than the average is about 16% and of being more than two standard deviations about 2%. For a journey of half an hour in the peak this would be a chance of 16% of being five minutes late and 2% of being 10 minutes late on the average journey time (and similar chance of being correspondingly early).

## 6.2.2 Supply side variation – planned reductions in capacity

Transport routes have to operate at reduced capacity from time to time to safely carry out maintenance and construction work. This can require speed and capacity reductions, and partial or full route closures. Such work is generally organised to cause least disruption but can be for a prolonged period. Where construction has an impact on users, the EEM requires that such impacts be evaluated.

This research was interested in the impacts of general traffic delay on freight transport. Freight operators normally have the same advance notice of such restrictions as for general road users and the impact is to limit capacity and increase congestion over a period. Any increase in travel time variability is as a result of the additional congestion effect.

Where planned road capacity restrictions are in place for a relatively long period and are well advertised, then it can be argued that the resulting additional delay becomes part of the expected delay. Koorey et al (2008) in a review of incident management held this view.

So, there does not appear to be any reason to treat planned outages that are well advertised and recognised by travellers and of reasonably long duration any differently from more permanent changes in network capacity through road building, apart from being a reduction rather than an increase.

However, some short period planned maintenance is *not* well advertised and the delays are unexpected. It can be argued that these are more akin to unplanned incidents in their impact on travellers, even though the intervention options differ. However, it does prompt consideration of interventions that more effectively limit the capacity reduction effects of maintenance and construction work.

## 6.2.3 Supply side variation – unplanned reductions in capacity (incidents)

The Transport Agency's Auckland region has developed an *Emergency procedures manual* (NZ Transport Agency 2012) for emergency responses on the Auckland motorway network. The five levels of incident defined are summarised in table 6.1.

**Table 6.1 NZ Transport Agency recognised incident levels and example causes**

Level	Name	Description	Expected delay/ impact	Impact on the road
1	Minor	An event resulting in a small to moderate impact to traffic flow of no longer than 30 minutes.	<30 min	<ul style="list-style-type: none"> <li>• <i>Single lane closure quickly clearing to shoulder</i></li> </ul>
2	Significant	An event resulting in a moderate to significant impact to traffic flow of no longer than 90 minutes.	>90 min or <3h in light traffic conditions	<ul style="list-style-type: none"> <li>• Multiple lanes causing moderate delay</li> <li>• Short-term full carriageway closure</li> </ul>
3	Serious	An event resulting in major impact to traffic flow of usually no longer than 3 hours. A coordinated response will be required with multiple resources and the Transport Agency's Remote Incident Manager role activated.	<3 h or >3h in light traffic conditions	<ul style="list-style-type: none"> <li>• Multiple lanes causing significant delay</li> <li>• Longer-term full carriageway closure</li> <li>• Major restriction to traffic flow</li> </ul>
4	Headline	An event resulting in major disruption to traffic flows for a period greater than 3 hours, having regional effects and requires a coordinated response from a command centre.	>3 h	<ul style="list-style-type: none"> <li>• Long-term full carriageway closures</li> <li>• Major restriction to traffic flow</li> </ul>
5	Catastrophic	An event involving massive long term disruption to traffic flows, probably due to a natural disaster and damage to roading, requiring a strategic response (includes civil emergencies).	>1 day	<ul style="list-style-type: none"> <li>• Long-term full carriageway closures</li> <li>• Major restriction to traffic flow</li> </ul>

Source: Adapted from NZ Transport Agency Region 2 (2012) *Emergency procedures manual*

To be consistent with this classification of incident levels, we propose to treat incidents that are the source of unusual delays as levels 1 to 3, resulting in delays of up to three hours in heavy traffic or longer in light traffic. This will take in most surface flooding events which are generally of short duration, sometimes linked to high tides and road closures by the Police for crash site attendance.

The types of incident contributing to restricted operation, short period closure or part closure of routes include crashes, breakdowns, spills, high winds and surface flooding.

Koorey et al (2008) identified incidents as

*events that can cause temporary reductions in road network capacity (relative to the demand):*

- *vehicle-based incidents, ranging from minor vehicle breakdowns to multiple injury;*
- *accidents;*
- *debris/obstructions on the road network;*
- *maintenance activities;*
- *recurrent congestion;*

- *any combination of the above.*

*Another possibility is extreme weather events, such as heavy rain or hailstorms”*

The authors subsequently discuss incident detection technology using buried loop and microwave detectors to identify traffic speed reduction and queue formation. So the flow disruption to the traffic stream sufficient to trigger incident detection becomes the lower threshold for the definition of an incident, the boundary between day-to-day and unusual delay/reliability. At the least there should be some recognisable relationship between the definition of an incident and the incidents that are detected/ measured.

Combining the threshold for detection with the duration from table 6.1 can then be used to classify incident severity which could vary from acute but short-lived to low level but chronic.

It can be asked whether it is useful to know all the various causes of incidents and, for the purposes of this research, the answer must lie in what types of intervention can be applied to reduce their incidence and impact. So there will be a class of preventive measures to avoid incidents occurring in the first place and another class of incident response measures to hasten their resolution if and when they do occur. These are discussed in the next section.

#### 6.2.4 Migration of delay and reliability effects through the transport network

Both demand- and supply-side sources of route unreliability can lead to traffic diverting to other routes, increasing the demand on them and causing unexpected delays for regular users of those routes. These effects can cascade on to other parts of the surrounding road network, particularly if the network is already congested and may take a substantial time to disappear.

Route choice is affected by both past travel experience and information relating to current conditions. With the increase in access to real-time information, users are more likely to have information that might result in their changing route. The dynamic nature of route choice has been recognised for some time. For instance, Iida et al (1992) analysed the dynamics of route choice behaviour via laboratory-like experiments in which participants were repeatedly asked to indicate which route they would choose in various hypothetical network conditions. They found that static traffic assignment models might not be adequate for predicting actual route choice and traffic conditions.

Polydoropoulou et al (1994) investigated route choice behaviour in the presence of traffic information, and developed a method for modelling the acquisition and processing of pre-trip and en route information, route switching behaviour, and willingness-to-pay for information. They found that en route diversion is primarily influenced by attitudinal factors and information acquisition, including drivers' own observations of traffic conditions.

The last two decades have seen the development of dynamic traffic assignment methods, which have several advantages over the traditional static traffic assignment methods in describing and analysing time-varying network and demand interaction, based upon a behaviourally sound approach (Transportation Research Board 2010).

Dynamic traffic assignment methods are only in the early stages of being implemented, and it is likely to be quite some time before they are widely adopted and available for addressing travel time reliability issues in real-world regional or national networks.

#### 6.2.5 Sources of unreliability in public passenger transport

As for general traffic, demand side journey time variability stems from the interaction of traffic volume and road link/intersection capacity with additional variation introduced from the bunching effect of



passenger boardings. A boarding time delay at one bus stop increases the headway from the bus in front and a larger expected number of passengers waiting at the next stop and so on in a feedback loop. The following bus finds fewer people waiting and catches up on the bus in front. The result, if no corrective action is taken, is for scheduled services to vary from timetabled arrival at each stop and for unscheduled high-frequency services to bunch or for one bus to leapfrog another. Supply-side variability arises from the availability and performance of equipment and crew.

Recent research by Wallis (2011) reviewed the factors contributing to unreliability of bus services. The following paragraphs include some of those findings as well as additional information. Starting from the position of a well-planned service that is fully reliable under normal traffic conditions and is responsive to demand, the researchers grouped factors leading to service unreliability into:

- those external to the operator such as weather, traffic incidents and bus passenger incidents
- unpredictable operator factors such as unexpected and uncharacteristic breakdowns and staff absences
- predictable or performance-related operator factors such as persistent vehicle breakdown and failures to operate to schedule due to staff and management failures.

Buchanan and Walker (2002) describe the nature and causes of unreliability in urban bus services:

- from the traveller's viewpoint (late, missing, early, bunched, full buses variable journey times and unpredictable arrival)
- from the direct causes of a service delay (late/early bus starts, bus/driver unavailability, weather variations in running time, congestion delays, delays in required linking with other services/modes, breakdowns, accidents, obstructions etc)
- cumulative effects over the day between services – sequentially on the same service and across connecting services.

Nicholson and Hong (2004) cite Chapman (1976) who similarly considered reliability from the different viewpoints of traveller, operator and also the transport analyst and how performance indicators that are important to one group may be less so or irrelevant to another. The authors go on to describe a probabilistic model of the bunching phenomenon.

Van Oort (2011) gives a comprehensive theoretical analysis of the various interactions.

Vincent (2008) provides the most recent analysis of travel time variability for public transport in New Zealand. He identifies four types of reliability:

- 1 Punctuality, adherence to timetable, with measurement as minutes early or late
- 2 Service cancellations resulting in a delay related to the mean service headway
- 3 Variability around the expected departure/journey/arrival time, typically measured as standard deviation
- 4 Waiting time variability – spread around the expected waiting time, again typically measured by standard deviation.

However, this analysis does not discuss the sources of unreliability.

In international literature there is little quantitative diagnosis of the underlying reasons for unreliability and the contributions from various sources and their interaction and, in particular, the demand side variation. For example DfT (2010) in its guidance to local authorities on 'bus punctuality partnerships'

recognises that the traffic authority, the operator congestion and unplanned incidents all play a part but does not discuss their relative importance.

Tahmasseby and van Nes (2010) note:

*stochastic choice behaviour and demand alterations cause variations on traveller's behaviour. For the demand side, regular fluctuations of travel demand over periods of the day, days of the week, and seasons of the year are sources of uncertainties. Furthermore, stochastic nature of traveller's choice behaviour should not be forgotten. Normally, there is randomness in traveller's behaviour which can be observed in departure time choice, mode choice and route choice.... In addition to variations that take place based on regular demand pattern, there are irregular demand fluctuations arise due to external factors in a short time scope. For instance, in case of bad weather, cyclists normally shift to either private car or transit, thus increasing transit demand. A second example is the temporary demand pattern due to public events'.*

Suburban rail is less susceptible to demand-related travel time variation as the vehicles and seated/standing capacity are fixed by the operating plan and timetable and there is usually no other competing traffic (assuming freight and passenger services are well time separated or on different track). There is still some opportunity for boarding time at stations to vary although, as passengers do not have to pass a single ticket purchase/card validation point, the extent of boarding time variation is much less. Also, because trains are required to maintain separation, bunching does not occur, although there can be a progressive build-up of delay on schedule as the travel time is effectively controlled by the slowest train on the route.

The literature review has not identified any useful analysis of the day-to-day variation in passenger demand and the impact that this has on public transport reliability, particularly for urban schedule bus services. While there has been some study of bus schedule adherence using GPS (eg Mazloumi et al 2010) which explores day-to-day variation and the influence of observable effects such as weather, it would be instructive to know the influences of variation in numbers boarding and boarding times and how demand varies by time of day, across the week and seasonally. It is possibly unrealistic to expect that passenger demand variation as a source of public transport unreliability can be reduced but, if its significance was better determined, it could help in designing and targeting interventions.

## 6.3 Interventions to improve reliability

### 6.3.1 Introduction

As a general opening statement, it can be observed that there appears to be a great deal more published research on the theory of journey reliability, its valuation, measurement and modelling, than there is on practical interventions to improve reliability, the comparative performance of interventions and evaluation methods.

Another observation is that the traffic densities on New Zealand transport networks, particularly inter-urban road and urban passenger transport, are generally lower than in the overseas countries where most research and development has been based. Consequently, many of the interventions, which rely on scale economies and networks that are large enough and configured to include redundancy in transport routes and services, will have limited application in New Zealand.

### 6.3.2 Actors and types of intervention

The possible actors who may intervene to improve reliability and reduce delay (for freight) or mitigate their impacts are:

- the infrastructure supplier and/or network manager (local authority, the Transport Agency, KiwiRail and their agents) – through increasing infrastructure capacity, through better utilisation of existing capacity and better information to public transport operators, freight operators and general transport users so they can adapt their behaviour
- the public transport operator – through measures to improve service punctuality and avoid service cancellations and to provide better information to users so they can adapt their behaviour
- the freight operator – by scheduling and managing operations to limit exposure to routes and time periods where there is a higher risk of delay and reliability risk, with information from the infrastructure supplier and network manager
- the road and public transport user – by scheduling their travel to avoid or mitigate the impact of reliability risks using information from the public transport operator and road network manager
- third parties – acting in a facilitating or support role, such as the NZ Automobile Association, the road freight transport organisations (Road Transport Forum (RTF), regional transport authorities (RTAs), National Road Carriers Association (NRCA)).

### 6.3.3 Road infrastructure and operational management

Methods for improving reliability and, in some cases, also reducing congestion and delay through interventions in road infrastructure and operational management can be broadly categorised into:

- increasing road network capacity by upgrading and new construction – new links, widening roads, enlarging intersections and changing intersection form and control
- increasing road capacity without physical widening – temporary use of shoulders in peak periods, increasing traffic lanes by lane narrowing
- smoothing traffic flow – by conventional signs and markings and using various forms of intelligent transport systems (ITS) such as variable message signs (VMS) to control speeds, lane use and merges
- incident avoidance – maintenance techniques to limit or reduce lane closures; traffic information, signing and other driver education to encourage safe and smooth driving
- responding faster to incidents – incident detection and rapid response by the road network manager or agents, and by emergency services
- traveller information and guidance – provision of real time information and guidance on the level of network congestion, quickest routes and best times to schedule travel to minimise delays.

The UK Highways Agency ([www.highways.gov.uk/specialist-information/highways-agency-toolkits/the-journey-time-reliability-toolkit/](http://www.highways.gov.uk/specialist-information/highways-agency-toolkits/the-journey-time-reliability-toolkit/)) has been developing a toolkit of ways to improve travel time reliability as part of its service agreement with the UK government. This website gives a good general overview of the techniques available.

#### 6.3.3.1 Road upgrading and new construction

Increasing the capacity of infrastructure to eliminate bottlenecks and provide an even level of service commensurate with traffic volume and cost is the traditional aim of road infrastructure planning. From the viewpoint of road freight users, congestion is viewed as the most important constraint on operations and

source of delay. Any interventions that either increase capacity or reduce demand will benefit freight transport, particularly on those routes most used by freight vehicles.

However, it is recognised that there are physical limits to development, financial constraints on building new infrastructure and some future uncertainty regarding the balance between capacity provision for private and public transport, both road and rail and on future urban form. It is also recognised that in the more heavily congested urban centres it is probably impractical to provide sufficient capacity to fully satisfy the latent demand and that small capacity increments will be to some extent offset by new induced traffic.

Research by Tau Squared (2011) has reviewed the effects of infrastructure expansion on congestion, in part with a view to identifying the induced traffic effects of road building in already congested urban areas. The research concluded that induced traffic will offset but not negate increases in capacity, with the induced traffic effect being greater in the long term. However, the extent will differ depending on the congestion levels in each urban centre. The benefits of capacity expansion would also be improved with congestion pricing to better face users with the incremental costs of additional road space and avoid overbuilding of capacity.

While road upgrading is an obvious intervention to reduce delay and, in consequence, improve reliability, it is not really the subject of the research so has not been taken further.

#### **6.3.3.2 Increasing road capacity within the existing road formation**

The aim is to increase capacity within the existing road formation (ie carriageway and shoulders). Possible opportunities are:

- narrow traffic lanes on multi-lane roads in urban areas, combined with speed control to create additional lanes – while used overseas where traffic lane width standards are 3.6m–3.75m, standard traffic lane widths in New Zealand of 3.5m are already relatively narrow, and the limited number of multi-lane highway sections do not allow the same scope for creation of additional lanes. Also in the locations where additional width could be useful, lane widths are often already narrowed to near minimums.
- hard shoulder running – use of the road shoulder as an auxiliary traffic lane under certain conditions using VMS control; this is being introduced on UK motorways as part of the ‘managed motorways’ either as full traffic lanes or as slip lanes innovation which aims to increase road space utilisation under intelligent lane control; the applicability to New Zealand conditions is limited by relatively narrow motorway shoulder widths, particularly at pinch points; other surveillance and lane control systems need to be in place so that use of the shoulders for breakdowns can be managed.

#### **6.3.3.3 Active traffic management to improve reliability at high traffic flows**

Travel time variability increases with congestion. Indeed, as discussed in section 3.3, the New Zealand evaluation procedures assume a fixed relationship between v/c ratio and the standard deviation of travel time. However, the New Zealand evaluation procedures and underlying research recognise that there are separable disutilities for the road user from driving in congested traffic and from reliability in journey time. The former value derives from a loss of control and discomfort while the unreliability is related to risk of schedule disruption.

This class of active traffic management is interventions that aim to reducing journey time unreliability while the level of congestion is held constant. This exploits the characteristic of traffic flow that the maximum capacity point occurs at a certain speed and mean vehicle headway; if the demand flow exceeds this level traffic speeds and the effective capacity fall and a bottleneck forms. A full bottleneck is preceded by an unstable flow regime where lower and higher-speed traffic waves form. These can persist long after the conditions causing the flow instability have passed. The aim is to control traffic speeds and lane changing to smooth the tendency for instability so the effective capacity of the road can be maximised.

This can be coupled with ramp metering so the traffic entering a section of limited access road is not allowed to exceed the practical capacity.

Active traffic management is probably at its most advanced in the UK based on the M42 motorway as a test bed and in Holland and Germany, with some development in the US. The Auckland ATMS system is headed in the same general direction. The main components are road embedded or overhead vehicle detection systems including number plate recognition, variable message signing either overhead or adjacent to traffic lanes, closed circuit TV surveillance, centralised traffic control centres, traffic signal linking and optimisation and intelligent traffic management decision software linking the various components. Such systems can also be integrated with incident response and traveller information systems as is the case in Auckland (travel time advisory signing).

Recent reviews of active traffic demand management in practice are given in Schreffler (2011), Parsons Brinkerhoff (2010) and the National Audit Office (2011). A monitoring report on the M42 (Mott McDonald 2008a) found that the VMS mandatory speed limit equipped road had reduced journey times during periods of severe congestion and had reduced travel time variability by 22%. Koorey et al (2008) provide a good overview of the Auckland system and New South Wales directed at incident management capabilities.

Most overseas research and practice applies to multi-lane roads and urban networks. There has been relatively little research into reliability interventions for two-lane rural roads.

#### 6.3.3.4 Incident avoidance

We are not aware of any analysis of the respective contributions of congestion, incidents and planned road maintenance to traffic delay in New Zealand. In the UK the National Audit Office (2011) cites evidence from the Transport Research Laboratory that the responsibility for congestion in that country was 65% attributable to 'weight of traffic', 25% to accidents and incidents and 10% to roadworks.

It seems likely that there are useful congestion and reliability gains to be made by reducing the numbers of incidents, including accidents, breakdowns, spillages, short period flooding, icing and other weather related events. Crash reduction has a particular prominence in government transport policy, although directed particularly at fatalities and serious injury.

The largest gains will be made on roads and at times where an incident has the greatest consequences – so any intervention should concentrate on high-volume roads and peak periods and on medium-volume roads where incidents can have a relatively large impact, for example strategic highways with no convenient route alternatives.

Interventions to reduce incident occurrence include:

- all crash reduction measures – on high-volume roads the UK Highways Agency toolkit suggests use of advisory speed limits (using VMS), vehicle safe separation road markings (chevrons used in the UK), other (raised) road markings to alter speed behaviour, safety messaging signs (take a break etc), intelligent road studs (light up warning of obstruction/incident ahead), intelligent icing alert signs (change colour). It may be noted that some measures to improve reliability, such as hard shoulder running also have the potential for counter-effects in road safety (emergency access to crashes)
- higher than normal penalties for vehicles that cause incidents on high-volume roads – such as losing loads, breakdowns
- designing roads for ease of maintenance, reduced maintenance requirements and reduced need to close lanes – such as protected access for overhead working, low maintenance berms
- designing and retrofitting roads against weather-related closure or constrained operations – wind protection barriers, drainage retrofits.

### 6.3.3.5 Incident anticipation, detection and response

Koorey et al (2008) reviewed ITS measures and their effectiveness in detecting and responding to unplanned traffic incidents. They noted that most automatic incident detection systems had been implemented on motorways and there was little use so far in area-wide signal control networks on urban arterial roads and for isolated junctions. Where automatic in nature they relied on either buried loop or overhead microwave vehicle detectors to sense vehicle headway, speed and queue formation with various software algorithms to identify abnormal flow conditions. The automatic systems are typically supplemented with CCTV cameras and control centre surveillance.

However, they noted some research on detection of lane blocking incidents on arterials in Zhang and Taylor (2006) and a practical example in Auckland of automatic queue detection and intervention to vary signal control plans at isolated signals or to temporarily remove signals from the network control plan where abnormal queues had formed. Because of the relevance of Koorey et (2008) we restate their conclusions below:

*A literature review of techniques and software/systems to manage traffic congestion and respond to incidents found that:*

- *considerable research has been done in the areas of incident detection and management, ITS methods such as adaptive signal control (e.g., SCATS) and network reliability measures. However, little work has been done to bring all three research areas together*
- *while automated incident detection techniques on traffic networks have become increasingly sophisticated, in practice there is still limited use (and trust) of them. However, there has been some success in using simple detection systems to monitor and treat isolated problems such as intersection approach queues*
- *motorway incident detection is often relatively well established, but there has been less attention to incident monitoring of arterial road networks. This is despite the fact that such incidents regularly affect the adjacent motorway networks, and vice versa*
- *there is a lack of robust incident detection available at present in NZ. The Auckland TMU is expanding its data collection in order to improve its response to the traffic conditions and respond to incidents*
- *there is a lot of variability in the effectiveness of using driver information systems such as VMS to redirect road users away from incidents. However, it is possible to 'learn' the effectiveness of such treatments in a particular location using an expert system and cumulative treatment/effect data*
- *while overall network travel time is still a strong measure of network performance during incidents, other measures such as variability of travel times and time to recovery may be just as important for motorists and other parties*
- *SCATS was not originally developed as an incident management system and has a relatively limited ability to detect and treat significant incidents. However, its predominance here in NZ means that it has an important role to play in any such system*
- *modelling dynamically adaptive signal control systems using micro-simulation enables a more realistic response to be produced (compared with fixed-time signal systems) when testing the effects of incidents on the network*
- *although micro-simulation is a good tool for evaluating incident management strategies, using a model calibrated under normal operating conditions may not be sufficient to*

*properly test incident scenarios. It may be necessary to calibrate micro-simulation models using data from real incident conditions (where driver behaviour may be different than under normal conditions). The practicality and robustness of doing this will need to be assessed too.*

*An exploratory study modelling incident detection and response in a NZ urban network using micro-simulation found that:*

- *SCATS can be modified in anticipation of additional demand due to diversions resulting from an incident to reduce the delay to the diverted traffic*
- *SCATS can be modified at the time of the incident in anticipation of the change in demand from an incident*
- *although SCATS will respond to the change in demand caused by traffic diversions due to incidents, an immediate and targeted intervention will produce better results*
- *the benefits of incident management interventions such as SCATS adjustment may be limited to particular journey paths. Micro-simulation modelling can help to identify which routes efforts should be concentrated on.*

#### **6.3.3.6 Traveller information and guidance – private transport**

Even if delay and travel time variability cannot be entirely avoided, the impact for travellers can be mitigated by providing accurate real-time information on schedule delays so that travellers have the opportunity to choose alternative routes or departure times. Mobile phone technology allows applications to be developed that can feed information to travellers based on their routine journeys. In urban traffic networks, active traffic management can now extend to real-time route guidance, so that vehicles are recommended the fastest routes by on-board instrumentation linked to a system monitoring centre fed by 'crowdsourcing' data from GPS positioned vehicles.

### **6.3.4 Interventions in public passenger transport**

Wallis (2011) reviewed the opportunities for interventions to improve the reliability of bus services. The following paragraphs include some of those findings as well as additional information.

#### **6.3.4.1 Pre-planning of public transport operations**

The configuration of public transport networks can influence the scope for schedule adherence; for example long routes tend to increase the risk of off-schedule running and there will be compromises between route length and numbers of transfers to limit schedule delays. The use of advanced simulation software can assist in testing the susceptibility and resilience of public transport networks and operations to factors that interfere with punctual operation. Close coordination between public transport operators, the public transport authority and road controlling authority and their contractors will enable them to develop and implement guidelines for better delivery of punctuality. This may be supplemented with commercial incentives such as bonuses and penalties for high/low achievement of punctuality performance.

Tahmasseby and van Nes (2010) discuss strategic and tactical levels of planning urban transit systems for improved reliability. They review operating experience in several European cities, with a case study in The Hague. One observation was that all the operators reviewed regularly failed to meet scheduled service performance on a daily basis for a small proportion of services, through cancellations and delays. For both rail and bus operations, infrastructure outages and maintenance work were regular contributors to unreliability.

At a strategic level they identified the following measures to improve network reliability:

- avoiding inter-reliance between different services, such as common running sections on rail and light rail systems; the more services can be independently operated and scheduled the more robust the network is to unreliability spilling over from one service to another; the independence is even better if the services are regular enough to not require timetabling
- keeping service routes short – the longer the service the more the potential for delay to accumulate; however, there is a trade-off between long service routes and requiring more travellers to transfer service, with the added unreliability of the transfer, so there is some optimum
- providing redundancy in the network so there is an alternative service route for pairs of origin/destinations; which of course requires a fairly large interconnected system with sufficient demand. The redundancy can be between modes, so there is a bus alternative for rail and vice versa. Networks that have a combination of radial and circular routes or are planned as a grid are more able to provide this redundancy. Unfortunately most New Zealand systems are either too small or are through geography restricted to a radial pattern (Auckland and Wellington in particular).

At a tactical level, Tahmasseby and van Nes (2010) suggest:

- allowing slack time in the schedule so that delayed services have a chance to catch up; the downside is increased journey times and annoying waits at certain points to keep to schedule, so again there is an optimum to be struck
- allowing slack layover time at the service end points to reduce the risk of a service late arrival not resulting in a late start to the next service
- adding slack time also marginally increases the peak vehicle requirement so adds costs – so there is a balance to be struck between attempting to meet a tight schedule at lower operating cost but with more delay risk versus a slower more reliable but higher cost service.

Wallis (2011) discusses the importance of good selection of ‘timing points’, bus stops where an early running service will dwell to bring it back on timetable, noting that these should be a peak load points but that competition for space at these often busy locations can make an optimal selection difficult. This report also goes into some detail on how to construct a schedule that can be adhered to in practice and gives the traveller the minimum sufficient information to plan their trip, doing this by publishing departure times for the timing points, typically 10 to 15 minutes apart, when services are less frequent and reverting to an arrival frequency for the busier parts of the day (eg a bus every 10 minutes). A well-planned timetable, route and selection of timing points then gives a service that can be more easily memorised by the passenger but gives as much flexibility as possible for the operator to deal with unplanned variability.

Wallis (2011) also comments on the resilience of a bus service plan to respond to fluctuations in demand and to cope with supply side incidents by being able to either introduce or remove buses from the schedule in a way that does not cause significant passenger disruption. Transporting school children in particular can be difficult for service planning, unless school bus services are provided separately from the general passenger demand. The home-bound journey places more demands on the bus service because of students being concentrated at certain bus stops and at a particular time, whereas students are more dispersed in both space and time for the journey to school. Carrying school children as part of the general service can make it harder to adhere to the timetable. Wallis (2011) also identifies operational factors, such as driver changes, which can add about two minutes to the service running time for the change itself plus some changes in driver behaviour that can occur around the end of shift, for example early running to increase the length of the driver’s break. Driver changes do not occur on every service and are not predictable enough to be incorporated within timetable planning.



#### 6.3.4.2 Traveller information and guidance – public transport

Traveller information systems in public transport have the potential to:

- assist users to make better choices of transport service to suit their departure and arrival time constraints
- mitigate the impacts of unscheduled delays by forewarning travellers with up-to-date information on expected arrival times.

Traveller information systems include web-based applications that can be accessed before or during travel, information systems at transit stops and in-vehicle. Systems can be information-only or interactive giving the traveller the opportunity of rearranging travel before setting out or changing services en-route. However, while there may be several route and service options combining different modes in large cities, in New Zealand the choices are likely to be fewer and in many cases there will only be one public transport service available.

#### 6.3.4.3 Transport service operation

Wallis (2011) discusses the management techniques available to bus operators to reduce service unreliability. Many of these depend on the operator inculcating performance and punctuality throughout the organisation by example and incentives, providing effective supervision of bus operations both centrally and on the road and having trigger points, procedures and response arrangements to counter problems that inevitably occur. The performance standards that the operator is required to adhere to by the public authority contracting the service, and the rigour with which they are enforced will also contribute to the outcome. If poor performance does not draw some form of corrective action or penalty, then this is an invitation to slackness and corner cutting. Conversely, recognition and rewards will encourage good performance. In this ‘carrot and stick’ approach, rewards and recognition are likely to generate more harmony and striving to do better than will assigning blame and penalties, particularly if the root causes are not well diagnosed which will just cause resentment.

Wallis (2011) further discusses intervention methods available to the bus operator in the event of off-schedule running of a service exceeding an allowable minimum or trigger point. The process is one of reassigning resources in real time, backed with an intimate knowledge of the operation and the possibility of mobilising limited additional resources. However, there is an inherent conflict between cost-efficiency and maintaining performance targets, as “spare” capacity (buses, drivers) constitutes an additional cost on the operation. There is similarly a conflict between minimising average passenger journey times and meeting journey time reliability targets, as one way of improving reliability is to ease slack time into the schedule so that there can be extra dwell time at identified heavily used stops to improve punctuality but at the expense of increasing average journey times and peak vehicle demand.

DfT (2010) has recently issued a guide on ‘Bus punctuality partnerships’ to encourage bus operators and local authorities to work together to improve service punctuality. The results of several case studies showed ways in which service punctuality can be improved, for example:

- monitoring of actual service schedule performance to highlight where and when delays are occurring along the route, followed by investigation of operating practices
- if necessary scheduling changes so that end-to-end route times are realistic and intermediate timetabled stops are accurate
- driver changeover locations/procedures altered where found to be a source of delay
- providing real-time data to the driver on time ahead or behind schedule as a tool to help manage schedule adherence

- detection and resolution of obstructions to schedule performance – such as removal of illegally parked vehicles, improvements to intersection layouts and signalling, design changes to make bus stops easier to negotiate for buses and to return to the traffic stream and for passengers boarding
- just drawing attention to the importance of punctuality to bus drivers, setting of targets and monitoring performance appears to have been effective in better timekeeping
- information sharing between the bus operator and local authorities so that the local authority can make changes to improve bus service performance from an informed position – a specimen data sharing agreement is given.

The bunching problem has existed for decades and has proven very resistant to effective solutions. Bartholdi and Eisenstein (2012) have suggested that instead of attempting to maintain scheduled times or a target headway a more useful approach may be to dynamically equalise the headway along the route by either slowing down or speeding up services rather than trying to combat the inherent instability of a scheduled service when faced with uncontrollable perturbations. This relies on a bus departing from a stop having data on the headways to the service in front and following, and then timing its departure to an algorithm that acts to damp headway variation. Limited road trials have been carried out and show promise. This appears to be an interesting alternative approach to public transport reliability and could reduce the reliance on expert knowledge from supervisors who attempt to manage service fluctuations from their familiarity with the route. Provided buses are fed into a route at the appropriate frequency, then a self-adjusting schedule should deliver a better passenger experience as buses should arrive at more regular intervals and with a more even loading, even though it may involve some divergence from the timetable. It can be noted that this method of governing headway fluctuation may be at odds with the concept of ‘timing points’ and highlights the need to draw a distinction between seeking service punctuality (which is probably how operators will be monitored) and seeking customer satisfaction.

In the case of rail passenger transport, Schmöcker et al (2004) discuss recovery strategies for rail platform crowding, which is the analogous demand fluctuation effect to crowding in buses, although without the same capacity of the train to bunch and leapfrog. Platform crowding has safety implications as well as contributing to unreliability with effects that can persist long after the initiating event has ceased. They review strategies such as early turning of services in the opposite direction to feed in additional trains in the direction of the overcrowding problem, station skipping, removing unaffected trains to increase capacity, adding extra gap trains and demonstrate theoretical modelling methods for assessing the performance of each intervention.

### 6.3.5 Interventions to improve reliability for tourism

Apart from interventions that improve the supply-side reliability of the transport system or act generally on all travellers to reduce demand-side unreliability, there are some examples in the literature on interventions aimed specifically at recreational travellers, mainly in relation to demand time shifting.

Beecroft et al (2003) noted that statutory holiday periods, Christmas/New Year holiday periods, summer holidays and weekends (Friday to Sunday evening, particularly in summer) are ‘pressure points’ for domestic travel. They presented the concept of staggering statutory holidays and school term breaks to spread the leisure-related congestion in holiday travel. Scotland has implemented staggered ‘bank holidays’, the Netherlands staggers school summer holidays and half-term holidays are staggered in the UK.

An alternative proposal by Beecroft et al (2003) is to alter working patterns (eg fortnightly schedule of nine to 10 days on, followed by four to five days off) as a means of spatially redistributing trips. This raises issues in the context of couples and families, not all of whom are likely to be on the same schedule. The

third suggestion is to encourage a modal shift for holiday transport, eg from private vehicle to coach or train, a move which is also suggested by the American Highway Users Alliance et al (2005).

The American Highway Users Alliance et al (2005) study proposes that visitors themselves could adopt other tactics including avoiding travel at peak times (the implication could be to re-time the holiday); access the latest information on traffic conditions (and either re-schedule or re-route). Failing either of these, they encourage good (eg allowing sufficient time to reach the destination) and safe driving habits. They recommend that transport agencies minimise traffic construction delays, expand network capacity, improve the efficiency of the road/highway through better traffic management and programmes to quickly clear crashes and breakdowns; and provide better real-time information. Zimmerman and Burt (2004) examined the impact of real-time information (via internet and/or telephone) about traffic conditions and incidents at four selected US sites on tourist travel. They questioned key informants and stakeholders, who could only speculate on the attitudes and (revealed) behaviour of the tourists.

## 6.4 Evaluating the effectiveness of interventions

The literature review has not identified useful frameworks or methods for evaluating the effectiveness of interventions to improve journey time reliability in personal transport.

The evaluation processes that do exist are within frameworks developed for the jurisdictions and transport systems of the countries and cities concerned, so are not necessarily directly transferrable to the New Zealand context. In the end, the evaluation processes applicable in New Zealand may need to be designed specifically to fit with local institutional structures, transport policy formulation processes and evaluation procedures, as discussed in section 2.11.

However, one notable methodology for evaluating reliability improvements as they relate to incident management is the UK Department for Transport's incident cost benefit analysis (INCA), a spreadsheet based programme for evaluating the economic effectiveness of incident management initiatives<sup>10</sup>. INCA is distributed on a commercial basis and implemented only for limited access roads although it is being extended to two-lane rural roads (Mott MacDonald 2009). It is a software tool similar in concept to that developed by the Transport Agency for the EEM. It may be useful in developing New Zealand tools but probably would not be suitable for direct adoption.

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<sup>10</sup> [www.dft.gov.uk/topics/appraisal-evaluation/tools/inca/](http://www.dft.gov.uk/topics/appraisal-evaluation/tools/inca/)

## 7 Journey time delay and reliability for freight

### 7.1 Introduction

In this section we review journey time delay and reliability for road and rail freight transport, including freight terminals and modal interchanges with sea and air. The review is ordered as follows:

- **Impacts** of freight journey time delay and unreliability, including the various components of vehicle and freight time values and losses as introduced in section 2.8
- **Sources** of freight journey time delay and unreliability, apart from those sources of delay common to general road traffic, discussed in the previous chapter
- **Interventions** that have been used or proposed to reduce freight delays and improve freight journey time reliability, or to reduce the impact of unreliability, as introduced in section 2.10.3.

### 7.2 Impacts of freight journey time delay and variability

This section of the review focuses on the different approaches taken to identifying the consequences (impacts) and valuing the costs of commercial vehicle and freight time savings/losses and reliability, and what the international literature contributes to the state of knowledge.

#### 7.2.1 Approaches to valuing freight delays and travel time variability

As discussed in section 2.8, there is a distinction to be drawn between the impacts of a delay (that is an extended time of freight delivery) where this is anticipated even though unwanted, and the impact of unanticipated delay, that is the reliability component.

There are two main approaches that have been taken to identifying and assessing the impact of freight time delays and variability in the international research literature. The first is through analysis of the freight transport operation and tracing the consequences of schedule variations to gain a detailed understanding of the various system elements and their interaction. This method then goes on to attribute costs to those consequences using cost analysis of: freight vehicles and operation; freight stock value and consequences of lateness; and cost of freight despatch preparation and freight reception.

The second approach is through stated preference (SP) experiments that offer respondents alternative freight journeys that vary the components of journey time, departure and arrival punctuality and cost. While this method requires a sufficient understanding of the freight choices facing respondents so as to be able to design a logical and realistic survey, it does not require any direct knowledge of cost consequences of delays and variability. The SP experiment yields these values provided there is a cost attribute from which values of delays and punctuality can be inferred by statistical analysis of the survey results. As noted elsewhere, the choices and costs facing the shipper may differ from those facing the transport logistics operator, unless they are one and the same, and different approaches to the SP design will be needed depending on whether it is the shipper or the transport operator who is the subject of the questioning.

There are other considerations when interpreting the results of SP experiments. The choice of respondent is important – ideally the respondent should take a holistic and dispassionate view of the organisation's best interests and be aware of the costs of the resources being deployed, and not have a blinkered view of only that part of the operation for which he/she is responsible with little understanding of the costs of the operation, as the results will reflect the viewpoint and knowledge of the respondent. Another

consideration is that the choice decisions will inherently bundle several factors that contribute to perceived cost and the result will not necessarily shed light on individual factor costs and interaction.

In New Zealand there has so far been relatively little SP work aimed at freight transport, and the values of freight time in the EEM are derived purely from an analysis of vehicle, crew and freight cost components and assumptions regarding the redeployment of time savings – that is the first approach.

In the Netherlands SP trade-off ratios are used in the short run and it is assumed that in 10 years from now all vehicle and staff costs will be reflected in the value of time. Between years 1 and 10, linear interpolation is used, and after year 10 the full cost is assumed.

A further approach would be to interview operators to get values related to the provision of transport services (vehicles, staff, etc).

We now go on to discuss the two main approaches and review relevant international findings.

## 7.2.2 Analysis of freight transport operations

### 7.2.2.1 Impact and value of marginal changes in vehicle and driver time

A marginal increase or reduction in journey time, as noted in section 2.8.1, impacts initially on the time that the transport equipment and crew take to complete the trip. The cost of vehicle operation has a time-related component of fuel or energy consumption, but this is normally accounted as part of vehicle operating costs when analysing interventions that affect vehicle average journey speeds.

The time-related component of vehicle cost is the annual standing charges of vehicle ownership, storage, and age-related depreciation, costs which are spread over the annual time utilisation of the vehicle to give a dollar per hour unit cost.

For some freight, there are additional costs of maintaining product condition or special containment during transit, costs which are reflected in the additional costs of the vehicle bodies, the lesser scope for alternative utilisation of specialised vehicles and higher time-related costs of operating on-board equipment such as refrigeration. These costs can be considered as part of either vehicle operating costs or time costs but in either case they are probably not incorporated in the current vehicle operating cost estimates used in the EEM.

Similarly there is a unit time cost associated with providing a vehicle driver/operator and crew, also spread over the annual time utilisation of the vehicle, taking account of any non-driving time.

The extent to which a reduction in journey time results in a useful saving in resources, measured using this unit cost, depends on the extent to which that time saving can be redeployed into additional productive use of the vehicle. It is in this area that the findings of overseas studies are potentially useful. The present assumption in New Zealand evaluation practice is to assume that 100% of the saved time is redeployed which, as discussed in section 3.2.3, has been regarded as an unlikely assumption that needs to be reviewed.

Section 2.8.3 noted that this 'utilisation factor' would likely depend on the size of the vehicle fleet, and the opportunity for small time savings across a large enterprise to result in a reduction in the required fleet size. This is in tune with the complaints of carriers in Auckland that when congested the arterial system becomes a truck park, and has resulted in an expansion of their fleet numbers to service the same volume of freight demand.

### 7.2.2.2 Value of marginal time changes time for freight carried

As introduced in section 2.8.4, as well as the time costs of the transport equipment, there are time costs associated with the cargo in increased stockholding and deterioration in value over time, either through

physical deterioration (such as in certain foodstuffs) or through gradual obsolescence over time. This excludes the costs of unplanned lateness through travel time variability, discussed in section 7.2.2.3.

The value of the freight is not something that the international literature can usefully inform. It requires a local analysis based on the market value of the freight commodity at the point of despatch and taking into account the packaging and any difference between net and gross measurement. Some analysis using current New Zealand sources of net commodity values has been shown in table 4.1.

Whether there is in practice any additional stockholding cost depends on whether there are stockholdings at the start and/or end of the trip. For example, if the freight is coal with stockpiles at each end of the journey, then the fact that a portion of the stockholding is in transit at any particular time may not constitute any significant additional cost – the transit stock is just part of the total and this can be allowed for (bearing in mind that we are considering predictable delay). In fact, in some transport situations, it may be a cost saving to the shipper to use the transport provider as an intermediate storer of the goods, if the cost of storage at the end points is high or limited.

However, for lean production and just-in-time delivery with minimal stockholding, the stock in transit will constitute an additional work-in-progress cost.

### **7.2.2.3 Impacts and value of improvements in reliability**

As introduced in section 2.9, McKinnon et al (2008) have identified five levels of disruption that can arise when a freight delivery is delayed, from minor delays that are small enough to be accommodated within normal operating procedures through to serious consequences of missed connections and stock-outs with considerable cost and possibly reputational damage. In between these extremes are graduated levels of increasing cost consequences involving redeployment of staff resources and equipment, additional overtime working and delays to the next activities in the supply chain with whatever cost consequences this entails.

Also Fowkes et al (2006) suggest cost consequences from forcing an earlier than optimal despatch time, possibly to accommodate an anticipated delay or time uncertainty.

Where travel time variability is sufficient to force a change in normal operating procedures, particularly where a time window is not met, goods may have to be returned to base and delivered at a later time, involving additional vehicle running as well as time delay. Additional vehicle running can also be an outcome of congestions as vehicles are rerouted to a quicker but longer route. Additional vehicle running may be at lower load factor, if a special delivery trip is required and overall, marginally adds to congestion as well as detracting from the transport operator's efficiency. A missed time window at one point in the day may flow on to fleet utilisation problems later in the day, so may have a ballooning effect, depending on the available backup.

Sanchez-Rodrigues et al (2010) have identified four sources of extra-distance running from

- route diversion
- delivery delays caused by loading delay at the shipper and/or road congestion
- mismatches between the loads advised and the loads presenting
- distribution network failures – vehicle breakdowns, products not loaded or mis-loaded, delivery planning failures.

It is the first two of these that are the subject of the research.

Intermediate activities including transfers of mode, transit storage, cross-docking and freight (de)consolidation are links in the transport chain where delays in travel time have the opportunity to disrupt efficient working and add cost, so are also part of the impacts.

### 7.2.3 Stated preference studies for freight value of time and reliability

The SP method requires a sufficient understanding of the freight choices facing respondents to be able to design a logical and realistic survey but does not require any direct knowledge of consequences and costs of delays and variability. SP experiments are usually based on an observed reference shipment of the respondent.

The examples of preference studies for freight choices that include both delay and reliability are relatively few, and have been mainly targeted at freight mode choice decisions with a view to identifying the potential for attracting rail freight in a market dominated by road.

Fowkes and Whiteing (2006) carried out SP surveys to jointly elicit values for time saving and various measures of reliability. They derived values of time varying by commodity from low-value bulks such as coal at £0.60/hour to express goods at £18/hour. The value per hour of lateness was similar to the value of time saving for the low-value bulk goods but rose to three times the value of time saving for express goods. The survey scenario was such as to eliminate vehicle and driver savings from the responses, so they can be interpreted as only the time value of the freight carried. Container cargo showed values of time of £9/hour and lateness of £15/hour. However, the reliability ratio showed no obvious relationship to freight form or value and varied between 0.4 and 2.0 around a central value of 0.8. It should be noted that this does not include the transport service component of the value of time and the value of reliability. A reliability ratio of the combined value of reliability to the combined value of time will be substantially smaller than 0.8.

Wigan et al (2010) carried out an SP survey of shippers of long haul and metropolitan freight in Australia, deriving values of freight time and reliability on a freight pallet-hour basis. The values of time for metropolitan multi-drop (less than truck load), metropolitan full truck load and inter-state capital full truck loads (> 1000km overnight) were A\$1.4, A\$1.3 and A\$0.66 per pallet-hour (1998 values); while the corresponding values per 1% reduction in 'late' deliveries were A\$1.97, A\$1.25 and A\$2.56. The commodities studied were automotive parts, food and beverages, building materials and packaging; low-value/low time sensitivity bulk commodities and high-value time sensitive goods were not included and there was little discrimination in the time and reliability values by commodity type. Values were also elicited for freight damage as part of the same SP design. The survey was acknowledged to be of a small available sample of freight users and not necessarily representative of freight movements overall.

## 7.3 Sources of freight delay and travel time variability

The aim in this section of the review is to provide a checklist of delay factors as encountered in overseas contexts, their features and relative importance, and their relevance in the New Zealand freight transport system. The information from this review will subsequently be included in the design of the market research of transport operators and freight interests in stage 2 of the project. There is a certain amount of overlap with the discussion under personal travel and reliability where common factors affect both the passenger and the freight market.

Where so far encountered, we have included information on readily available New Zealand practical examples through the literature and other contacts, which will be amplified at the next stage when commencing market research.

We have structured this discussion by freight mode and inter-modal terminal type, although there are various ways in which the sources of delay can be grouped.

### 7.3.1 Transport and supply chain uncertainty in general

This research focused on travel time delays and variability in the transport component of the supply chain. However, it is useful to put this within the wider context of transport and supply chain uncertainty in general in order to more clearly identify the boundaries of this research and how travel time uncertainty interacts with other sources of uncertainty.

The conceptual model developed by Sanchez-Rodrigues et al (2007) is useful in this respect. They identify five sources of uncertainty: the shipper, carrier, customer, control systems and external factors. Uncertainty can arise from any one of these five sources and influences the others through the physical flow of goods, the accompanying flow of information and the relationships between parties. The uncertainties identified under each source were:

- 1 shipper uncertainties:
  - a purchasing uncertainty – reliance on the performance of external suppliers
  - b marketing of the product – promotional policy, packaging changes, integration of marketing and production
  - c manufacturing/production – quality control, production scheduling, capacity and technology constraints
  - d supply chain management – planning of supply chain strategies, dispersion and flexibility in the supply chain infrastructure.
- 2 carrier uncertainties:
  - a of fleet capacity utilisation
  - b of capacity availability as scheduled
  - c carrier-imposed inflexibility, rigidities in vehicle configuration affecting load consolidation
  - d double handling risks at inter-modal transfers
  - e uncertainty in current position and status of vehicles and drivers
  - f integration and collaboration of successive logistics companies in the chain
  - g efficiency of routing
  - h uncertainty due to driver working time limits.
- 3 customer uncertainties
  - a order and inventory management variation causing fluctuation in ordering demand and delivery time requirements, order size and frequency, inappropriate order consolidation, non-standard ordering
  - b off-loading at the customer's premises – lack of delivery synchronisation, rigid delivery windows, equipment failures and workforce unavailability at deliver
  - c supply chain management and integration with the shipper's systems.
- 4 control systems uncertainty – all of the sources of uncertainty in the information flows related to the freight shipment, mainly arising in the ICT systems, and involving:
  - a physical inventory and movement control systems for the goods



- b ICT system logic and optimisation
  - c interaction and integration of the ITC systems between shipper, carrier and customer.
- 5 external factors – these include:
- a congestion from other traffic on the network and from traffic incidents
  - b macro-economic factors influencing freight demand and cost – fuel prices etc
  - c natural and man-made disasters.

These uncertainties involve product volume uncertainty, and shipment size, frequency and scheduling uncertainty. It was not the aim of this research to consider all of these dimensions of uncertainty in freight movement and we needed to confine the research to those that can be the subject of useful interventions by the government policy and investment agencies either on their own or working in conjunction with the private sector and freight industry state-owned enterprises.

The sources of freight delays and schedule variation that were of interest to this research derived from the last category, external factors, in particular those associated with day-to-day congestion on the transport network and incidents that affect the capacity of the network. The unpredictable delays resulting from external factors acting on a freight journey will have the potential to flow through and impact upon subsequent freight trips, depending on the amount of float time within the schedules of shippers, carriers and customers. So the journey time uncertainty originating with external factors such as traffic congestion and incidents may cause (referring to the above list) subsequent shipper uncertainty (1a), carrier uncertainty (2a, 2b, 2d, 2g and 2h) and customer uncertainty (3b). There will be a tendency for these knock on effects to accumulate through the working day and for some trips to fail to complete and spill over to the next day or later.

### 7.3.2 Sources of freight delay and schedule variation

This research therefore focuses on external factors that impact on the time to carry out the freight transport operation and the ability to adhere to schedule, including collection time (early/late), travel time (expected/variance) and delivery time (early/late).

Day-to-day road traffic congestion as a result of interaction between transport demand and capacity constraints, planned and unplanned supply-side incidents that reduce road capacity have been covered in section 6.2. This section concentrates on freight system-related delays and rail freight transport, discussed under the headings of:

- rail, port and ferry delays
- freight delays at inter-modal terminals and at transfer points for (de)consolidation, temporary storage and yard/warehouse handling, sorting and cross-docking, and at international borders for customs, security and biosecurity inspection
- delays arising from the information processing and approvals process that accompanies the freight, where this does not keep pace with the physical consignment, including consignment/waybill/packing notes, financial instruments and border clearances for security, biosecurity and customs.

### 7.3.3 Rail, port and ferry delays

For all transport systems, throughput efficiency declines with increasing capacity utilisation, although the fall-off in efficiency differs with the technical design of the system and the nature of the traffic.

### 7.3.3.1 Rail freight congestion and delay

The unimpeded journey time between points on the rail network, as noted earlier, depends upon a number of factors:

- track geometry, with limiting gradients and curves
- speed restrictions applied because of limited loading gauge (side and height) clearances and bridge impact load capacity
- general limiting speeds taking account of the rail weight and ballasting, track alignment and other operational safety factors through particular areas
- performance constraints of the train depending on its weight, maximum drawbar load and loco power.

Most of these are fixed operating conditions which can only be relaxed through improvements to the infrastructure and/or rolling stock.

Day-to-day variation in rail freight journey times, aside from those that occur due to equipment faults or external impacting incidents such as flooding and slips and rail crossing crashes, are most likely to occur as part of the process of freight reception, storage (if not loaded directly), wagon loading/unloading, shunting and train make-up.

Apart from unit trains where the train consist is fixed and freight is moved point-to-point between freight terminals or customer premises (industrial sidings, port rail grid), there may be a shunting operation at one or both ends of the journey to move wagons between customer's sidings and the rail yard, and goods may be temporarily stored at the rail freight yards prior to loading and after unloading. Depending on the origin/destination, some trips may require the train to be split and rakes of wagons marshalled onto other services. There are opportunities for delays through this storage/flow process, including for wagons to become temporarily misplaced or to be misrouted, although radio frequency electronic tag tracking of consignments is reducing this possibility. Other delays that can arise stem from unavailability of wagons, staff and other equipment and bookings in excess of capacity.

As noted earlier, rail freight schedules for general goods specify delivery in days rather than hours, with much rail freight moving overnight. A practical measurement of delay on schedule could be the percentage of freight consignments delivered one, two, three etc days late.

### 7.3.3.2 Port congestion and delay

The time to process freight through a port and the points where delay can occur are:

- at the road freight reception – depending on the arrival pattern of trucks in relation to terminal operating hours, the extent of booked delivery/collection times, and the efficiency of working between the container yard and the road grid
- at the rail grid – depending on shunting movements (if any) from the main rail terminal, and the efficiency of working between the rail grid and the container stack
- where an 'inland port' is being operated, the additional time to move freight between the quayside and the inland port and the freight transfer processes involved (road or rail)
- the type of equipment used (forklift, reach stacker, straddle carrier, portal crane) and the capacity of the container stacks in relation to demand which affects the efficiency of picking boxes and the amount of repositioning required; the need for segregation of different container types (dry/reefer, 20'/40', hazardous etc) also affects the efficiency of working; and similar considerations for other cargo forms

- the equipment used and efficiency of ship/shore transfer, including the mixture of self-supporting (geared) vessels and those reliant on shore-based cranes, the method of moving boxes to and from the quayside (tug-trailer, straddle carrier)
- berth capacity, shipping arrival pattern and berth occupancy, with over-capacity resulting in ship queuing
- harbour limitations in draft and size of vessels that can be accommodated alongside, in the approach channels and harbour bar, if any, depending on the state of the tide.

The focus of the research was on the landside part of this system, that is the road and rail reception facilities, and the delays that can occur due to layout constraints, equipment availability and hours of working.

New Zealand's largest ports (ie Auckland and Tauranga) have moved to 24/7 operation in recent years and to increasingly sophisticated paperless booking systems; other ports operate a 12-18 hour reception service. Performance of road reception facilities is measured by truck turnaround time, for example Tauranga claims to achieve an average 20 minutes for a container collection or delivery.

Truck queuing has been a perennial issue at some New Zealand ports and 24/7 working has not entirely solved the peaking of vehicles at certain times of the day, which is connected with the customer's depot opening times.

New Zealand's ports are littoral rather than estuarine and have not faced the need to relocate as a result of increasing vessel sizes over the decades. However, this has often resulted in the ports being confined by urban development. This is being countered, primarily in Auckland, with the development of inland port terminals, which free up waterfront storage space and ease central city road congestion but add an additional transport link and may add additional handling. The balance of advantage in regard to freight delay and reliability is unclear.

#### **7.3.3.3 Cook Strait Ferry delay**

The inter-island Cook Strait ferries form a link in the inter-regional road and rail journeys that involve inter-island crossings. Strait Shipping and KiwiRail provide RoRo road freight services and KiwiRail also provides a rail RoRo service, including some dedicated freight sailings.

The ferry adds an additional source of possible schedule delay to inter-island trips, with weather delays being the main source of journey time variability, including delayed and cancelled sailings.

#### **7.3.3.4 Rail network**

Incidents affecting the rail network and rail freight services include:

- equipment failure – defects in locos and wagon rolling stock, signalling and communication failures
- level crossing crashes/incidents – the only point where rail traffic is impacted by road traffic
- weather-related line closures – surface flooding and erosion.

KiwiRail (2010b) issued a turnaround plan for improving the rail business. Part of the emphasis was on improving reliability, from a 75% on-time freight delivery performance to a >95% performance.

For consistency, we suggest a similar standard as for road of >3 hours and <1 day outage should be used when separating incidents causing unusual time variation from exceptional delays from rare events.

### **7.3.4 Inter-modal terminals and transfer points**

Apart from rail and port terminals already discussed, other sources of delay are at other depots and transfer points where freight is consolidated/deconsolidated, cross-docked between services or transferred between transport modes.

This includes LCL de(vanning) services at ports, 3PL logistics operators' warehousing and distribution centres, and at distribution centres for shippers large enough to support their own goods distribution operations. At the international borders, the inspection, documentation and approval processes for security, biosecurity and customs clearance are also potential sources of delay uncertainty.

The sources of delay in these intermediate transport chain activities are also demand/supply fluctuation and interactions associated with equipment, systems and staffing of the activities, which may include resource constraints and time windows. The result is variation in the time between receipt of the freight and its availability for onward despatch on a different vehicle, mode or make up of consignment.

The possible sources of delay at these intermediate transfer points are many and complex and there is probably little to be gained from attempting to understand all of the possible combinations. Rather, an empirical understanding of the potential for these intermediate processes to either act as a buffer to reduce overall freight time variability or as an exacerbator to amplify variability is probably all that can be contemplated.

### 7.3.5 Information processing and approvals

The carriage of goods is underpinned by a legal framework and commercial arrangements that determine the ownership, responsibilities for, and insurance of goods in transit; these can give rise to delays when information flows either do not keep pace or are poorly integrated with the physical movement of goods.

These occur mostly where freight moves across international borders and includes biosecurity, customs and excise, quarantine and immigration. How and where regulatory clearances such as these are satisfied and the capacities of the responsible agencies can interfere with the efficient movement of freight. This area has become much more critical in recent times due to international terrorism and bio-security concerns and requirements imposed by foreign governments.

An example is the requirement to obtain a prior clearance for all consignments. NZ Customs requires at least 48 hours' notice for a shipper's detailed declaration of export consignment contents before approval to pack for export is given. Consignments to the USA are also subject to particular prior clearances from the USA before goods can be shipped, although New Zealand has negotiated streamlined processing as a trusted partner.

## 7.4 Interventions for reducing delay and unreliability

### 7.4.1 Introduction

Interventions to reduce freight delays and improve reliability fall into the general groups of:

- 1 Increasing the capacity of bottleneck links in the transport part of the supply chain – this is a frequent response and often an essential requirement where the full capacity of a transport system has been reached; it includes targeted increases in capacity through special arrangements, such as permitting of certified and monitored vehicles carrying large loads on recognised freight routes
- 2 Active management of freight movements to avoid congestion hot spots by mode, route or time shifting; the time shifting may involve increasing the time windows for goods collection and delivery which link with land-use changes (see 4 below)
- 3 Improved mode transfers – while these are just links in the transport supply chain, responsibility often changes at mode transfer points and developing efficient interfaces and inter-operability between modes is one area for delay reduction. This includes intermodal systems whereby two or more modes

of transport are used to transport the same unitised package (container, truck etc) in an integrated manner, without loading or unloading, in a transport chain

- 4 Land-use planning interventions – public policy applied to land-use controls that facilitate organisation of freight chains into more efficient configurations, while maintaining environmental standards and not disadvantaging passenger movement; this includes zoning to encourage the development of large blocks of land well connected with the primary transport network as freight hubs that are not restricted by proximity to residential development
- 5 National level planning that facilitates efficient transport solutions where there is modal contestability – by ensuring that taxation and financing arrangements are mode-neutral; also the case for positive intervention in national transport network planning in the face of potential dominance from external interests – such as reduction in the number of gateway ports with a view to retaining international competitive advantage
- 6 Interventions aimed at improving the interface between production transport and consumption – an example of this is where supermarket stocking is linked back to distribution and from there to external ordering, so as to deliver goods to the end demand as close as possible to the required time. The interventions lie in better working arrangements between industry and transport in areas such as despatch and delivery working hours, industrial agreements, inter-linked systems.

The identification of interventions is structured to include all freight modes – rail, road, coastal shipping and surface transport links to international air and sea gateways. Road freight has been subdivided into urban distribution, rural collection/delivery (dairy, fertiliser, waste disposal etc), inter-urban long distance road transport. We also draw distinctions between own-account freight operations and hire-or-reward operations.

## 7.4.2 Reducing bottlenecks and increasing freight network capacity

This part of the review considers interventions that are targeted specifically at reducing bottlenecks to freight transport and increasing the capacity of the freight network. General road network decongestion measures also provide benefits to freight transport although not specifically targeted at freight.

### 7.4.2.1 Urban road freight

Interventions to selectively improve traffic flow for road freight are likely to be more effective and justifiable on roads that carry a higher than average percentage of freight traffic. Identifying networks of freight routes is therefore bound in with freight interventions. At its simplest, defining the freight network is a matter of carrying out classified traffic counts to identify those roads with higher than average goods vehicle traffic, in terms of vehicle per hour and/or percentage composition. Identifying the freight generators and their location with respect to roads carrying higher than average freight traffic is the next step. Existing use does not provide the complete picture. Future growth needs to be anticipated and points of conflict between freight and other land uses along routes used by goods vehicles identified with a view to modifying the treatment of freight routes or using traffic management and creating new freight links to reduce conflicts.

On high-capacity arterial roads that are identified as freight routes, interventions to give freight priority over other traffic come from the same toolbox as other traffic priority measures, such as:

- dedicated freight traffic lanes or lane sharing with other prioritised traffic such as buses and/or high occupancy vehicles
- pre-emption and special routing of goods vehicles through intersections
- freight-only traffic links and service roads at critical locations, such as at approaches to freight terminals.

These measures tend to have been reserved for public passenger transport with some extensions to other forms of personal transport that reduce the use of single occupant private cars, hence high-occupancy vehicle or transit lanes (referred to as T2 and T3 lanes) and bus lanes shared with cycles. Assigning priority to goods vehicles has not been common practice; in fact most urban traffic management has tended to treat goods vehicles as a problem that needs to be managed rather than as a necessary part of the urban system.

A number of New Zealand cities have identified freight routes, and the Transport Agency has also done so at the national level. At the national level New Zealand's highway network does not provide many opportunities for alternative routing between cities and regions and most of the higher volume state highways are important freight routes. It is in the urban context that identification of the freight network is most useful, particularly in the larger urban areas and conurbations. Once identified, the freight network needs to be reinforced with signage and design treatment that makes the network visible to freight operators and the general public, and is tied in with strategic land-use planning for freight distribution.

While several New Zealand cities have developed freight strategies and action plans, physical treatment of roads to give priority to freight over other traffic movement does not feature in these plans. Where bottlenecks and reliability risks are identified, the solutions advanced are to improve conditions for traffic as a whole by construction of new and upgraded infrastructure.

The *Auckland regional freight strategy* (ARC 2006), included freight priority as a possible action area, noting the potential for priority vehicle lanes, motorway ramp metering and toll lanes to form part of a set of priority measures. The suggestion was made that access to priority vehicle lanes could be controlled by time period, with buses having priority in commuter peaks and freight vehicles being given priority access at other times. However, the scope for priority measures to favour freight was expected to be limited and specific to localised circumstances. The freight strategy has not yet been updated by the recently formed Auckland Transport.

In its *Liveable arterials plan*, Auckland City Council (2008) suggested treatments for arterials with a freight emphasis but these were largely to avoid features that disadvantaged freight. On reserved freight lanes the council stated 'freight lanes similar to bus lanes could be considered in the future, with a wider dimension than standard travel lanes'. The earlier identification of a freight network was softened to routes with a freight emphasis, which were mapped as being in and around the industrial areas of the South and West Isthmus. This plan has not yet been updated by the recently formed Auckland Transport.

The *Waitakere City freight study* (Maunsell 2009) proposed a hierarchy of freight routes for west Auckland. The design treatments were mainly related to geometry and pavement to ensure the identified routes were suited to larger vehicles. Suggestions made for positive priority treatment were:

*Provision of priority treatments is very much site specific and will depend on policy objectives, stakeholder interest and funds. Options to improve efficiency include (subject to further detailed investigations):*

- *Installing dedicated or shared priority advances at intersections for heavy vehicle lanes in industrial areas.*
- *Enabling heavy vehicles to use special vehicle lanes (i.e. bus lane, HOV lane etc.) already in place or under investigation (e.g. Lincoln Road, Te Atatu Road) and determining any special constraints to be introduced such as:*
  - *Restricting heavy vehicle size operating on special vehicle lane; and*

- *Restricting freight operational hours of HCV to lanes so that it does not coincide with the AM and PM Peak hours (i.e. 7am – 9am and 4pm – 6pm). This will improve the reliability and efficiency of the public transport system.*

The Transport Agency<sup>11</sup> is implementing truck priority measures in conjunction with ramp metering and signalling, viz:

*The New Zealand Transport Agency is aiming to improve journey times and create a more free-flowing motorway with the opening of priority lanes at on-ramps.*

*Truck priority lanes allow trucks to bypass the ramp signal without stopping and losing momentum, especially when on-ramps are on an incline. The faster access also means that trucks can maintain a good speed onto the motorway, and will not slow down other vehicles. The first trucks-only priority lane opened in October 2007, from the Grafton Road southbound on-ramp to the Southern Motorway.*

*The truck, bus and car-pool priority lane gives car-pool vehicles (two or more people per car), trucks and buses faster access to the motorway. The benefit of the lane is to move more people rather than more cars to the benefit of commuters who car-pool or use buses. The priority lanes will also make a big difference to the freight industry giving truck operators more reliable travel times on the motorway.*

*The priority lane for trucks, buses and car-pool vehicles will be operating soon at the Mt Wellington and South Eastern Highway northbound on-ramps. Motorcycles can also use the priority lanes, except at Grafton Road southbound on-ramp.*

*A total of 14 selected on-ramps across the Southern (SH1), Northern (SH1) and Northwestern (SH16) motorways will feature priority lanes for trucks, buses, with car-pool vehicles being added at a later stage.*

*Priority lanes are also an outcome of the objectives detailed in the New Zealand Transport Strategy's Assisting Economic Development section, by contributing to improving the flow of people, goods and services within and between cities in New Zealand.*

Sharing of bus lanes with freight vehicles is being introduced by local councils in the UK, with the urban centre lanes being renamed 'essential user lanes', recognising a higher priority for freight deliveries and public transport vehicles over general light vehicle traffic. On arterial routes, heavy trucks are being permitted to use high occupancy vehicle lanes (eg Leeds, Bristol) and dedicated large vehicle lanes are being considered (eg Aberdeen).

The Vicroads' initiative 'Smartroads'<sup>12</sup> states, among other features 'while trucks will have full access to the arterial road network, they will be given priority on important transport routes that link freight hubs and at times that reduce conflict with other transport modes'.

#### **7.4.2.2 Road freight capacity and reliability interventions on rural highways**

New Zealand's rural road network is predominantly a two lane highway, with a 3.5m lane width standard and shoulder widths depending upon traffic, terrain and traffic composition. The capacity of a two lane highway is constrained by passing sight distance combined with gradient effects. Where passing sight distance is restricted, moving queues of traffic form at relatively low volumes and passing lanes become

<sup>11</sup> [www.nzta.govt.nz/projects/rampsignalling/about/](http://www.nzta.govt.nz/projects/rampsignalling/about/)

<sup>12</sup> [www.vicroads.vic.gov.au/Home/TrafficAndRoadConditions/HowWeManageTraffic/Smartroads/](http://www.vicroads.vic.gov.au/Home/TrafficAndRoadConditions/HowWeManageTraffic/Smartroads/)

economic where daily traffic exceeds 4000 veh/day. Slow vehicle bays are a less frequent device for reducing delay, designed primarily for slow heavy vehicles on gradients to pull out of the traffic stream to allow other vehicles to pass.

At the periphery of the larger urban areas and on a few of the busier inter-urban routes, traffic has reached a level where passing lanes, even at frequent intervals, fail to provide the capacity needed for efficient operation and European style alternating 2+1 lane treatments with wire rope medians have been introduced. The next stage is full four lane treatment but this is reserved for the peripheral urban motorways and expressways (eg Auckland-Hamilton).

Traffic volumes are not to a level where full motorway treatment on the main inter-urban highways is a viable option, and are unlikely to be so in the foreseeable future particularly as road funds are quite heavily constrained.

The New Zealand Business Council for Sustainable Development (NZBCSD) (2011) in its recent 'Future Freight Solutions' report has proposed 'a network of freight priority lanes, linking Auckland, Hamilton and Tauranga, where access might be charged for at peak periods and is available for private motorists on an 'opt-in' basis'. There are layout and management complications in running tolled and untolled lanes in parallel.

Relevant to the NZBCSD proposal is Lindsey (2009) (also in de Palma et al 2007) who reviewed the literature and analysed the economic case for separation of light and heavy vehicles using dedicated lanes or differentiated tolls supported by ITS technology. Lindsey concluded that using differentiated tolls to encourage an efficient separation of classes of traffic would lead to smoother more homogenised flows without the inflexibilities and indivisibilities of fully dedicating lanes to a particular class of traffic. Over time, such a separation could become reinforced with facilities built to accommodate the needs of the segregated traffic. It would allow different design standards to be employed for maximum efficiency and lead to separated light vehicle and truck networks. However, there had to be a sufficient basic volume of heavy vehicles to make toll-induced traffic segregation an economic proposition. The availability of vehicle positioning systems and electronic tolling facilitates a toll-based system for preferentially segregating vehicles.

Truck toll lane projects are being considered by several states in the USA although the contexts are multi-lane divided carriageway highways. A recent business case (Wilbur Smith & Associates 2010) for truck toll lanes on Interstate I-70 through five states showed a benefit-cost ratio of about 1.6 for the construction of two truck toll lanes in each direction flanked by two light traffic lanes per direction (eight lanes in all).

Poole (2009) provides a general review of the options for separated light vehicle and truck lanes in various contexts putting forward arguments that separation would allow more customised design standards for each class of traffic, such as narrower light vehicle lanes. However, the economics of provision are not discussed and the contexts are relatively high-volume traffic corridors. The possibility of truck roads in place of railway expansion is also proposed, together with hybrid solutions such as trucks operating under a high degree of automation and guidance when on specialised truck routes.

So far, while there have been several theoretical studies and feasibility investigation for projects, there is relatively little practical experience with dedicated truck lanes internationally. The contexts tend to be high freight volume roads which can support a business case for the infrastructure development required for separation of lanes. For the lower traffic flows on most New Zealand roads, the economics of dedicated or preferential lanes will be harder to economically justify and likely to be confined to the northern half of the North Island

Another impediment to inter-urban and inter-regional road freight flows is where freight traffic wishes to bypass towns. General and truck bypasses are gradually being constructed but there are still many locations where the existing truck bypass is either inadequate (eg unsuitable minor rural roads or lengthy outer urban



diversions signed as bypasses to divert trucks for environmental reasons) or lacking. The merits of truck bypasses can be assessed on a case-by-case basis and as part of a strategic route or network study, provided that appropriate values of time and reliability are included in the analysis procedures.

#### 7.4.2.3 Rail freight

When considering interventions by freight mode, in New Zealand long-distance rail is used almost exclusively for freight. Apart from the single daily Auckland–Wellington, Picton–Christchurch and Christchurch–Greymouth services, interaction between freight and passenger traffic occurs only for the suburban rail services. So improvements to the inter-regional rail infrastructure and services are by their nature freight oriented.

Also, as well as benefiting rail freight, where these interventions capture a larger mode share for rail, there will be decongestion benefits for road freight as part of the decongestion for general traffic on inter-regional road routes.

To a large extent, KiwiRail's plans for developing its business are rail freight focused as set out in its turnaround plan *Statement of corporate intent 2010–13* (KiwiRail 2010b) and briefing to the incoming Minister (KiwiRail 2008). The emphasis is on reducing transit times on the main north-south backbone (Auckland–Wellington–Christchurch) with the aim of reducing travel times (two hours improvement between Auckland and Wellington to become more competitive with road travel times), and adding a second rail-capable freight ferry. Infrastructure improvements comprise track and structures upgrading to increase speeds and reliability, provision of additional crossing loops and improving the entry/exit to Auckland and Wellington. The plan recognises the need to reverse 15 years of underinvestment in maintenance and renewals, plus the introduction of new rolling stock and IT technology.

Some additional traffic is being targeted but the plan recognises that KiwiRail's main freight business lies in specialised bulk commodities, mainly export traffic for a few large customers.

As well as considering improvements to existing inter-regional rail links, a number of less used rail lines are under consideration for closure or 'mothballing'. These include the North Auckland Line (Auckland–Whangarei–Otiria), the Dargaville Branch, Napier–Gisborne, North Wairarapa and Stratford–Okahukura. The commercial business case from a NZ Rail Corporation viewpoint for closure of these lines will differ from a national economic viewpoint perspective that includes the incremental congestion effects of decanting this traffic onto the road. These closures also potentially stand to reduce the network benefits of rail to certain users, so could flow on to reductions in traffic on the remaining lines. Closure will also risk foregoing some option benefits from future traffic, for example from the long proposed rail link to Marsden Point.

In Auckland and, to a lesser extent Wellington, interventions that free rail to carry freight without being constrained by rail suburban commuter service timetables are a potentially beneficial intervention. This includes rail freight moving north/south through Auckland as well as freight terminating in Auckland. With increasing passenger services in Auckland, rail freight is becoming confined to night-time movement. Adding parallel tracks for freight and construction of a line parallel with the SW motorway (SH20) between Avondale and Southdown have been possibilities for many years, but will to some extent depend on the future of rail traffic north of Auckland.

#### 7.4.3 Active management of freight movements

The aim of this group of interventions is to avoid congestion hot spots by change of mode, by active selection of the least congested route and by shifting the time of collection and/or delivery. This group has most application for road freight as the aim is to avoid congestion delay and travel time variability caused by traffic peaks to which passenger travel is the main contributor.

The amount of advanced planning varies. Mode shifts are longer-range decisions, mainly for long-distance movements where there are opportunities other than road – either rail or possibly coastal shipping. In these cases the decision on mode choice takes in a number of factors of which time and reliability are important but not the only determinants. The selection of mode for longer-distance freight ties in with freight demand cross-elasticities, discussed later.

Choice of pick-up and delivery time may be constrained by time windows for despatch and delivery of goods at the premises at each end of the journey dependent on staff working hours and any other restrictions on opening or access. The many freight studies, plans and partnerships both in New Zealand and overseas identify time shifting as a way of avoiding road congestion, usually involving night movement of freight. Line haul road freight already moves substantially by night or in the early morning to clear the main city road networks before the morning peak.

Choice of route to avoid congestion delay is tied in with general operational planning and optimisation of freight capacity utilisation, including maximising load factor and freight revenue while minimising freight costs. Many New Zealand fleets are already under active management through vehicle tracking systems and there are companies offering freight matching services to small carriers to improve backloads.<sup>13</sup>

The SMARTFREIGHT project<sup>14</sup> is a development and demonstration project with test sites in Bologna, Trondheim, Dublin and Winchester with the aims of:

*Develop new traffic management measures towards individual freight vehicles through open ICT services, on-board equipment and integrated wireless communication infrastructure*

*Improve the interoperability between traffic management and freight distribution systems*

*Coordinate all freight distribution operations within a city by means of open ICT services, on-board equipment, wireless communication infrastructure and CALM MAIL implementation in on-board and on-cargo units, for all freight vehicles.*

The final report (Westerheim and Natvig 2008) and a large number of subject and site reports give the impression of systems still somewhat unproven and at a developmental stage and probably not of direct interest to this research. Related to SMARTFREIGHT is the EURIDICE programme<sup>15</sup>, another EC-sponsored university/industry consortium series of research projects with the following main objectives:

*Supporting the interaction of individual cargo items with the surrounding environment and users on the field*

*Improving logistic performances through application of the intelligent cargo concept and technologies in the working practices of operators and industrial users*

*Developing collaborative business models to sustain, promote and develop an intelligent cargo infrastructure*

*Realizing more secure and environment friendly transport chains through the adoption of intelligent cargo to support modal shift and door-to-door inter-modal services.*

Again, the objectives are a high level of integration of freight information and movement management using centralised ITS with multiple objectives of freight efficiency and minimising environmental impact.

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<sup>13</sup> For example, [www.Backload4u.co.nz](http://www.Backload4u.co.nz); [www.freightfinder.co.nz](http://www.freightfinder.co.nz); [www.freighthub.co.nz](http://www.freighthub.co.nz)

<sup>14</sup> [www.smartfreight.info/](http://www.smartfreight.info/)

<sup>15</sup> [www.euridice-project.eu/](http://www.euridice-project.eu/)

Supporters of the project appear to be shippers and city councils, with carriers and logistics providers less convinced of the benefits and wary of the complexity. The Intelligent Cargo Forum<sup>16</sup> is related to EURIDICE.

#### 7.4.4 Improved mode and vehicle transfers

Mode transfers for surface freight are between road and rail and, for import/export, between rail/port, road/port and road/airport. Vehicle transfers for goods (de)consolidation and onward routing occur at LCL vaning/devanning facilities either portside, inland port or private yard and for inland distribution at transport logistics operators premises and dedicated distribution centres for larger shippers and receivers of cargo.

Ways of improving the efficiency of the inter-modal transfer operations include:

- Good site layout permits ease of access for each mode, sufficient channels or docks to accommodate the arriving vehicles, and sufficient resources including efficient handling equipment, trained staff and control systems to efficiently execute the loading/unloading and the movement to/from transit storage. These are design matters that are situation specific and the solutions vary according to site constraints and the freight volumes and types being handled.
- Removal of constraints on operating hours may be for industrial/labour reasons, conditions imposed by local authorities related to adjacent land use, and the costs of extended operating hours in wages, security and the like.
- Level demand over the day, through the week and seasonally. In some cases there are seasonal fluctuations in demand and busy periods have to be expected and catered for; in other cases short period demand fluctuation is a result of opening and closing hours at the other end of the freight trip or shift working of transport operators; for example queuing at shipping container terminals.
- Changing the location of modal transfer terminals is a solution that allows some of the above constraints to be removed and is being increasingly adopted in New Zealand cities through the creation of inland ports, of company distribution centres and 3PL warehousing away from congested parts of urban areas on level open industrial sites and close to arterial routes.
- Increase the standardisation of freight units for ease of handling, consignment tracking and security. The almost complete penetration of the international sea freight market by ISO containers, apart from products shipped in bulk, is because of their standard design for ease of intermodal transfer between flatbed road truck, rail wagon, stacking at freight terminals and sea transport on cellular container vessels. For LCL, in overseas countries companies offering specialised pallet cargo network services offer a smaller form of cargo unitisation to assist in the ease of transfer and handling of these small consignments.<sup>17</sup> Pallets are to a standard international size in wood, plastic or metal with two-sided entry for fork lift handling. Standard small containers (crates, cages, boxes) can then be used to load goods and loose goods can be shrink-wrapped. Pallet systems operate on similar lines to containers, in that they are standard reusable and exchangeable units that can be owned, hired or leased from companies who own the pallets and deal with maintenance and supply. This is a form of service that fits into the business model of the 3PL provider. Some New Zealand companies reliant on a variety of suppliers specify that freight be received on standard pallets as part of their supply reception and inventory and quality controls.

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<sup>16</sup> [www.intelligentcargo.eu/](http://www.intelligentcargo.eu/)

<sup>17</sup> For example: [www.pallex.co.uk/](http://www.pallex.co.uk/)

- Use swap bodies for rapid turnaround. These are a lightweight form of demountable vehicle body of similar size to an ISO freight container but less robust and not stackable; their potential advantage is quick transfer between modes and the opportunity to reduce truck turnaround time compared with the typical up to 30 minutes to unload or load a large delivery truck. However, the requirement for delivery docks is increased. They are suited to closed distribution loops. They are not common in New Zealand but prevalent in Europe and used in Australia.
- Identify consignments electronically. Radio frequency electronic tagging of packages and containers allows the location, current status and responsibility for the goods consignments to be tracked in real time, assists in the flow of electronic documentation and provides the means for warning if consignments become delayed or misdirected. At the inter-modal transfer point, electronic processing at the point of reception avoids the processing delays in paper systems.

The *National freight demands study* (Richard Paling Consultants et al 2008) has identified ease of mode transfer as an important determinant of the choice of mode for both containerised cargo and bulks, with the bulks requiring specialist transfer facilities. The attractiveness of rail to new cargo depends upon reducing the rail transit time and on being able to provide very efficient road/rail transfers which, in turn, is facilitated by standard size containers that can be transferred easily with standard equipment.

#### 7.4.5 Land-use planning interventions

Public policy can be applied to land-use controls that facilitate organisation of freight chains into more efficient configurations, while maintaining environmental standards and not disadvantaging passenger movement. This includes zoning to encourage the development of large blocks of land well connected with the primary transport network as freight hubs that are not restricted by proximity to residential development.

National level planning facilitates efficient transport solutions where there is modal contestability by ensuring that taxation and financing arrangements are mode-neutral. This also applies to public intervention in national transport network planning in the face of potential dominance from external interests – such as reduction in the number of gateway ports with a view to retaining international competitive advantage.

Interventions can improve the interface between production transport and consumption – an example of this is where supermarket stocking is linked back to distribution and from there to external ordering so as to deliver goods to the end demand as close as possible to the required time. The interventions lie in better working arrangements between industry and transport in areas such as despatch and delivery working hours, industrial agreements and inter-linked systems.

Upton (2008) produced a report on freight best practice for Environment Canterbury. This report commends regional government in recognising the emerging international best practice development of freight hubs for regional and urban distribution, but recommends more action should be taken on implementation and on national inter-connectivity through designated freight routes. The report discusses the concept of public logistics terminals, which have been introduced in some parts of Europe, a publicly supported facility available to all carriers with inter-modal facilities, noting that while there was some early development of this concept, the growth of several large logistics companies with their own national freight networks and distribution centres have largely overtaken this idea.

MoT (2008a) states 'Fundamental to meeting the growth in total domestic freight movement is the concept of intermodality: the effective use of different transport modes in combination, to achieve an optimal and sustainable use of resources and the most effective supply chain. In the context of domestic sea freight this means integrating freight movement by ship with delivery to and from ports, by rail and road, on the basis of 'best fit' for the particular consignment'. However, government commitment to

coastal shipping and the establishment of a special unit within MoT to assist in the coordination and development of intermodal freight solutions involving coastal shipping appears to have been short lived.

The role of public agencies at regional and local level therefore appears to be as a facilitator to the private sector which is better equipped, commercially motivated and probably quicker at innovating to suit the local conditions, the public role being:

- identifying the land-zoning demand for freight hubs at strategic locations around the urban centres that will not become compromised in future by encroaching residential or other sensitive development
- ensuring that areas selected are well connected to an identified arterial freight network, both road and rail, that there are sufficient available sites to allow effective private sector competition among transport logistics operators and sites for larger companies to site freight distribution centres
- encouraging coordinated action between the regional/district councils, the Transport Agency and KiwiRail, port and airport companies and the main shippers for long-term planning of the freight network – which can be through the medium of freight forums and partnerships that have been established in some cities
- ensuring good road and rail links to the main commercial ports and road links to the airports, with inland port facilities integrated into the freight hub developments.

#### 7.4.6 National level policy, planning and investment interventions

The performance of the freight network is influenced by national level policy positions, degree of market intervention and proactive planning, and investment decisions in public infrastructure. While not directly connected to freight delay and reliability at the micro level, national level policy, planning and investment interventions are very influential in how the physical transport infrastructure supports efficient freight movement.

Areas of national intervention include:

- Central government intervention, or non-intervention, in port ownership and development - there is a well-rehearsed debate over the future of New Zealand's ports, the large number of ports in relation to the population size, possible port amalgamations and cooperation and changes in ownership structure, degree of hubbing out of Asia and Australia and economic implications for New Zealand, the implications of moving away from local government ownership of ports, vertical integration in the land/port/maritime sectors, and the role of the major shipping lines and international private port operators. While these are matters of potentially major significance to the future efficiency of the freight network, particularly for import/export, we judged that they were not intended to be the subject of this research.
- Modal neutrality in charging for freight modes – again, there is a long history of debate and investigation on the charges faced by road freight operators for the use of road infrastructure, whether there is modal neutrality with rail which is required to operate as a commercially competitive business, even though a public monopoly; there are also modal neutrality issues related to coastal shipping.
- The funding of rail infrastructure in comparison to road infrastructure and whether the networks are evaluated as a whole in investment decision making, taking account of the implications for road investment and congestion with shifts of traffic away from rail and vice versa. For example, if KiwiRail evaluates investment purely from its commercial viewpoint, this ignores the externality effects on road users. There are also questions of the network effects of investment or divestment decisions for particular lines and short versus long-term viewpoint.

- Government policy and investment in areas such as intelligent permitted access of larger and heavier trucks on main freight routes, which has the potential to reduce the number of freight movements and so marginally reduce congestion as well as giving efficiency gains – this policy interacts with the establishment of regional freight hubs and a defined national freight network.

In relation to these matters we note the following published material as well as the many conference papers and presentations in recent years:

- Mackie et al (2006) concluded that between 3% and 7% rail freight addition was contestable (from road) and that the 20% target in the NZ Transport Strategy (2002) would require a revolutionary change in the way freight is transported. However we note that KiwiRail's turnaround plan does expect to compete for additional market share.
- Rockpoint et al (2009a; 2009b) identified that about 8% of the total freight tonnage and 20% of freight tonne-km was potentially contestable by coastal shipping and that reliability was the most important choice factor. However reliability is affected by the current cabotage regime that allows domestic freight to be carried coastally by overseas vessels visiting New Zealand ports but this receives lower priority than the international business. The study also draws attention to pricing practices in the freight industry including strategic pricing dependent on the presence of absence of competing modes. Container cargo was recognised as a growth opportunity for coastal freight (and would require good inter-modal transfers as noted above). Depending on any future hubbing to a limited number of New Zealand ports, coastal shipping has the potential to provide container feeder services. It was recommended that the government articulate its policy position on port consolidation.
- The New Zealand Productivity Commission (2011) has recently published the results of an enquiry into international freight transport services to:
  - identify and analyse the cost of all components of the international freight transport supply chain for New Zealand importers and exporters
  - identify any impediments to the accessibility of the international freight transport services, and to competition within and between the components of the international freight transport supply chain
  - identify mechanisms available to improve the accessibility and efficiency of the international transport supply chain.
- MoT (2008b) provided an analysis of short and long-run marginal and fully allocated costs of road, rail and coastal shipping modes and a comparison with transport charges and the relationships between them. This and the subsequent Understanding Transport Costs and Charges project which updated the information provides the numerical basis for analysing transport policy in relation to government's ownership, investment in and charging for transport services.
- Heatley (2009) argued that part, if not the whole, of the rail network is uneconomic and that targeting a percentage of freight transfer to rail risked forcing freight onto a mode not naturally suited to its carriage.

However, we have taken the view that these matters, having broader implications than freight delay and reliability, were not the intended focus of research and have not been reviewed further.

#### 7.4.7 Goods supplier, freight operator, freight customer interface

These are interventions aimed at reducing sources of travel delay and uncertainty arising at the interface between the goods production process (the shipper end), the transport operation and the goods on sale or use (the consignee, buyer end).

The situation where these are most likely to occur and to be important is in just-in-time delivery, characterised by relatively short times between placing orders and requiring delivery, and where there are narrow time windows for the pick-up and delivery operation. High-turnover consumer items such as food supermarkets are a typical case.

Cultivating an understanding between the public regulators/infrastructure providers and how urban transport distribution operates at a detailed level is a necessary step if public policy interventions are to be useful.

Some of the interventions already discussed for inter-modal transfer are relevant, including standardised packaging (pallet, container) that is easily loaded and unloaded, electronic identification of goods through radio frequency electronic tagging linked directly into ordering and stock control systems and the use of swap bodies for rapid truck turnaround.

## 8 Freight demand elasticities

### 8.1 Introduction

In this section we review the literature on freight demand elasticities, based on the introduction in section 2.12. The only prior New Zealand review of freight transport demand elasticities is believed to be that undertaken by Symonds Travers Morgan (1996), as discussed in section 3.5. The following discussion broadly covers this earlier work as well as more recent sources. The review includes examples of generalised cost models developed for freight demand and modal analysis and the techniques used to determine modelling parameters.

Elasticity evidence has been examined separately for the main trip components (time, cost, quality aspects etc) as well as on a total generalised cost basis. It is structured as follows:

- Section 8.2 discusses expectations and evidence relating to the price elasticity of the total freight market, including some relevant New Zealand evidence.
- Section 8.3 outlines appropriate elasticity measures and hypotheses relating to relative elasticity values in mode choice situations, where freight is contestable between two (or more) modes.
- Section 8.4 summarises and discusses the international evidence on freight price direct and cross-elasticities in modal choice situations.
- Section 8.5 discusses the influence of other service and quality factors on freight demand, again with emphasis on mode choice.

Appendix A provides a detailed review of New Zealand evidence relating to road use and fuel consumption price elasticities. Appendix B provides details of the international studies reviewed relating to freight mode choice situations.

The literature reviewed on freight demand elasticities represents the main ‘original’ studies which are in the public domain. It is acknowledged that these studies are quite old and heavily focused on mode choice. In addition, there are quite a number of ‘review’ studies, which include reviews/summaries of the ‘original’ studies but have not involved any additional market research.

It is recognised that there are more choices in freight transport (eg on transport efficiency and freight efficiency) that might be cost sensitive, and that mode choice elasticities vary significantly by tonnes, tonne-km, vehicle-km or the modal share (and short versus long-run distance).

The international references reviewed were:

- Abdelwahab (1998)
- Beuthe (2001)
- Bureau of Transport, Infrastructure and Regional Economics (2009)
- Bureau of Transport and Regional Economics (2003)
- de Jong et al (2004b)
- Friedlaender and Spady (1980)
- Kells (1997).
- Meyrick and Associates (2006)
- MM Starrs (2005)



- Norojono and Young (2003)
- Oum et al (1990).

New Zealand sources are primarily work carried out for the Ministry of Transport and one study for Land Transport NZ:

- Deloitte Access Economics (2011)
- Kennedy and Wallis (2007)
- NZIER (2009a)
- NZ Productivity Commission (2011).

## 8.2 Total freight market price elasticities

Most of the freight price elasticity literature relates to a single mode (generally truck or train), where the dominant response to any price change on that mode (or a competing mode) is switching between modes. The extent of evidence on overall freight market price elasticities, in either the short or long run, appears to be very limited.

In general, we would expect total market price elasticities to be very low, particularly in the short run:

- For typical commodities, transport costs are in the order of 5% of total costs of production (including distribution, retailing) and of the final sale price of the finished goods.
- Any change in transport costs in the short run will have a small effect on total costs of production, and an even smaller effect on the relative costs of similar products from different sources. Any cost impacts will tend to be passed on to the consumer. As most substitute goods will tend to have a similar transport cost component, in the short run consumers will have little reason to switch to alternative products.
- In the longer run, the transport/distribution sector would be expected to respond to consistently higher transport costs by sourcing inputs nearer to the point of production of the goods, and maybe locating this point nearer to the point of retailing/consumption. Thus freight price elasticities would be expected to be significantly higher in the long run.
- We might speculate that market price elasticities with respect to total freight transport costs would be well below -0.1 in the short run, possibly higher than this in the long run<sup>18</sup>.

In the longer run, lower transport costs are likely to lead to longer transport distances (eg more globalisation).

In regard to total freight market elasticities with respect to fuel prices, these would be expected to be an order-of-magnitude lower than the elasticities with respect to total freight costs, as fuel prices are typically in the order of 10% of total freight costs, certainly for the trucking sector (the dominant freight mode in New Zealand):

- Booz Allen Hamilton (2004) estimated fuel costs at 12% of total costs for typical longer-distance trucking operations in New Zealand.

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<sup>18</sup> In this regard, we note the comment by the NZ Productivity Commission (2011), in relation to international trade, that 'International evidence suggests that a 10% reduction in transport costs could lead to a 1% to 2% increase in trade'. Prima facie, we would consider this elasticity (-0.1 to -0.2) to be on the high side, and would not necessarily apply to domestic freight movements.

- EU analyses give the fuel costs in three Western European countries as between 8% and 15% of total freight transport costs (Chevroulet 2008).

Hence the short-run fuel price elasticities are likely to be in the order of -0.01<sup>19</sup>. The elasticities with respect to oil prices will be even lower, given that oil prices (excluding taxes, etc) are typically around 50% or less of fuel prices to the user.

The above hypotheses in regard to total freight market price elasticities are essentially consistent with the New Zealand evidence on heavy truck km price elasticities<sup>20</sup>, which is set out in appendix A (table A.1). The New Zealand evidence indicates that the New Zealand heavy truck km elasticities with respect to both heavy RUC rates and diesel prices are very small, in the order of -0.01 or lower. The conclusion we would draw from this evidence is that both the total freight market price elasticity and the truck/rail mode share elasticities are very small, in the order of -0.01 or lower.

## 8.3 Freight mode share price elasticities

### 8.3.1 Direct and cross price elasticity measures

This section focuses on situations where the dominant response to price changes on any mode (relative to alternative modes) is switching between modes. Most of the international freight price elasticity literature is focused on such situations, primarily the impacts of price changes on freight switching between truck and train (or vice versa). The following discussion is expressed in terms of these two modes, but in principle could similarly apply to other alternative modes (principally coastal shipping in the New Zealand domestic freight context).

The discussion covers **direct** price elasticities between modes and related **cross** elasticities; in each case the relevant price variable is the price difference between the two modes.

Examples of direct and cross-price elasticities for competition between two freight modes, and generally road and rail are by far the most common market situation examined in the literature, are:

$$\begin{aligned}\text{Road direct price elasticity} &= \frac{\% \text{ change in freight transport demand by road}}{\% \text{ change in price of transport by road}} \\ \text{Road cross price elasticity} &= \frac{\% \text{ change in freight transport demand by road}}{\% \text{ change in price of transport by rail}}\end{aligned}$$

Freight transport demand is most commonly expressed in tonnes carried, but also as tonne-km. Some of the literature expresses elasticities as mode shares, which are similar to the above formulations, but replace the numerators by the percentage points change in mode share rather than freight volume, which is often a more useful parameter. As an increase in price of a mode leads to a reduction in demand, direct price elasticities are negative, while an increase in price of a competing mode leads to an increase in demand, so cross-elasticities are positive. When discussing elasticity, higher/lower or larger/smaller refers to the magnitude (irrespective of sign) of the elasticity, a higher value implying a more elastic response and a lower value a less elastic response.

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<sup>19</sup> This estimate is broadly consistent with New Zealand evidence on the short-run elasticity for truck km with respect to diesel prices (refer appendix A). It may be contrasted with typical fuel price elasticities of demand in the order of -0.2 for car travel (refer Kennedy and Wallis 2007).

<sup>20</sup> We have been unable to find any evidence on total market price elasticities for New Zealand rail traffics.

We note that in markets where road and rail are in close competition, the base rail and road freight prices may well be similar, so the direct and cross price elasticities are also similar in magnitude in such cases.

### 8.3.2 Market structure and elasticity hypotheses

The major part of the New Zealand domestic freight market is effectively **captive** to road; that is there is no feasible rail service available for the freight movement in question, which can generally be attributed to there being no rail link between the required origins and destinations (even taking into account road-rail-road transport chains that use intermodal terminals)<sup>21</sup>.

The response to any price changes in this captive market is effectively a total freight market response, as addressed in section 8.2.

For the remaining (**choice**) sector of the market, direct and cross-elasticities are likely to be very situation specific, depending principally on how closely the two modes are regarded as substitutes by the shipping decision-maker. However, the following general comments can be made:

- Assuming that the market share vs cost function follows a typical S-shaped curve, and provided that the market share of the mode of interest is significant, then its direct elasticity and cross-elasticities will tend to decline as its mode share increases<sup>22</sup>.
- The relativities between road and rail elasticities (both direct and cross-elasticities) will depend on their initial market shares: the elasticities will tend to be higher for the mode with the lower market share.

Hence one clear conclusion is that elasticities are affected by the initial market shares. Unfortunately, much of the literature does not specify what the market shares are, making the interpretation of elasticity results problematic.

Numerous factors other than price will affect market shares and elasticities for contestable freight movements. These include the nature of the goods (time sensitivity, perishability, robust/frangible nature etc), the suitability of the modal alternatives (speed, quality, reliability and security etc), and the need for access trips, trans-shipment and interim storage at the trip ends of the main mode (generally to/from a railhead or port). Again, unfortunately, much of the literature does not provide information on the quality of the alternatives on offer and how well or poorly these suit the goods being shipped.

The New Zealand/Australian experience is that rail carries a significant market share of total freight for only two broadly defined market segments:

- For bulk commodity movements (in New Zealand, the largest movement is export coal between the West Coast and the Port of Lyttelton). Given prevailing cost structures, over medium/longer distances such movements may be regarded as captive to rail.
- For containerised/general freight, over longer distances (in New Zealand, major movements are Auckland-Wellington and Auckland-Christchurch, with the latter having a higher rail mode share). Such movements are likely to be particularly price-sensitive (and also quality-sensitive), and this is the market segment for which modal price elasticities are most relevant in the New Zealand market.

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<sup>21</sup> Estimates are that only 10%-15% of the New Zealand domestic transport task is contestable between rail and truck modes (ref RTF etc).

<sup>22</sup> The elasticity can be shown to equal (the gradient of the market share vs cost curve at any point)/(the slope of the line between the point and the origin).

## 8.4 International evidence on modal elasticities – review and interpretation

This section presents the summary findings of evidence from our international review in relation to price elasticities within and between modes in situations of modal competition; that is situations where the primary market response to changing relative prices on two competing modes is for freight movements to switch between modes. Most international evidence on freight price elasticities relates to such situations and have estimated direct price elasticities (usually for truck and rail) and cross-elasticities between the alternative modes, as noted earlier.

Table 8.1 provides a summary of relevant studies and the elasticity values derived. Further details of each study are given in appendix B.

The main conclusions we have drawn from this evidence are as follows:

- Most relate to manufactured and/or containerised goods movements over medium and long distances for which truck and rail are competing alternatives.
- In such circumstances, it would be expected (as outlined in section 8.3) that elasticity values will be strongly influenced by the base modal shares for the competing modes. Unfortunately the reviewed literature provides very limited information on these modal shares, thus making it difficult to draw useful conclusions from the study evidence, for example on comparative elasticities for different commodities.
- In most cases, for both direct and cross-elasticities, rail elasticities are greater than truck elasticities in response to any change in relative prices of the two modes. This result is consistent with rail generally having the minority mode share, although it is not clear from most of the studies whether or not this is the case.
- Rail direct price elasticity values (by mode) are typically in the range -1.0 to -2.0, while truck elasticities are generally lower, often in the range -0.5 to -1.0.
- For cross-elasticities, in most cases the results (for both modes) cover similar ranges to the direct elasticities. This similarity is as expected, given the similarities in the definitions of the direct and cross-elasticities. However, in one case (Friedlaender and Spady 1980), the cross-elasticities appear to be much lower than the direct elasticity values; this difference appears implausible.
- It should be noted that the magnitude of all elasticity estimates will depend on how tightly the individual studies have defined the commodity movements analysed. To the extent that a study includes some movements which are barely contestable (hence have very low elasticities), the overall resulting elasticity will be reduced.
- Because of the lack of mode share data in particular, it has not been possible to draw any further conclusions on underlying elasticity differences by market segment (such as by specific commodity and by travel distance).

Table 8.1 International review summary – modal choice (direct and cross) elasticities

Country	Reference	Commodities	Scope/methodology notes	Estimates and comments Direct elasticities	Estimates and comments Cross elasticities
Australia	BITRE (2009)	Inter-capital non-bulk freight/containerised		<ul style="list-style-type: none"> <li>Rail (-1.66) &gt; truck (-0.48)</li> <li>Likely to reflect lower rail mode shares, particularly in the 2 shorter corridors (SYD-MEL, SYD-BNE).</li> </ul>	<ul style="list-style-type: none"> <li>Rail (1.04) &gt; truck (0.58)</li> <li>Likely to reflect lower rail mode shares.</li> </ul>
Australia	BTRE (2003)	Inter-capital non-bulk freight			<ul style="list-style-type: none"> <li>Rail (0.9)</li> <li>Close to 2009 estimate (above).</li> </ul>
Australia	Kells (1997)	Inter-capital non-bulk freight (MEL-SYD, MEL-ADL corridors)		<ul style="list-style-type: none"> <li>Rail -1.1 MEL-ADL, -2.2 MEL-SYD</li> <li>Truck -0.77</li> <li>Likely to reflect lower rail mode shares.</li> </ul>	
Indonesia	Norojono and Young (2003)	4 commodities	Rail vs truck choice for movements in Java	<ul style="list-style-type: none"> <li>Rail -0.88, truck -0.53</li> <li>Likely to reflect lower rail mode shares(?).</li> </ul>	<ul style="list-style-type: none"> <li>Rail 0.26, truck 0.42</li> <li>This suggests rail may have higher mode share.</li> </ul>
Belgium	Beuthe (2001)	Not specified	Modelled (rather than observed), assuming shippers minimise generalised cost function	<ul style="list-style-type: none"> <li>Range of values -0.6 to -2.1.</li> <li>Rail generally &gt; truck</li> <li>Likely to reflect lower rail mode shares.</li> <li>No clear pattern long v short distances</li> <li>No clear pattern tonnes v t-mm values.</li> </ul>	<ul style="list-style-type: none"> <li>Wide range 0.1 to 3.0</li> <li>Rail &gt;&gt; truck</li> <li>Likely to reflect low rail mode shares.</li> </ul>
USA	Abdelwahab (1998)	Manufactured goods – multiple commodities		<ul style="list-style-type: none"> <li>Range of values -0.7 to -2.5</li> <li>Values generally similar to rail vs truck – may indicate similar mode shares.</li> </ul>	<ul style="list-style-type: none"> <li>Range of values 0.9 to 2.5</li> <li>Values very similar to rail vs truck – may indicate balanced mode shares</li> <li>Values generally very similar to corresponding direct elasticity values.</li> </ul>
USA	Friedlaender and Spady (1980)	Manufactured goods – multiple commodities		<ul style="list-style-type: none"> <li>Rail values mostly -1.5 to -5.0, truck values -1.0 to -1.5</li> <li>Rail values &gt;&gt; truck in every case, suggesting that truck has the dominant market share.</li> </ul>	<ul style="list-style-type: none"> <li>Mostly low (both rail and truck), up to 0.20 – a few high outliers and some negative values</li> <li>Unclear why values so much lower than direct elasticity values and values from other studies.</li> </ul>

## 8.5 The impact of freight service attributes on mode choice

### 8.5.1 Introduction

The problem of transportation choice for shippers is not limited to pricing of modes. In the field of freight, the value of various service quality factors that bear upon the firms' logistics play an important role and must be taken into account. In fact to understand modal switch strategy, it is necessary to understand fully the role played by service attributes in determining mode choice. In the preceding section, we discussed price and the elasticities associated with it. In this section, we discuss the service attributes considered important by the shippers in determining the mode to use and their role vis-a-vis price.

This literature review deals with the international evidence on freight and the role of service attributes. The aim of this review was to investigate the service attributes considered most important by the shippers and the values attached to them. For this purpose, a large array of literature was reviewed and the results are attached in appendices A and B. The literature was chosen so as to encompass the renowned researches in the field covering a wide variety of commodities in different countries.

In today's competitive environment, firms are characterised by complex logistics. For shippers, it is important to identify the attributes that are the biggest concern for the receiving firms or receiving warehouses. When we look at the literature, we find that most authors conducted their research choosing travel time, reliability, damage, flexibility and frequency as the main attributes (McGinnis 1990; Baumol and Vinod 1970; Danielis et al 2005; Beuthe and Bouffieux 2008).

### 8.5.2 Reliability

At first glance, it seems that reliability is a clear winner among other attributes. An example of this is Maier et al (2002) who found that managers are willing to pay six times more for an increase in reliability compared to journey time, although the importance attached to reliability must be addressed in context of each study. According to Bolis and Maggi (2002), reliability was the most important attribute for firms with developed logistics concepts or firms with clients that had developed logistic concepts. Thus, a developed state of logistics was a precursor to the importance attached to reliability.

Norojono and Young (2003) also found reliability to be the most important consideration for shippers but the commodity mix chosen for the study excludes bulk commodities. Inclusion of these products could have resulted in a larger importance attached to cost (Beuthe and Bouffieux 2008). Shippers transporting products such as parts or components essential for the smooth running of production in manufacturing companies also value reliability highly, as a delay in delivery could effectively halt production. It is no surprise then that Danielis et al (2005) found reliability to be a key attribute for Italian manufacturing companies.

Beuthe and Bouffieux (2008) explain this on the basis that the relative importance and the value that a transport manager may give to the quality attributes of a service depends on many factors, including:

- Type and value of goods: Danielis et al (2005) and Beuthe and Bouffieux (2008) found that shippers of bulk commodities such as metals are very cost sensitive while shippers of minerals, fertilisers and agricultural products prefer quality attributes over cost.
- Distance and time of transport: Beuthe and Bouffieux (2008) found cost to be the most important attribute over short and long-distance hauls and only over intermediate distances did shippers showed any interest in quality attributes.
- Internal and external logistics of the firms and the configuration of the network.

The large variations in numbers between studies has also been explained by Swait (2001) which states that many studies do not define cut-offs for attributes and suffer from high estimates. Swait believes that not considering a cut-off can alter a shipper's freight mode choice and result in parameter bias. Thus, it is extremely difficult to compare studies by different researchers in different countries.

By definition, reliability refers to the arrival of goods on time with minimal loss. Thus, we would expect to find a direct and stable relationship between reliability and journey time. However, due to a different mix of commodities, different methodologies of computing values of attributes and different shipper preferences in various countries, it is impossible to find a consensus among authors on the relationship between these two attributes. Transek in its 1990 study found the importance of reliability to shippers was three times the value of freight time. However, in its 1992 study, Transek found the relation to be double that ( $6 \times \text{time} = \text{reliability}$ ). No clear reason has been given for this difference. This differs from Small et al (1999) who found reliability to be  $2 \times \text{time}$ , and Maier et al (2002) who found the relation to be  $7 \times \text{time}$ .

In addition to the problems in comparing the studies mentioned above, another reason could be due to the different definitions of reliability used by different authors as we notice when we compare the Transek study (1990) and Small et al (1999) study (refer to appendix B).

### 8.5.3 Inventory, consignment size and frequency factors

Combes (2010) questions the approach to mode choice as purely a comparison of the transport attributes of cost, time reliability, damage etc, noting that freight mode choice modelling has not been notably successful and that there may be other decision processes at work. He discusses the influences of inventory holdings on firms' choice of quantity, timing and mode of supply, arguing from the viewpoint that both suppliers and buyers will include the inventory holding cost of the products, the fixed and variable costs of a consignment, and the risk of stock-outs due to shipment delays. Ideally firms will try to closely manage their stockholdings to a minimum and match purchases with sales or processing of the inventory. Windisch et al (2010) make similar points, noting that freight models seldom incorporate logistics choices in a sufficiently disaggregated and realistic way. In particular mode and shipment size are now recognised to be simultaneous rather than sequential choice. Windisch et al (2010) present a disaggregate choice model based on Swedish national freight data that takes account of multiple legs in the transport chain, consignment size/delivery frequency, and logistics cost components including those at transport terminals. Kraemer et al (2010) developed a model also incorporating frequency and consignment size for German data, but using a numerical simulation modelling approach.

### 8.5.4 Freight condition

Freight damage or loss is secondary to reliability but of similar importance to time and cost and clearly will have a different significance for a bulk commodity than for a customised or irreplaceable item, and will have consequences in terms of lost opportunity and value in a similar way to late delivery.

### 8.5.5 Conclusion

It is clear from this review that studies on freight mode choice cannot be directly compared. The inherent differences in the models and inputs make it extremely difficult to reach a consensus. The results of these studies are variable and cannot readily be interpreted in a New Zealand context.

There therefore appears to be a strong case for New Zealand-based freight mode choice research to be undertaken to gain better understanding of shipper preferences in the New Zealand context, and to better understand how mode choice elasticities vary by tonnes, tonne-km, vehicle-km or the modal share (and short versus long run, distance).

## 9 Priorities for future research

### 9.1 Targeted approach

The discussion on market segmentation and the concepts of, and approaches to, reliability between passenger transport and freight and between private and public passenger transport leads us to the conclusion that there are as many differences as commonalities in the subject areas of the research. Also, the research scope under an omnibus project is very broad, with many specific areas that could be pursued, and in our view would be more manageable if compartmentalised within an overall framework.

We see three main divisions in planning future research:

- Reliability in general road traffic – common to private transport and buses in the general traffic stream, and road freight. This area includes interventions to reduce variability of travel time in general traffic flow and/or its impact, and the treatment of reliability in traffic network modelling and evaluation using trip data.
- Reliability in personal transport – the research needs for reliability in personal travel are, in comparison with freight, more closely focused on the theory of reliability valuation, and the identification and evaluation of interventions to improve journey time reliability. The research does not specifically extend to identifying interventions to reduce delay.
- Value of time, reliability and demand elasticity for freight transport – the freight areas of research are more extensive in that they:
  - quantify the impact of delays and identify and evaluate interventions to reduce time delays and improve time reliability
  - develop new freight values of time and reliability for the EEM
  - research freight demand elasticities.

There is also more complexity in freight journey time reliability arising in the production and delivery chain, including linked trips, inter-modal transfers and intermediate storage, whereas reliability for passenger journeys is in most cases confined to within a single trip.

We discuss each of these in turn below.

### 9.2 Reliability in general road traffic

#### 9.2.1 Incorporation of reliability in traffic network modelling

If drivers exhibit an aversion to unreliability, then logically this should be incorporated into traffic network modelling, assuming that drivers have some appreciation of the comparative reliability of alternative routes and travel at alternative times of day (such as commuting before or after the peak to avoid unreliable travel time as well as congestion delay). However, the review concludes that reliability has not so far been successfully incorporated into the assignment stage of the staged traffic model commonly used in the main New Zealand urban centres; nor has route reliability been fed back into the earlier model stages. How drivers perceive the reliability of routes when planning their trip is another point at issue and standard static modelling does not allow for drivers to vary their route in response to congestion encountered or advance information obtained after the trip has commenced. Also, the equilibrium assignment commonly used in route choice modelling is not easily extended to include travel time variability.



Dynamic multi-period models (ie within-day dynamic traffic assignment incorporating travel time variability) and micro-simulation approaches may be better at handling reliability. However, for multi-period models this introduces the problem of non-additivity across links, and the problem that a route may cross several time periods. Consequently, both calibration and validation would be more difficult. For micro-simulation models, relatively few of these deal with route choice consistently, and where they do it may not be in a way consistent with the reliability-ratio approach. Also, micro-simulation models often capture very different kinds of variation, but omit the ones identified above.

These questions are currently being addressed internationally and some papers have already exist covering this topic. However, it will probably take some years to resolve.

### 9.2.2 Improving the EEM procedure for estimating and evaluating changes in day-to-day journey time variability, with emphasis on traffic networks.

The EEM links reliability with degree of saturation for characteristic link and intersection v/c relationships commonly used in New Zealand traffic network modelling, so that a change in capacity in a part of the network can then be associated with a change in journey time reliability for trips passing through it. The function linking reliability with v/c was calibrated using the day-to-day variation in traffic flow volumes for the flow period in question, which were advised to show standard deviations of 3% or 4% depending on link type and urban/rural location. Some further work to confirm and further detail these numbers may be useful as it is not clear how robust they are or how they were obtained.

Reliability of travel between an origin/destination pair is obtained by aggregating the reliability of consecutive trip segments using the sum of squares of the individual segment travel time variances. While this assumes no correlation between variability on consecutive trip segments, a condition that several commentators show to be unlikely, it is not clear to what extent this approximation leads to significant errors in the estimates of reliability. An alternative approach could be that used in the UK where an empirical relationship has been derived for reliability based upon distance and average speed for trip data using a dataset of probe vehicle runs; something similar could be done using the congestion monitoring data collected in New Zealand. However, there are definite advantages in being able to use link and intersection data along a route to estimate route reliability, since changes are likely to be specified on a link and intersection basis and network modelling is also based on this disaggregate data. So we need robust adjustment factors for estimating the change in trip time variability, given estimates of the changes in variability for parts of the trip. A way forward may be to develop a modification to the existing EEM procedure that uses parts of the UK approach to ensure that variability is not exaggerated when aggregating segment data to trip data but which still allows link and intersection travel time variability to be incorporated.

### 9.2.3 Identifying interventions to reduce day-to-day unreliability and its impacts in general traffic

The EEM procedures and advice are geared to evaluating changes to traffic network capacity or demand which reduce delay and in the process improve reliability. Possible interventions can be broadly categorised into those that:

- increase road capacity through additional road space
- maintain existing road space but, within this, increase capacity and reduce travel time variability
- smooth traffic flow to reduce travel time variability at a constant level of demand flow
- reduce the demand flow (traffic demand management or TDM).

In regard to the first of these, building additional capacity, Wallis (2009) reviewed the evidence for road building reducing congestion. The research broadly confirmed that additional road space does lead to reduced congestion although, in the larger more congested cities, this is partly offset by induced demand. They concluded that parallel investment in both road capacity and public transport helps maintain the balance between use of modes and should be favoured over an either/or approach to road building and public transport. However, there are recognised ‘limits to growth’ for road building, an observation that was clearly made as far back as Buchanan (1963) in *Traffic in towns* who reached the conclusion that universal car ownership and use in cities could only be accommodated by layering development or by massive conversion of building land and open space into roadways, solutions regarded as unacceptable. It was not considered the purpose of this research to revisit road building, in terms of new and enlarged links, as a means of reducing congestion and hence reliability.

Similarly, TDM to reduce travel demand is a broad subject that has received a lot of attention in recent years. One of the main tools of TDM is road pricing which can be applied in various forms such as route and cordon tolls and area pricing. Travel time variability starts to increase at a lower level of traffic intensity than does travel time itself, so introducing a value for reliability into models of road pricing could affect the pricing structure deemed to be optimal. However road pricing is also large subject which has received a lot of attention in recent years and we doubt that it was an expected focus when this research was conceived.

This leaves the other two types of intervention which we suggest be continued in future research:

- 1 Extracting additional capacity out of existing road corridors such as by narrowing traffic lanes, or by allowing hard shoulder running in some controlled situations – this relies on travel time variability decreasing with decreasing congestion
- 2 Through active control of traffic flow at high traffic volume to dampen the flow instability that arises near the capacity point exhibiting as short period fluctuation in demand volume, causing speed and headway fluctuation. Ramp metering is an example, others are interventions to influence driver headways (eg chevron markings as used on high-volume UK arterials), VMS speed and lane changing controls. There is also the future prospect of vehicle self-guidance systems, which have been at a development stage for some years. These would allow operation in short headway platoons, increasing the effective link capacity, although we do not suggest more than keeping a watch on developments in this area.

Having identified and investigated the effect of interventions on reliability, the next step is to incorporate the findings into the EEM evaluation procedures. Two methods can be considered:

- 1 Modify the v/c relationship of the road segment to increase the peak capacity and/or maintain traffic speed closer to the capacity point
- 2 Alter the variance of the day-to-day flows used to calibrate the reliability relationship, for example an intervention might reduce the standard deviation from 3% to 2%.

In either case, the manner in which the variance of flow rates is calculated needs to be considered.

Apart from interventions being more focused on commuter peaks than on other periods, there is no differentiation by commuter/other trip purpose.

In these areas we suggest that some more detailed review of current practice and developments could be made, engaging the main public and private sector players, before deciding on what further work may be researched.

There is the related question of the extent to which interventions can reduce the cost of unreliability, if even the physical performance of the transport system is unchanged. As described in the review, information

channels are increasingly being made available to travellers on the current state of network congestion and predicted journey times for both private and public transport for both urban and long distance travel. As these systems improve they should also be able to offer an estimate of the uncertainty in the predictions being made. This information enables users to mitigate their trip time costs by avoiding unproductive waiting time, allows them to reschedule dependent activities and to lessen the costs of unplanned lateness. Whether traveller information reduces the reliability ratio (value of reliability/value of time) is not an area that appears to have been researched (see also under public transport).

#### 9.2.4 Interventions to reduce incident-related unreliability and its impacts on motorways and arterial roads

Delays due to traffic incidents are currently excluded from the evaluation procedures and so tend not to be included in project assessment. Koorey et al (2008) carried out exploratory research on incident modelling (micro-simulation was preferred) and made observations on the use of SCATS as an incident management tool. Further research was recommended.

There are three aspects that could be subjects of future research

- 1 Incident detection and response using ITS incorporating SCATS because of its predominance in New Zealand and quantifying the potential for, and value of, reliability savings, possibly including micro-simulation modelling; there is also some cross-over between use of ITS for incident detection and use in day-to-day management of travel time variability
- 2 Incident detection, response and management on rural and peri-urban highways for crash, spillage, flood and slip incidents and the evaluation of the potential savings
- 3 The use of mobile communications and IT for real-time communication of network conditions and route selection.

The first of these is a large area in its own right and research on it is at an advanced stage at Canterbury University. Again, it was probably not part of the research focus as originally conceived, but further research in this area should be considered once the Canterbury results are published. Similarly, the second area ties in with a body of research and application of risk management in the national road networks. The third area is primarily an area of private sector commercial development and future research should keep abreast of developments and make available its real-time information on the network to third parties; in turn third parties are independently monitoring the network state through crowd-sourcing applications.

In these three areas we suggest that some more detailed review of current practice and developments could be made, engaging the main public and private sector players, before deciding on further research.

### 9.3 Reliability in personal transport

#### 9.3.1 Theoretical framework

The theoretical underpinning of reliability valuation for personal travel can be considered a specific area of research. While the delay variance and the schedule delay approaches are respectively suited to private vehicle and public passenger transport, research is trying to reconcile the two approaches into a consistent framework that can be applied to private transport, timetabled public transport and headway-specified public transport. This is an area where there is continuing overseas research and, in view of limited research budgets, it may be advisable to monitor continuing theoretical developments rather than add to an already crowded field.

### 9.3.2 Value of reliability between commuting versus other purpose

There is already some differentiation in the value of journey time reliability between commuters and other trip purposes reflected in the different values of time applied to each. The time values have a research origin as willingness-to-pay values from SP studies for both private and public transport. Drawing a distinction between commuters and other trip purposes when researching values for reliability implies some expectation that there is a difference that stems from more than just the recognised differences in value of time. New Zealand research (Beca et al 2002a), included delay, congestion and reliability in a SP study but with results judged insufficiently conclusive to be used, including differences between commuting and other trip purpose that were not straightforward to rationalise; consequently practice fell back on overseas results available at the time. Since then there has been some limited research (such as in Australia) to indicate differences in the value of reliability between commuters and other trip purpose, although less difference in the reliability ratios. In assigning the future research priorities, it is perhaps debatable whether the return on research effort in trying to distinguish separate values of reliability for commuters and other trip purposes will be worthwhile. This work would certainly require a SP experimental approach and some care in dealing with the several trip purposes that make up 'other' which may well have differing values of reliability as they do differing values of time. There are also known differences in the value of time for formally (ie officially) employed people, who have more daily time constraints, compared with students and the retired, which will probably also be reflected in values of reliability. Not all of the factors that contribute to different perceived value of time are incorporated into the EEM evaluation process, partly for equity reasons. Unless there is an appetite for a relatively large SP study to differentiate commuting and other purpose, we suggest that research would be more usefully focused elsewhere.

### 9.3.3 Value of reliability and interventions to reduce unreliability and/or its impacts for tourism trip purpose

Tourism is a relatively small contributor to 'other' trip purpose, composed of several subsets and various definitions. Transport planning datasets and definitions do not align well with those used in the tourism industry and Government statistics on tourism. Inbound international tourism appears to be the focus of Government's interest in pursuing research on journey time reliability. Three subdivisions of inbound international tourism are suggested where journey time reliability is potentially of importance:

- access trips to international travel, mainly by air, where arguably reliability is of greater than average importance to all outbound travellers not just tourists
- tourism operators, principally tourist coaches on long-distance sightseeing routes where adherence to a schedule is important to the operator in the first instance – although there is no obvious reason why tourism operators should place a value on reliability substantially higher than other commercial bus and freight operators
- self-drive inbound international tourists exploring New Zealand attractions, mainly longer distance, although intuitively values of journey time reliability are likely to be lower than those for more regular and time-bound travellers because of lack of familiarity and lesser time constraints, and their contribution to the traffic stream in any case is very small.

We suggest that the most useful ongoing research will lie with:

- package tourism and excursion bus operators who rely on being able to maintain a schedule to deliver the promised visitor experience; inter-urban route bus operators could also be included as they also have scheduling targets to meet

- airport access trips, where it has long been thought that travel time and/or reliability has a higher value than the norm, and where investment to provide less congested and more time consistent access would be desirable, coupled with real-time information on current traffic conditions and access times; again it may be useful to widen the study beyond purely tourism to departing airport passengers in visitor and business categories and include tourists and New Zealand residents.

While the government's interest appears to be in international tourism, in the larger domestic tourism sector the recreational traveller experiences travel delays during holiday peaks on the outlets to the main urban centres and on certain rural highways. Difficulty in accessing New Zealand holiday destinations may influence the decision on whether to holiday in New Zealand or instead to make short international visits to Australia and the Pacific. There has been no attempt to elicit a separate value of time for this group of domestic recreational travellers and any study would need to include both the value of time saving and the value of travel time variability. To be able to apply the results would also require an estimate of the recreational travel component in the traffic stream. In order to definitively distinguish between recreational and other trip purposes, such a study would need to sample both groups under similar road and traffic conditions.

#### 9.3.4 Interventions to reduce unreliability and/or its impact for public transport passengers (apart from general road traffic reliability)

There has been some research for the Transport Agency on (bus) public transport service reliability and intervention measures (Wallis 2011), although mainly from the viewpoint of improving bus adherence to timetable and actions lying with the bus operator. Improving punctuality to schedule is treated as a measurable proxy for improving reliability for bus passengers although these are not quite the same. Alternatives to a strict focus on bus punctuality in favour of evening out bus headways may be preferable from a passenger viewpoint even if contradicted by performance measures placed on bus operators and these have been considered from a theoretical perspective and with at least one practical demonstration (Daganzo and Pilachowski 2009, Bartholdi and Eisenstein 2012).

As well as interventions by bus operators to improve bus reliability, there are measures that can be taken by the road controlling authority to selectively improve reliability for urban bus services, where the range of bus priority measures bring both time saving and reliability benefits. Again, bus priority is a well-researched topic in its own right and probably not the intended focus of this research. There are a number of before and after studies of bus priority schemes that demonstrate improvements to punctuality once signal pre-emption and bus lanes have been implemented.

For the two rail suburban services, Auckland and Wellington, unreliability causes and improvement measures will be very system specific, and in large part incident-related including equipment failures as well as external causes. The operators have the responsibility and should have motivation for improving the service provided. Investigating this area in further detail, including the dynamics of the relationship between the public agency, KiwiRail and the operator and the contractual responsibilities, penalties and incentives lying with each party, was not an intended part of this research.

As with private transport, there is also the question of how the impact of unreliability can be mitigated through reducing the cost consequences to the traveller, for example through better real-time information on public transport arrivals and predicted journey times. The literature on advanced traveller information systems (ATIS) includes some qualitative analysis of traveller benefits but little in the way of user cost saving estimation and evaluation frameworks. Reduced impact (cost) of unreliability could be an unmeasured benefit of real-time information systems in both public and private transport and a useful niche area for research.

## 9.4 Reliability, value of time and demand elasticity for freight

### 9.4.1 Value of time for freight in economic evaluation

Government agencies that include values of time for commercial vehicles in their economic appraisal procedures have mainly adopted a cost savings approach, costing the driver's time as wages plus employers' costs and in some cases the redeployment value of the saved vehicle time (as in New Zealand in the EEM). In some cases the value of freight time has been ignored, or acknowledged but considered minor by comparison and attaching only to high-value, time-sensitive freight. This is the case in New Zealand, a very rough estimate of freight value of time had been made which indicated the value to be small in comparison to time-related costs of the driver, other occupants and the vehicle.

In recent years there have been a number of SP studies to elicit values of time saving for freight, with freight commodities, full or part load, hired transport/own account and urban or long-distance delivery being ways in which freight markets have been segmented. Indeed, due to the complexity and variation in freight logistics with industry type and freight arrangements, it is difficult to see how a cost-saving approach could be feasible. Some of these studies have attempted to jointly elicit values for predictable delay (value of time) and unpredictable delay (reliability). Studies have recognised that different parties to the freight task perceive different aspects of value – the transport operator sees the driver and vehicle deployment costs while the shipper only sees the value of freight delay. Only where shipper and operator are the same will both sets of costs be perceived and then it may still depend on who within the company is interviewed. There are also difficulties in using a SP approach for driver and vehicle time in that the opportunities for increasing productivity may not be immediately obvious and may accrue incrementally over time and across many small infrastructure improvements as firms gradually rearrange their operations to best fit the transport network. However, this still leaves the issue of whether or to what degree to scale down driver and vehicle time savings for less than fully productive redeployment.

For the EEM, the present method of estimating the driver and vehicle cost components continues to be appropriate, although the calculations need updating and matters such as the proportion of time and use-based depreciation should be reviewed. An important adjustment to these values is a factor or factors to reflect that only part of the time savings are likely to be efficiently redeployed in additional vehicle and driver productivity. No recent studies on this particular point have been identified in the literature and this may warrant specific market research.

Existing overseas studies of the value of freight time and reliability may be sufficient to develop interim advice on values for use in the EEM. However this will desirably be followed up with a SP study that targets freight shippers using hired transport services and which covers low-value bulk, medium-value general freight and high-value time-sensitive freight, and which jointly seeks responses on the value of predictable and unpredictable delay. How unpredictable delay is described in the survey will require careful consideration, as will the way that cost is included as a choice variable. Some accompanying work will be needed to establish the relative size and composition of each of the high, medium and low-value/time-sensitive market segments so that the resulting values can be appropriately weighted. Our expectation is that while high values of time and particularly reliability will be found for high-value/highly time-sensitive freight, in practice this will form a very small percentage of the freight traffic stream.

### 9.4.2 Identifying, quantifying and mitigating the impact of time delays to freight

The review has described the nature of predictable (time losses) and unpredictable (reliability) delays in freight systems and has presented the results of studies that have attempted to quantify types of delay and rank their importance in relation to freight costs and other service characteristics. The review confirms that achieving reliable delivery time is as important as saving on the expected delivery time and that competitive pressures on industry have encouraged firms to operate lean inventories and to move to manufacturing and delivering to order, reducing the working capital for stock holding. The more reliable and faster the transport system becomes the more firms will take advantage of this to reduce costs and become more competitive. If the transport system is unreliable and slow, then firms must compensate by holding extra stock. Firms will also optimise the frequency of orders and consignment size to suit the performance of the transport system. There is good reason to expect that faster and more reliable delivery and reduced delays at intermediate transshipment points will translate into useful economic gains on both the domestic and import/export market.

Urban traffic congestion, including congestion local to freight hubs such as port access routes usually through mixing of urban peak commuter and road freight traffic, is the most frequently reported source of delay and unreliability to road freight. On longer distance routes, unforeseen delays due to incidents rather than congestion appear to be the main concern, including traffic incidents, road works and weather-related events; rail is similarly affected. These are largely covered in focus areas under section 9.2, although the question of developing and maintaining uncongested and reliable access to freight transfer terminals may need specific attention.

Factors contributing to freight delay other than road conditions are either within the control of the enterprises generating the freight demand, and essentially their responsibility to solve, are at other freight transfer points (rail, port, airport terminals and road cross-docking hubs) or are on other freight modes (rail, inter-island ferry, coastal and international shipping, domestic and international air freight). The strategy of some larger New Zealand producers reliant on distribution networks internal to New Zealand and for export sales has been to take control as far as possible of the distribution operation, to the extent of directly chartering specialised shipping so that transport to market is as free as possible from external disruption. However, this solution is not available to smaller firms.

The main commercial ports are using ITC to more efficiently control goods handling, particularly containers, within the port area and are making use of booking systems to limit congestion at the landside pick-up/delivery points. Electronic tagging and tracing of consignments is now used extensively for internal management and customer information. Nevertheless, queuing delays at road freight reception points still occur for various reasons. Efficiencies in freight handling allows exporters to consign shipments closer to sailing times; however, 'slow steaming' practices (ie the practice of operating ships at less than their maximum speed to save money on fuel) and changes to shipping services can easily negate these time savings and are outside the control of all except the largest shippers.

The development of off-wharf storage terminals, notably by Ports of Auckland, in response to portside land constraints, adds an extra transport link into the chain but does allow some consignees to avoid urban congestion. The overall effect on freight delays and reliability is not clear. Some delays arise from document flows and approval processes being started too late or not keeping up with the physical movement of freight moving across the border, particularly on entry. LCL shipments requiring deconsolidation off-wharf and authorities for movements to inland terminals add complexity and can be a source of delay, although the overall significance is hard to judge.

As well as slow steaming, there is also a debate on the need to consolidate New Zealand's international seaports, on port ownership reform, on international shipping company consolidation, what this all means for inland road and rail freight routes and how to best ensure that New Zealand does not become a spoke on Asian or Australian port hubs (or more so), with the loss of direct transport links that this implies. Fortunately, New Zealand is still well served with international shipping connections, although this could change. There have already been some constraints on capacity for air freight exports.

At an urban delivery level, urban centres established in the first half of the 20th century require an accommodation between trucks and passenger vehicles, non-motorised transport, pedestrians, residential and other sensitive land uses. This accommodation involves a mix of planning, environmental and safety controls, building and road network design to balance the interests of businesses receiving and despatching freight with others in the community. Minimising freight delays and costs will only be one of many criteria in balancing the objectives of all parties.

In suggesting a way forward for useful research, we note that commercially driven firms and central or local government owned commercial enterprises have an inbuilt competitive incentive towards operational efficiency except where they are in a position of market dominance through removal of competition or regulatory privilege and can extract monopoly rent. They are aware as anyone of opportunities to improve efficiency and have the best internal knowledge of their business on which to base decisions; also some of this information will be commercially sensitive and not obvious to external parties. While there are various published case studies from conference material and firms' publicity that could be used to prepare some form of best practice guide, this has to some extent already been done (eg Environment Canterbury 2005) and solutions are in any case very tailored to each firm's business, size and structure which would make any recommendations very general.

We suggest that continuing research should focus on the interface between the public and private sectors, where policy, regulation and investment by central and local government can assist in removing unnecessary barriers to make freight movements more reliable and less subject to delay. Making the network of inter-urban road freight routes less subject to delay from congestion and incidents seems the most effective way for the government to intervene. To some extent, ensuring that appropriate parameter values and methods are used in evaluating investment will assist. Similar considerations apply to rail, which largely serves freight. Improving transit times on the core long-distance rail routes through infrastructure and operational improvements, reducing the risk of delays from incidents and improving inter-modal transfer efficiencies are all objectives that KiwiRail has already incorporated in its business plan. Ensuring that the evaluation of the investment in publicly provided road and rail infrastructure is satisfactorily integrated is clearly an important component, so that incremental improvements to (or disinvestment from) certain lower traffic rail lines are made on a freight corridor basis from a national economic viewpoint, and take account of wider transport network effects, rather than being seen as separate business decisions by the Transport Agency and KiwiRail. However, we doubt that it is the intent of this research project to comment on these matters.

### 9.4.3 Freight demand elasticities by mode, level of service and other factors

The review of freight demand elasticities indicates that whole of market freight elasticities can be expected to be low, as freight cost is only a small proportion of market price, but are likely to be slightly higher in the long run as market adjustments are made to source products more locally. There seem few obvious reasons to further research whole of freight market or captive mode demand elasticities.

Most studies focus on freight mode competition between road and rail (and occasionally sea or air) and this is where practical interest in applying demand elasticities is likely to lie either for demand modelling or policy



analysis purposes. However, little can be usefully applied from the international literature as insufficient information is presented on the starting modal market shares and how tightly the studies have defined contestable freight markets. As indicated in this review several factors other than cost are influential in mode choice where there is genuine contestability, so price elasticities on their own are not very informative.

Elasticities derive from underlying transport choice models where the influence of each factor forms part of a generalised cost or utility function. The review has shown that reliability of on-time delivery is an important variable, as much as or more so than the freight charge in many cases. Other factors contributing to the choice decision are delivery time, frequency, consignment size and consignment damage. The review has also shown that an understanding of the interaction between inventory holding costs, transport costs and other logistics costs is needed to form a realistic mode choice model and that this will likely require a highly disaggregate approach, possibly down to enterprise level.

A better understanding of the relative importance of each factor in decision-making by New Zealand firms will be useful for the planning of road, rail and seaport development, where issues such as investment or disinvestment in certain rail lines, and the role of various ports, their specialisation and size of their inland catchment are in question. From this point of view the previous focus area of identifying and quantifying freight delays links in as a precursor. Until there is a qualitative understanding of the freight system it will not be possible to produce any useful quantitative data such as values for choice parameters in modelling and their corresponding demand elasticities.

We do not see any benefit in a more detailed attempt to meta-analyse international findings on demand elasticities. It will be more beneficial to recognise the advances in freight choice modelling in international practice and apply this knowledge to some useful New Zealand case studies where there is contestability between road and rail, possibly where the continuation of rail service is currently in doubt; examples are the East Coast (Gisborne) rail line (currently cut and costly to reinstate) or the continuation of service of the North Auckland line.

## 9.5 Prioritising future research

The foregoing discussion has identified many lines of future research and we present a comparative assessment of each topic using the following six criteria:

- 1 Importance of knowledge gap - in either preventing the application of potentially useful new methods or improving the quality of information applied
- 2 Size of each market segment addressed by a research initiative – larger segments and those with potentially larger gains to be made should be prioritised over those that are smaller and/or where gains are likely to be relatively small
- 3 How New Zealand-specific the gaps are – those less able to be filled by adopting and adapting existing or future overseas research should carry a higher priority
- 4 Chance of success – the probability of achieving useful results
- 5 Intended research focus – whether the topic is considered part of the intended research focus or has been/is being researched under other Transport Agency projects or by others
- 6 Research cost - in view of constrained research budgets, the relative costs of items of research and; in this regard market surveys form a potentially large cost.

Table 9.1 provides an assessment of the potential focus areas for ongoing research using these criteria. We have rated each topic A, B, C for high, medium and low under each of the criteria, with corresponding

'scores' of 1, 2, 3. A combined rating of high, medium or low priority has been assigned to each area of research using the product of the individual scores for the first five criteria divided by cost to give a rough proxy benefit-cost ratio.

Against this combined rating are proposed actions of include, exclude and explore, assigned as follows:

- The high-rated areas are recommended to have first priority on research resources and are labelled as 'included'.
- Some of the medium priority areas are labelled as 'explore' meaning that they warrant some further more detailed review including discussions with the transport industry, local and central government and more work on establishing the market size in some cases.
- Some other medium priority and all low priority are marked as 'excluded', meaning that either the combination of knowledge gap, market size and cost/risk/reward of the research is insufficient, or that the area of research is more likely to be advanced internationally and New Zealand should wait on progress.

**Table 9.1 Assessment of ongoing research focus areas**

	Importance of knowledge gap	Size of market segment	Specific to NZ context	Chance of success	Research focus	Indicative Cost A=High	Overall Rating	Action
<b>General Road Traffic Flow</b>								
Incorporation of reliability in traffic network modelling :								
in network assignment and staged models generally	B	A	C	C	A	A	Low	exclude
improving the EEM procedure for reliability evaluation	A	B	A	A	A	B	High	include
Identifying and evaluating interventions for DTDV that								
rely on new, widened or upgrading roads	C	A	C	B	C	C	Low	exclude
increase capacity & reduce JTV, including incidents, on existing arterials	B	A	B	B	B	B	Medium	explore
rely on traffic demand management (e.g. road pricing)	B	A	C	B	C	B	Low	exclude
<b>Reliability in Personal Transport</b>								
Further developing the theoretical framework								
Value of reliability between commuting versus other purpose	C	A	C	C	A	A	Low	exclude
Value of reliability and interventions for tourist trip purpose :								
Package tourism, excursion and route bus reliability	B	B	A	B	A	A	Medium	explore
Airport outbound passenger trip reliability/VOT	B	B	B	B	A	A	Medium	explore
Domestic recreational travel on congested rural arterials	B	A	B	B	B	A	Medium	exclude
Interventions to reduce unreliability and/or its impact for PT passengers								
Regularising bus headways to improve reliability	B	A	B	B	B	B	Medium	explore
Bus priority measures to improve reliability	C	A	C	B	C	B	Low	exclude
Operator/public agency interaction	B	A	B	B	C	B	Medium	exclude
ATIS to improve reliability and reduce its impact	A	A	B	B	B	B	High	explore
<b>Delay and Reliability for Freight</b>								
Value of time for road freight transport in economic evaluation (EEM) :								
Review/revise framework and values of vehicle and driver time	A	A	A	B	A	B	High	include
Establish size of freight market segments for VOT/reliability	A	A	B	B	A	B	High	include
VOT/reliability for freight using SP surveys	B	B	B	B	A	A	Medium	explore
Identifying, quantifying and mitigating the impact of time delays to freight :								
Improving reliability and reducing delays at freight terminals	B	A	A	B	B	B	High	include
Freight delay reduction measures on strategic freight networks	B	A	B	B	A	B	High	include
Evaluating the role of inland ports in freight reliability	B	A	A	B	B	B	High	include
Rationalisation of NZ import/export ports	B	A	A	C	C	A	Low	exclude
Balancing competing demands in local freight delivery	B	A	B	B	C	B	Medium	explore
Freight demand elasticities by mode, LOS and other factors								
Meta-analysis of overseas elasticity study findings	C	A	C	C	B	C	Low	exclude
Whole of freight market demand elasticity study	B	A	B	B	B	B	Medium	exclude
Freight mode choice parameter values for disaggregate modelling	B	B	A	B	A	A	Medium	explore

# 10 A proposed future research programme

The higher priority focus areas from table 9.1 have been taken forward into a programme of work, with topics listed in assessed order of priority and some topics grouped together. The resulting programme is shown in table 10.1 and the content of each stage is described in the following paragraphs.

**Table 10.1 Proposed ongoing research topics and tentative schedule**

Research Area and Milestones		Estimated Time Period, months														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Review the EEM reliability procedure:															
1a	Analyse existing survey data	■	■													
1b	Development of a revised procedure for private vehicles				■	■										
1c	Add a procedure for public transport (bus)							■	■							
2	Review EEM values of CV and driver time:															
2a	Update CV replacement values, kms/year & depreciation	■	■													
2b	Driver costs, hours/year, use of time saved, survey design/test				■	■										
2c	Main survey, analysis and report							■	■	■						
3	Freight time and reliability, values and elasticities															
3a	Roadside freight and operator surveys															
3a1	- roadside survey design and pilot	■	■													
3a2	- freight operator enquiries				■	■										
3a3	- review official data and sample expansion method							■	■							
3a4	- main survey and analysis									■	■	■				
3b	Stated preference surveys of freight shippers/operators															
3b1	- industry approaches and development of sample frame		■	■												
3b2	- preliminary industry surveys				■	■										
3b3	- SP survey piloting							■	■							
3b4	- main SP survey and analysis										■	■	■			
3b5	- Derivation of perceived values and demand elasticities														■	
3d	Derivation of values of freight time for EEM															
3d1	- Interim freight values											■				
3d2	- Final freight values															■
4	Interventions to improve reliability and reduce its impact:															
4a1	Explore the range of interventions in general road traffic	■	■													
4a2	Assess their potential contribution				■	■										
4b1	Review of active management of bus regularity							■	■							
4c1	Use of ATIS to improve reliability and reduce its impact										■	■				
4d1	Measures to mitigate delay on strategic freight routes														■	■
5	Value of reliability in tourism:															
5a	Value of reliability for tour buses															
5a1	Initial discussion with representative operators	■														
5a2	Develop a sample frame and estimate market size		■													
5a3	Design and pilot an exploratory survey				■	■										
5a4	Execute the main survey analyse and report results							■	■	■						
5b	Value of reliability for airport access															
5b1	Traffic composition on airport access routes		■													
5b2	Initial scoping passenger survey				■	■										
5b3	Main passenger survey and analysis							■	■	■						

## 10.1 Review the EEM procedure for evaluating reliability

At present the EEM links reliability with the degree of saturation for characteristic link and intersection v/c relationships commonly used in New Zealand traffic network modelling, so that a change in capacity in a

part of the network can then be associated with a change in journey time reliability for trips passing through it. The function linking reliability with v/c was calibrated using the day-to-day variation in traffic flow volumes for the flow period in question. This showed standard deviations of 3% or 4% depending on link type and urban/rural location. Some further work to confirm and further detail these numbers may be useful as it is not clear how robust they are or how they were obtained.

Reliability of travel between an origin/destination pair is obtained by aggregating the reliability of consecutive trip segments using the sum of squares of the individual segment travel time variances. While this assumes no correlation between variability on consecutive trip segments, a condition that several commentators show to be unlikely, it is not clear to what extent this approximation leads to significant errors in the estimates of reliability. An alternative approach could be that used in the UK where an empirical relationship has been derived for reliability based upon distance and average speed for trip data using a dataset of probe vehicle runs. Something similar could be done using the congestion monitoring data collected in New Zealand. However, there are definite advantages in being able to use link and intersection data along a route to estimate route reliability, since changes are likely to be specified on a link and intersection basis, and network modelling is also based on this disaggregate data. A way forward may be to modify the existing EEM procedure that uses parts of the UK approach to ensure that the benefit of changes in variability for parts of a trip is not exaggerated when aggregating segment data to trip data but which still allows link and intersection travel time variability to be incorporated.

An aim of this research was to review and, if warranted, recommend changes to the present EEM method for evaluating changes in day-to-day journey time variability in a form that could be implemented for embedded road and intersection improvements in an urban network or on sections of open highway.

The proposed milestones are:

- **1a Analysis of existing survey data:** use the raw data from the Transport Agency's congestion monitoring surveys in several urban centres and peri-urban routes, to undertake a comparative analysis to investigate i) whether there is evidence for correlation between travel time variance for adjacent route segments, and ii) compare route travel time variance with the present method of aggregating segment variances. Carry out this analysis for the flow periods for which data has been collected, distinguishing between urban routes and rural highways and explore the effect of varying segment lengths, as there is a wide variation in the segment lengths in the data sets. Also consider the influence of the number of traffic lanes, lane width and, for rural sections, overtaking opportunities.
- **1b Development of a revised procedure:** depending on the results obtained, revise the procedure for evaluating reliability improvements capable of utilising output normally available from network models (origin/destination matrix based or segment volume based) and use this to evaluate the reliability changes from a road improvement project, adjusting for varying travel time variability with trip length, speed and degree of congestion. The revised procedure needs to take account of the varying degree of detail available on the frequency distribution of trip lengths passing through the area of influence of the project. Take account of the pros and cons of the UK method in developing the procedure.
- **1c Addition of a procedure for bus operators and users:** the present EEM procedures apply only to the benefits of improved road service reliability to private vehicle users. There is no provision for applying reliability improvements to the general traffic stream to bus operators and users. We recommend incorporating the findings of Vincent (2008) on the value of reliability for public transport users in the EEM. The application of such a procedure relies on being able to correlate road segment travel time variability with the early/late running of a bus service using the route, which requires

further research. The procedure also provides for service reliability improvements stemming from changes made by the bus operator.

## 10.2 Review EEM values for commercial vehicle and driver time

The literature review confirmed the three additive elements in the resource value of goods vehicle time, the time-related commercial vehicle costs, the time-related driver cost and the freight time value. This part of the work will focus on updating the commercial vehicle and driver time costs based on the already updated vehicle type specifications in the NZVOC model. Information from the Transport Agency indicates that the last time the NZVOC model was fully updated was 2002–03; since then updates have consisted of cost indexing.

It is preferable to fully update the time-based costs in the NZVOC model rather than rely on the indexed values. The vehicle categories will not change but the selected representative vehicles within each category will need to be established from recent sales figures. The 2002–03 NZVOC model update (Data Collection 2003) covered only the distance-based costs. The only common elements of vehicle costs that feed into both the NZVOC model distance-based running costs and values of time are the vehicle replacement cost, the vehicle service life, vehicle annual and lifetime utilisation, and annual utilisation declining with age. The split between distance- and time-based costs is done through apportioning the annual depreciation (see table 3.2). It may be noted that the NZVOC developed for the Transport Agency allows more flexibility in how utilisation and depreciation are treated, and it is important that compatibility be maintained between the vehicle operating cost values, tables and graphs in the EEM and the values of time.

The value of work time savings for goods vehicle drivers was established in Beca Carter Hollings & Ferner et al (2002a) as part of a wider update of EEM parameter values using the marginal labour productivity method. We recommend a repeat of this analysis, which would be relatively straightforward. Vehicle time utilisation appears never to have been reviewed and is a flat 1800 hours/year across all vehicle types which appears to be based on typical firm normal time annual operating hours providing for some downtime. As distance utilisation varies between vehicles and with age, hourly annual utilisation should follow a similar pattern, when divided by the average speed of travel. The average annual utilisation of LCV, MCV, HCV-I and HCV-II is 21, 25, 30 and 38.5 × 10<sup>3</sup> km which at an average network speed in urban areas of, say, 35 km/h yields annual in-travel utilisation of 600 to 1100 hours. So there is clearly a need to investigate time utilisation of goods vehicles more carefully and this can be done in conjunction with an investigation into the productivity of time saved.

At the same time, future research might also consider:

- a review of the distance-based cost elements for all vehicle types
- an analysis of the time values for vehicle types other than goods vehicles.

However, these are not included in the proposed ongoing work.

The milestones proposed in table 10.1 are:

- **2a Update the data on commercial vehicle replacement values, distance utilisation and depreciation:** obtain new commercial vehicle list prices for a representative selection of leading vehicles by sales volume in each NZVOC model category, using the vehicle registration database. Contact vehicle body builders and trailer manufacturers to obtain representative costs for different types of vehicle body and trailer chassis. Obtain an analysis of length of vehicle life from the registration database, based on numbers first registered and numbers remaining at each year of age. For diesel and heavy vehicles, the data held on RUC (access would be required via MoT) should enable an analysis on age and accumulated travel to determine

typical annual utilisation for different classes of vehicle. Obtain conversion factors from financial to economic costs – normally just a discounting of indirect taxes and duties, which in New Zealand is now primarily GST as most other import duties and excise on motor vehicles have been removed. (We propose that the split between age- and use-based depreciation, currently 80%/20% for heavy vehicles and 70%/30% for light vehicles not be revisited due to the difficulty, cost and imprecision of such an exercise<sup>23</sup>. We suggest that the work be limited to assessing the feasibility of such an analysis and commenting upon any recent overseas approaches to this question).

- **2b Driver costs, annual time utilisation and productivity of time saved, survey design and testing** – update driver hourly time values using Statistics NZ wage data with allowances for employers' on-costs as per Beca Carter Hollings & Ferner et al (2002a). Obtaining hours of utilisation and the proportion of saved time likely to be applied to increased vehicle productivity requires a market survey approach to obtain estimates of how different amounts of journey time saving over a working day could be utilised. We envisage that the questions would be phrased to distinguish between unexpected time savings/losses (reliability), predictable regular time savings in the short term (how the existing fleet could be redeployed), and predicted regular time savings in the longer term (with the opportunity to rearrange transport arrangements, locations and fleet structure). Dimensions of the survey will need to include size of fleet, own account versus transport operator, urban/long distance and other segmentation appropriate to the freight market and values of time (for this reason the research on freight market segments should be completed first, see section 10.3.2). A preliminary design should be piloted before reporting back on recommendations for the main survey and analysis. This survey could be conducted in conjunction with the proposed SP survey on value of time/reliability for freight (see section 10.3.3). However, we envisage that this part of the survey could be designed to elicit the required information without the need for a SP experimental design. A RP approach is unlikely to be possible as few suitable before and after survey contexts arise.
- **2c Main survey, analysis and report** – assuming the piloting is successful, the third milestone is the execution of the main survey on the recommended sample size and subsequent analysis. If substantial redesign is required then a second pilot stage could be undertaken.

## 10.3 Freight time and reliability, values and elasticities

### 10.3.1 Introduction

This is the largest of the separate pieces of work and combines the objectives of obtaining freight time and reliability values, extracting the corresponding demand elasticities, and finally adjusting the perceived values to reflect national resource costs to make them suitable for inclusion alongside the values of vehicle and driver time in the EEM procedures. A disaggregate approach is proposed using a utility-maximising model of freight choice combined with SP survey technique.

As discussed, it seems more appropriate to elicit the time and reliability values attached to freight from the shipper rather than the transport operator, as it is the shipper who responds to the end market for use of the

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<sup>23</sup> Overseas findings on the split between age- and use-based depreciation are of little use due to the unusual age structure of the New Zealand vehicle fleet. The values used in New Zealand for commercial vehicles come from Bennett (1985) and rely on access to data on real new vehicle prices and values of resale value, age and accumulated mileage across the age spectrum. This is difficult to obtain and requires some manipulation and matching of available sources, correction for inflation, price margins etc. The result is a fitted relationship of the form  $DEP = k \cdot \text{age}^a \cdot \text{kms}^b$  to the adjusted data, although with a good deal of statistical uncertainty. This then has to be translated into a simple division between age and use-based depreciation that can be applied as an average across the vehicle fleet.

goods and is most likely to be responsive to costs associated with late delivery. The transport operator and other intermediaries are less likely to reflect the shipper's values – indeed the way in which shipping contracts mainly isolate the freight agent from any liability for delays emphasises this point.

The discussion on market segmentation has identified four potential contributors to the value of delay time and value of reliability (see figure 4.5), these being the:

- 1 Pressure on delivery time expressed as the time between placing the order and delivery schedule
- 2 Uniqueness or degree of customisation of the freight (reflecting its substitutability in the event of delay)
- 3 Loss in value of the freight over time (perishability, which can be offset to some extent by additional costs in special handling and climate control)
- 4 Time value of stockholding (and if the stock value is expressed in a common unit of \$ per tonne of the commodity, then a way of converting this is needed to reflect the packaging to give a value per unit of freight such as pallet, container etc).

Unfortunately, this categorisation shows little or no alignment with the somewhat limited statistical data and study information on goods and goods movement. So if these factors are used when designing a study to elicit values, there is no obvious sampling frame or way of expanding sample results to the population. The most common descriptor for freight is commodity and ANZSIC06 is probably the best standard categorisation. However, this categorisation reflects none of the characteristics important to freight time value and reliability, apart from the stock value in some cases. Commodity statistics do not include freight form or consignment size, which are also factors likely to be aligned to time and reliability value.

For road project evaluation purposes the end objective is to apportion values of time and reliability to the standard traffic mixes (urban arterial etc) and time periods used in EEM analysis. At present the typical traffic mix data give a fairly broad categorisation of commercial vehicle size (light, medium, heavy single unit and heavy articulated commercial vehicles). So linking information is needed between time schedule-related freight characteristics and freight vehicle characteristics as observed at the roadside sufficient to apply the time and reliability values obtained from market surveys of freight shipper preferences.

Other countries carry out similar surveys as part of their collection of official statistics and may provide some useful guidance on technique. One of the known difficulties is the use of 'plain packaging' – vehicles carrying no external branding features that allow the goods to be classified, which is now quite common, and general dry goods in containers, van or curtainside bodies that may be full or part truck load and single commodity or mixed goods. Consequently, we suggest checking a sample of these commercial vehicles observed at the roadside to obtain information on unobservable characteristics.

We have therefore included, as a first step, observation of samples of traffic at the roadside, linked to interviews and questionnaires of freight operators to develop linking matrices between freight time and reliability values and observable road traffic. Other potentially useful data sources that may assist in categorising the commercial vehicle fleet are the permanent weigh-in-motion sites which capture axle weight as well as recording axle configuration and length and licence data for RUC.

Section 10.3.2 describes the proposed steps.

Another method that could be considered, and may have a lower cost, is a RP survey amongst shippers collecting data on a number of real shipments to/from the shippers.



### 10.3.2 Roadside and operator surveys of vehicles and freight

- **3a1 Roadside survey design and pilot** – test the feasibility of inspection using roadside video analysis versus manual roadside observation to identify: vehicle type including special vehicle bodies; loaded/empty/part load running; classification into LCV, MCV, HCV-I, HCV-II; freight form – container, palletised, refrigerated, dry and liquid bulk; freight commodity; own account/owner-driver carrier/freight company; freight operator name (for subsequent contact). Review possibilities for using existing fixed cameras on arterial/motorways. Draw up a list of roads and sampling time periods to give sufficient statistical coverage of the EEM categories, including any consideration for special freight routes (such as port and airport access routes).
- **3a2 Freight operator enquiries** – working through the Transport Agency’s freight industry contacts, approach freight operators, including those identified in the roadside sample piloting, to qualitatively identify the factors contributing to reliability value from an operator viewpoint (as opposed to shipper), and also obtain information on freight characteristics not directly observable from roadside survey.
- **3a3 Review official data and sample expansion method** – review other official data sources including Statistics NZ industry sector and business demographic data in relation to the ANZSIC06 classification for quantifying and categorising freight demand for business sectors; review RUC, weight-in-motion and vehicle fleet characterisation data available from MoT and the Transport Agency; also review freight industry sources (RTF, RTAs etc); develop an appropriate sample frame, sampling method and expansion to allow the freight reliability sample data to be mapped against vehicle type and road traffic type.
- **3a4 Main survey and analysis** – once the sampling basis, technique and sample expansion methodology are agreed, carry out the main survey, analyse data and report.

### 10.3.3 Stated preference survey of freight shippers and operators

The second part of this research area will be market research among freight shippers, leading to the design, pilot and execution of a SP survey to elicit values for delay and reliability<sup>24</sup> in relation to other factors influencing freight choice, in particular cost but also damage risk. The first stage is to identify a sample of organisations to give a broad coverage of industry sectors from primary through to service industry, across commodity groups and by degree of time sensitivity. This will require marshalling available data from official sources and extending the data to cover industry groups of particular interest because of more time sensitivity freight movements. To some extent this is covered in item 3a3 above. The mail, courier and express parcel industries, although not originators, carry a proportion of the urgent freight, and it will be useful to obtain some cooperation from within the industry both to identify shippers with urgent time delivery needs and to assist in better quantifying the size of the freight demand at the more time-sensitive end of the spectrum.

The freight contexts to be covered in the market surveys include situations where there is no choice of mode and those where there is modal contestability, chiefly between road, rail and possibly coastal shipping in long distance freight. Where there is modal contestability, the aim is to take a mode-neutral approach, concentrating on the underlying factors that influence freight performance and perception to reduce as far as possible unexplained ‘taste’ preferences for one or other mode.

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<sup>24</sup> Research along similar lines is underway as part of PhD research at Canterbury University and has so far reached the SP survey piloting stage. We would review the applicability of this work for inclusion/adaptation which could reduce the amount of work required and cost.

We envisage the survey will be applied to both shippers of freight and freight operators. In some cases these may be one and the same, but often they will be separate and have different drivers governing their choice behaviour. For example, choice of mode will often be left to the logistics or transport company, rather than be made by the shipper, in which case operational and cost factors of the operator may overshadow the shipper's delivery priorities.

Different approaches to sample identification and selection will be required for freight shippers, road freight operators and road/rail contestable freight:

- For shippers we envisage using either a Statistics NZ sample frame, subject to confidentiality, or alternatively a sample selection from business directories using ANZSIC to guide the size and nature of enterprises selected.
- For road freight operators the road freight industry membership (including logistic companies, large and small transport operators) would form the basis for sample selection.
- In the case of road/rail contestable freight, the first step would be to identify freight types and specific situations in which there is modal contestability to form the basis for sample selection. Initially, MoT and the consultants involved in the freight demands study (Richard Paling Consulting et al 2008) would be contacted to identify any useful lists of shippers using rail. Otherwise, KiwiRail is probably the best-placed organisation to assist with this identification as it will know the road freight markets in which it may be competitive, as well as freight that has recently moved between rail and road so is on the cusp of choice between modes. There may be confidentiality issues in identifying customers that will need to be discussed.

We would then develop a questionnaire to collect all relevant data on the organisations being interviewed to allow classification within the ANZSIC framework and also by enterprise and establishment size, before going on to select freight movements. It may be that an organisation generates several freight movements that are of interest, for example including both internal and export/import freight, raw materials and products, and more and less time sensitive consignments. We envisage that this would be done in at least two stages, the initial stage to develop the questionnaire and techniques, at the same time probing for factors that influence the organisation's view of important factors in freight delivery and the relative importance of travel time and reliability. Once we had amassed sufficient information to characterise the market and the choices being made, we would then proceed to a formal SP experimental design, pilot testing and full survey.

The aim will be to hypothesise and test disaggregate models of freight travel choice combining at the minimum time, cost, reliability but testing for other significant factors (probably a maximum of five variables in any SP choice experiment), with segmentation to include: shipper/operator decision-maker, captive/choice of mode, urban/long-distance/international consignments and freight market segmentation based on the four reliability parameters noted in section 10.3.1. The SP experiment will be based on a realistic choice context that the survey respondents can relate to, for example a recent freight consignment decision, and will face the respondents with pairwise choices between different levels of cost, time, reliability and other factors. The results of the choices made will then be analysed statistically to derive values of time savings/losses, measures of reliability and other factors such as damage risk.

Because of the potential number of variables and ways of segmenting the freight market, it may be necessary to concentrate on one or two of the more important freight contexts when carrying out the full survey, to maintain a manageable and affordable sample size. The resulting perceived values against time, reliability and other factors should be suitable for demand modelling in like situations. Demand elasticities against

freight cost, time, reliability and the other factors will also be directly obtained from the survey results and, likewise, will be applicable over a range of freight contexts similar to those covered in the survey.

The milestones for the above could be:

- **3b1 Industry approaches and development of sample frame** – analyse existing data sources to firm up on the market segmentation and segment sizes; and approach freight industry contacts to identify survey subjects, for the shipper versus freight operator contexts and road and road/rail contestable freight choices.
- **3b2 Preliminary industry surveys** – conduct flexible format interviews with a sample of respondents to obtain classification data and to identify the freight movements undertaken applicable, confirm choice factors and perceptions of time sensitivity (confirm or amend the four factors in 10.3.1 above); develop a design for an SP survey and identify the sample frame and method.
- **3b3 SP survey piloting** – test the survey design on a limited number of subjects, analyse and refine the methodology (note that a second pilot stage could be needed).
- **3b4 Main SP survey application and analysis** – following successful piloting and review of the survey application and analysis methodology, carry out the main survey, data analysis and report results.
- **3b5 Recommend values of freight time, reliability and demand elasticities** – reach conclusions on the perceived values of freight time, reliability and other significant choice factors for demand modelling and the respective freight demand elasticities.

#### 10.3.4 Derivation of values of freight time

- **3c1 Interim freight values** – prepare interim advice on the value of freight time and reliability using existing data sources, the results of the above pilot stages, industry surveys and international literature.
- **3c2 Final freight values** – a similar process using the final output from the SP surveys. Recommend adjustments to the perceived (behavioural) values of time and reliability from the SP surveys to a resource cost basis (net of tax) and apportion them across the standard EEM traffic compositions using the data from the roadside surveys and other official statistics.

### 10.4 Interventions to reduce unreliability and its impacts

The review identified four topic areas that fall into the general category of interventions to reduce unreliability and its impacts:

- 1 Interventions that apply to all road traffic
- 2 A specific intervention for urban bus transport not covered by other research aimed at improving headway regularity
- 3 The application of ATIS to reduce unreliability and its costs
- 4 Measures targeted at reducing freight delay and improving freight reliability on strategic road freight routes.

### 10.4.1 Intervention in general road traffic

This focus area is further exploratory investigation of interventions to improve reliability without increasing the supply of road space or changing overall traffic demand. We combine day-to-day travel time variation and incident-related variation as some of the interventions will be common to both forms of unreliability.

- **4a1 Explore the range of interventions:**
  - Use ITS including vehicle detection, variable message signing and SCATS-linkages, to influence driver behaviour and with some look to the future for automated speed and separation control, primarily on motorways and urban arterials
  - Look for opportunities to increase the utilisation of road space, particularly combined with peak period speed restriction, such as narrower lanes, shoulder running and through 2+1 lane arrangements with wire barrier separation, to increase capacity, lower the v/c ratio and improve reliability
  - Implement incident detection on rural highways and peri-urban roads
  - Mitigate incidents that occur, through the four Rs, 'reduction, readiness, response and recovery', ie reducing the number of incidents (for example vehicle and driver roadworthiness standards, testing and penalties to minimise incidents), being ready to deal with incidents by having pre-agreed procedures and resources to hand (such as rapid crash site investigation procedures), being able to respond quickly, and bringing the system back to normal operating condition as quickly as possible.

We note that adding road space and TDM measures, such as road pricing, have not been included, although they will have a role in improving reliability.

- **4a2 Assess their potential contribution:** look at the overseas experience in further depth and hold discussions with road controlling authorities plus seek input from ITS specialists in the researchers' organisations. The more detailed review will attempt rough order quantification for the contribution from each area. Develop recommendations for ongoing research as a result of the in-depth review.

### 10.4.2 Measures to improve bus reliability

The aim is to explore the potential interventions to improve reliability and reduce the impact of unreliability for public transport (urban bus) by reducing the variance in bus headways that arises from the bunching phenomenon. The intervention draws the focus away from strict timetable adherence to achieving regularity in bus arrivals through active management of bus speed/dwell time at stops and at the commencement of each service to dampen tendencies to bunching and off-schedule running. This approach is made possible by modern vehicle positioning systems, communications and information technology and is innovative for New Zealand.

The research will assess the potential of headway levelling techniques and has a single milestone:

- **4b1 Review of active management of bus regularity** – review the overseas theoretical and demonstration work on active management of bus regularity to assess its theoretical potential and its potential practical application in reducing passenger delay, reliability and crowding and their associated costs, in general and in the New Zealand main urban centres. Discuss the practicalities and with selected bus operators and with local authorities in relation to service performance requirements and monitoring. Assess the potential and recommend any further action in a working paper.

### 10.4.3 Use of ATIS to improve reliability and reduce its impact

The review indicates that ATIS can play an important role in providing real-time information on network status, transport services departure and arrival times, best route selection and expected journey time. By allowing delays to be avoided and travel uncertainties to be removed, ATIS potentially reduces the magnitude of journey time variance to users. It may also reduce the value of unplanned delay by allowing changes to be made to the scheduling of destination activities during travel so that the impact (cost) of lateness is reduced.

Increasingly real-time travel information is available on hands-free mobile devices before and during travel and, in the case of private transport, can be used automatically to provide guidance on routes and times. Third party providers are increasingly providing applications and crowd sourcing data from their users, but transport operators and infrastructure providers also have a role in providing key information. ATIS is also increasingly important in freight transport for similar reasons. Quantifying and assigning a value to the reliability gains from ATIS could prove useful for encouraging their wider adoption.

While there is plenty of qualitative information on time saving and reliability benefits, there is little that is quantitative making this a challenging area to attempt. However, it also seems to be under-researched, so is potentially of interest for this reason, and is also attractive as an area of developing smart technology where New Zealand could benefit.

On balance, we suggest there is some merit in preparing a state-of-development report on the use and possible future development of ATIS in New Zealand in private vehicles, public transport and freight transport, including discussions with the leading players. The milestone is therefore:

- **4c1 Review of ATIS** – review and report on the present status and potential future development path for ATIS and its equivalents in freight transport, including:
  - the roles of the central and local government agencies, transport operators, the ITC industry, motoring organisations and others
  - summarise the technology and applications
  - comment on the possible effects on travel choice behaviour and on travel time savings, reliability improvements and their value to travellers. Propose a course for any follow-up research or development.

### 10.4.4 Freight delay reduction measures on strategic freight networks

This focus area is on measures that can be introduced on strategic road freight routes to selectively reduce delay and/or improve reliability for freight traffic in relation to general traffic, recognising that traffic congestion is the leading problem cited by New Zealand freight firms. As with public transport, the rationale could be that national transport objectives are better satisfied through giving some advantage to freight at the cost of some disadvantage to private passenger transport, particularly where export freight consignments are concerned. While selective priority is reasonably well accepted for high-occupancy passenger vehicles, truck traffic is seen by many of the travelling public as more of a problem to be kept off the roads if possible. Indeed local authorities often place emphasis on shifting freight off road and onto rail for environmental and social reasons.

Many of the techniques used to selectively prioritise other traffic can in theory be applied to freight – reserved lanes, intersection priority, use of ITS assistance and complete segregation. Better integration of road freight network planning and design in relation to the location of freight intensive land use is already recognised in various freight strategies and best practice guides. Increased load limits to reduce the need

for deconsolidation at ports at the same time improving cost efficiency and reducing freight movements are other measures.

We propose some limited further work in this area with a single milestone:

- **4d1 Explore practical ways of selectively mitigating delays to road freight traffic on strategic freight routes** – conduct a more in-depth review of the freight delay reduction measures on strategic freight routes discussed in section 7.4, including industry and road controlling authority discussions to assess the scope for practical application and barriers to implementation. Prepare a working paper with conclusions on promising initiatives and recommended next steps.

## 10.5 Value of reliability and interventions in tourism

Three research topics have been identified to look at aspects of tourism travel where reliability is potentially a significant issue:

- 1 Sightseeing tours, excursion and route buses where there are scheduling constraints
- 2 Airport access trips
- 3 Holiday travel on rural routes where reliability is an issue, such as congested outlets from main centres.

For the first two, market surveys through interviewing operators and travellers can potentially yield useful qualitative and quantitative data for policy purposes. For travel on rural holiday highways, to obtain information on the values of time saving and reliability that can be used in demand modelling and economic evaluation requires a SP survey approach. However, this will not be possible within the overall budget constraint.

For the two selected topics the tasks are sequentially to:

- 1 Identify and quantify the market segment
- 2 Undertake exploratory surveys to investigate the relative importance and incidence of journey time unreliability
- 3 Report qualitative and, as far as possible, quantitative results
- 4 Make recommendations for changes to current practice and on whether more extensive market surveys (such as SP) are warranted.

### 10.5.1 Tour, excursion and route bus travel

The targets are journey time reliability from a transport operator viewpoint for the following:

- charter bus carrying international package tourists on sightseeing excursions where there are generally start and end timing constraints, a set of attractions to be visited, with intermediate time constraints for meals and rest stops
- long-distance timetabled route buses which carry a proportion of tourists.

As it is not clear just how significant delays and travel time reliability are to tourism bus operators, exploratory interviews and a survey to position reliability among other factors are suggested.

The milestone tasks are:

- **5a1 Initial discussion with a representative operator from each group** – have a preliminary free-form conversation with a charter and a route bus operator to identify issues and establish whether, and in what circumstances, journey time reliability is a significant issue; subsequent stages would be contingent on the significance of journey time reliability.
- **5a2 Develop a sample frame and estimate market size** – identify a sample frame and as far as possible quantify the market size and composition to enable appropriate stratification of a survey sample; the Bus & Coach Association is the obvious choice with its 200+ company members listed as carrying out tour/charter work – permission will be required to contact the membership and help in co-opting representative operators who would be willing to participate in an initial exploratory survey; the representation to include geographic coverage, size of operator, type of tourism service provided and shorter/longer tourism circuits/trips.
- **5a3 Design an exploratory survey** – to identify for the purposes of tourism travel organisation and motivations:
  - industry players, relationships and influencing factors – inbound tourism operators, travel agents, hotel and restaurant industry, commercial tourism attractions, cruise ship industry
  - the main tourist circuits and point-to-point destinations and their perceived constraints and issues
  - nature of the tourist clientele served, their perceived needs, likes and dislikes
  - the positioning of journey time savings and journey time reliability among other factors influencing the tourism experiences offered.
- **5a4 Execute the survey, analyse and report results** – recommend whether more detailed market surveys, including SP, are warranted to obtain behavioural values of travel time saving and reliability and if so, their general form.

### 10.5.2 Airport access trips

The targets are the airport access trips made by departing air passengers on domestic and international flights from New Zealand. Travel modes will include self-drive, taxi, airport bus and shuttle bus. Tour buses are not included as the responsibility for on-time arrival lies with the service provider. As well as being used to investigate travel time reliability, such a survey could have a number of other spin-off uses for those involved in airport access planning. The proposed milestones are:

- **5b1 Traffic composition on airport access routes** – using Auckland airport as the focus due to its leading role as the main international gateway, identify the mix of departing passengers and the proportions that these contribute to the traffic stream accessing the airport terminals and on the main airport access routes by mode, domestic/international travel and New Zealand resident/overseas visitor; some of this data is believed to be available from studies made for Auckland Transport (previously Auckland Regional Transport Authority) and Auckland International Airport Limited and co-operation from these agencies would be required; this will enable the departing passenger stream to be sized in comparison to other airport zone travellers and provide the likely significance of any distinction in value of time and reliability.
- **5b2 Pilot passenger interview survey** – design and execute a pilot structured interview survey of departing passengers to establish the main decision factors and constraints in the airport access trips for the various types of passenger. Mode choice will be one factor and for those arriving by car considerations of parking and related costs, drop-off by friends/family versus self-drive, off-airport

versus on-airport parking with shuttle bus connection. Include time allowed and time actually required for the access trip in relation to check-in and departure gate times to establish the time buffer allowed by various departing passenger categories, including whether travelling alone or accompanied, locally or New Zealand resident or overseas visitor, length of time away (day trip, overnight, longer trip), regularity/familiarity with air travel and the access trip, type of ticket (economy non-refundable, full economy, business), time of day and anticipated degree of traffic congestion or public transport delays. Put a set of positioning statements to travellers to gauge their level of risk aversion and the consequences of missing their flight. With a further set of questions aim to explore differences in value of time savings and reliability between airport access trips and general commuter travel. If possible, conducted the survey in the airside departure area subject to security requirements where passengers are more likely to be amenable to an interview.

- **5b3 Main passenger interview survey and analysis** – use the results of the pilot survey to amend and then execute a larger scale passenger interview survey. Analyse the full survey and report on the relative importance and experience of access travel time reliability. The results should provide some quantitative information on market segmentation and how time savings and reliability of journey time are valued for airport access trips compared with general commuter travel. Make recommendations on the desirability of more definitive surveys, such as SP experiments and their general form, for future research.



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# Appendix A: New Zealand evidence on road use and fuel consumption price elasticities

## A1 Introduction

This note provides a summary and interpretation of the main New Zealand sources of evidence on price elasticities for road use (vehicle-km) and fuel consumption. Fuel price as a component of transport costs has long been an area of interest for policy analysis because of its susceptibility to variation from external market influences, the prospect of 'peak oil' and efforts to develop petroleum fuel substitutes. It is also one of the more clearly identifiable components of transport cost and has moved over a wide range relative to other cost components. Such studies are therefore of use in estimating whole-of-market responses to change in transport costs.

## A2 Findings and interpretation

Three main studies have been reviewed, as listed under table A.1 (below). All were prepared by consultants in the last few years, two for MoT and one for Land Transport NZ/NZ Transport Agency.

Table A.1 provides the main findings from the two MoT reports, together with our comments on and interpretation of these findings, reflecting discussions with MoT staff on an earlier version of this table.

Table A.2 brings together the main findings from the two MoT studies and the findings from the earlier Land Transport NZ/NZ Transport Agency *Surface transport cost and charges* (STCC) research study (Booz Allen Hamilton 2004), which has been subject to independent peer review. Its findings have been open to wider scrutiny through presentations to groups of New Zealand professionals and at international transport research conferences.

The findings in table A.2 are grouped into three vehicle categories (petrol vehicles, light diesel and heavy diesel vehicles) and cover both vehicle-km price elasticities and fuel consumption price elasticities. Our conclusions relating to each of these vehicle types are summarised as follows:

### **Petrol vehicles**

- Fuel consumption elasticity estimates, from Kennedy and Wallis (2007) and Deloitte Access Economics (DAE) (2011) are reasonably consistent, at around -0.2 over the medium/long run with regard to (wrt) total petrol price. This figure is broadly consistent with wider international evidence (refer Kennedy and Wallis (2007) for an international review).
- Fuel consumption elasticity estimates wrt sub-components of the total petrol price (eg world oil prices, fuel excise duty (FED) charges) would be expected to be less than the 0.2 figure, according to the proportion of the total fuel price accounted for by the sub-component. In that context, the DAE estimates for elasticity wrt world oil prices are plausible, that for elasticity wrt FED charges is much too low.
- Vehicle-km elasticity estimates would be expected to be lower than the corresponding fuel consumption elasticity estimates (as reducing vehicle kilometres travelled (VKT) is only one of many possible responses to increased fuel prices). The vehicle-km elasticity given here (from Kennedy and Wallis 2007) is higher than the consumption elasticity: this is believed to reflect that the vehicle-km elasticity estimate relates to traffic only on state highways, which would be expected to be more elastic (higher proportion of recreational and other discretionary trips) than traffic volumes in general.

### Light diesel vehicles

- Both sources, DAE (2011) and NZIER (2009) give widely differing and inconsistent estimates for vehicle-km elasticities with respect to diesel prices and light road user charges (RUC). No useful conclusions can be drawn from this evidence.
- No New Zealand evidence is available on fuel consumption elasticities for light diesel vehicles.
- Very little relevant international evidence exists on either vehicle-km or fuel consumption elasticities for this vehicle group. Given the market characteristics of the New Zealand light diesel fleet, it might (a priori) be expected that its vehicle-km and fuel consumption elasticities would be between those for petrol vehicles and heavy diesel vehicles.

### Heavy diesel vehicles

- Both sources, DAE (2011) and NZIER, (2009) produce a similar finding, that the vehicle-km elasticity wrt diesel prices (and heavy RUC charges) is close to zero. In effect, changes in the costs of truck operation will be generally passed on to either the consigner or consignee of the goods, with minimal impact on the size of the market (at least in the shorter term).

**Table A.1 Evidence on New Zealand road use and fuel consumption price elasticities – evidence summary and comments/queries**

Reference	Report findings	Research consultant comments/queries
<b>NZIER (2009) Road user charge demand – responsiveness to changes in road user charges. Report prepared for MoT.</b>		
<b>P (i), 21</b>	<ul style="list-style-type: none"> <li>• Light RUC veh/km elasticity wrt light RUC rates (MR/LR) = -0.35</li> <li>• Light RUC veh/km elasticity wrt fuel prices (MR/LR) = -0.09</li> </ul>	<p>These two estimates appear inconsistent:</p> <ul style="list-style-type: none"> <li>• Typical RUC rates for light diesel vehicles are c. 3¢/km, with fuel costs around 15¢/km.</li> <li>• Thus RUC elasticity should be around 20% of fuel price elasticity.</li> <li>• Typical NZ veh/km elasticity values wrt fuel price for light petrol vehicles in NZ are around -0.20 SR and -0.35 LR (Kennedy and Wallis 2007).</li> <li>• Broadly similar, but probably rather lower, values would be expected for light diesel vehicles, say in range -0.10 to -0.20.</li> <li>• On this basis, the report's fuel price elasticity estimates of -0.09 is of the right order. However the RUC route elast should be c. 20% of this, ie around -0.02: the -0.35 figure appears implausible.</li> <li>• MoT (Michael B/(Tantri) agreed in discussions that the light RUC and fuel price elasticity figures are inconsistent.</li> </ul>
<b>P (ii), 28</b>	<ul style="list-style-type: none"> <li>• Heavy RUC volume elasticity wrt heavy RUC rates (MR) = -0.01</li> </ul>	<ul style="list-style-type: none"> <li>• Elasticity estimate very small – not clear if significantly different from zero.</li> <li>• This result is generally consistent with other research evidence of very low or zero price elasticity for heavy truck travel.</li> <li>• Report notes the possibility that increases in truck charges could have negative impacts on GDP, which in turn would reduce heavy RUC volumes – although insufficient evidence to support this hypothesis.</li> </ul>

Reference	Report findings	Research consultant comments/queries
P (i), 21	<ul style="list-style-type: none"> <li>Light RUC veh/km elasticity wrt light RUC rates (MR/LR) = -0.35</li> <li>Light RUC veh/km elasticity wrt fuel prices (MR/LR) = -0.09</li> </ul>	These two estimates appear inconsistent: <ul style="list-style-type: none"> <li>Typical RUC rates for light diesel vehicles are c. 3¢/km, with fuel costs around 15¢/km.</li> <li>Thus RUC elasticity should be around 20% of fuel price elasticity.</li> <li>Typical NZ veh/km elasticity values wrt fuel price for light petrol vehicles in NZ are around -0.20 SR and -0.35 LR (Kennedy and Wallis 2007).</li> <li>Broadly similar, but probably rather lower, values would be expected for light diesel vehicles, say in range -0.10 to -0.20.</li> <li>On this basis, the report's fuel price elasticity estimates of -0.09 is of the right order. However the RUC route elasticity should be c. 20% of this, ie around -0.02: the -0.35 figure appears implausible.</li> <li>MoT (Michael B/(Tantri) agreed in discussions that the light RUC and fuel price elasticity figures are inconsistent.</li> </ul>
<b>DAE (2011) Review and redesign of the NLTF revenue forecasting model. Report prepared for MoT</b>		
	<b>General comment</b> <ul style="list-style-type: none"> <li>Report states that, due to the structure of the models used, any coefficient values should be treated with great caution as representing elasticity estimates – refer pp80–81.</li> </ul>	<ul style="list-style-type: none"> <li>Thus need for caution in deriving elasticity estimates was highlighted in discussion with MoT (Tantri).</li> </ul>
s. 4.3.1, tables 6.3/6.4	<b>Petrol excise duty (PED)</b> <ul style="list-style-type: none"> <li>Petrol vol elast wrt petrol pump price is -0.16 in LR (table 4.5)</li> <li>Petrol volume elasticity wrt world oil price is -0.08 SR and -0.09 LR (table 6.3)</li> <li>Petrol volume elasticity wrt PED rate is -0.02 (table 6.3).</li> </ul>	<ul style="list-style-type: none"> <li>The relationships between elasticity wrt petrol pump price and wrt world oil price seem plausible – as world oil price is c. 50% of pump price.</li> <li>The PED rate elast appears low relative to the pump price elasticity, as PED accounts for much more than 1/3 of the pump price.</li> </ul>

Table A.2 Summary of New Zealand evidence on road use and fuel consumption price elasticity estimates

Source	Price measure	Vehicle-kilometre elasticity estimates	Fuel consumption elasticity estimates	Comments
<b>Petrol vehicles</b>				
Kennedy and Wallis (2007)	Total petrol price	SR -0.22 MR -0.30 (SH traffic)	SR -0.15 MR -0.20	<ul style="list-style-type: none"> <li>Would normally expect consumption elasticity &gt; veh-km elasticity – this contrary result most likely reflects that veh-km elasticity relates to SH traffic only (more elastic than other traffic).</li> </ul>

Source	Price measure	Vehicle-kilometre elasticity estimates	Fuel consumption elasticity estimates	Comments
DAE (2011)	Total petrol price		LR -0.16	<ul style="list-style-type: none"> <li>All DAE elasticity estimates to be treated with considerable caution (given modelling methods).</li> <li>Total fuel price and world oil price elasticity reasonably consistent. FED elasticity too low – expected to be similar to world oil price elasticity.</li> </ul>
	World oil price		SR -0.08	
	FED charge		LR -0.19 to -0.02	
<b>Light diesel vehicles</b>				
DAE (2011)	Light RUC charge	LR (1) -0.35 LR (2) 0.00		<ul style="list-style-type: none"> <li>Two widely differing estimates. High estimate appears implausible, given that light RUC charges are in order of only 20% of fuel prices.</li> <li>Note above caveat re DAE estimates.</li> </ul>
NZIER (2009)	Light RUC charge Total diesel price	MR/LR -0.35 MR/LR -0.09		<ul style="list-style-type: none"> <li>Two estimates are completely inconsistent: light RUC elasticity should be only a small proportion of diesel price elasticity.</li> </ul>
<b>Heavy diesel vehicles</b>				
DAE (2011)	Total diesel price	Very close to zero		<ul style="list-style-type: none"> <li>All evidence on this aspect is consistent, pointing to a clear conclusion that the elasticity is very close to zero (&lt;0.02).</li> </ul>
NZIER (2009)	Heavy RUC charge Heavy RUC charge	Very close to zero Very close to zero (-0.01)		

## A3 References

Deloitte Access Economics (DAE) (2011) *Review and redesign of the NLTF revenue forecasting model*. Report to Ministry of Transport, Wellington.

Kennedy, D and I Wallis (2007) Impacts of fuel price changes on New Zealand transport. *NZTA research report 331*.

New Zealand Institute of Economic Research (NZIER) (2009) *Road user charge demand – responsiveness to changes in road user charges*. Report to MoT. Wellington: NZIER.

## Appendix B: International evidence on freight mode choice elasticities

Table B.1 provides a summary of the international evidence on freight price direct and cross-elasticities, derived from studies where competing modes were available (these modes being truck and train for all the studies reviewed).

The following points should be noted:

- The elasticity estimates given in the table are, in almost all cases, from primary market research. In addition, there exist numerous ‘secondary’ review studies, which have assembled the evidence from the primary studies; to avoid double-counting, we have generally not included the secondary studies here.
- Most of the studies reviewed provide both direct price elasticities and cross-price elasticities.
- It is not usually clear in most cases over what period the elasticity responses have been estimated: we assume that these responses are generally short-run (ie within one year or so of the price change).
- A priori, we would expect elasticity values to be reasonably sensitive to (inter alia):
  - initial mode shares
  - the extent to which the alternative modes are close competitors for the traffic in question.

Most of the studies reviewed give little or no information on these points. This severely limits the extent to which useful conclusions can be drawn from them, for example on ‘underlying’ elasticity differences by commodity and length of haul. It also limits the extent to which it is possible to generalise from the available results as to how elasticities vary in different situations, and hence to draw any conclusions on the transferability of the international evidence to particular situations in New Zealand.



Table B.1 Summary of international evidence on freight mode choice elasticities

Country	Author	Title of article	Model	Modal share elasticity	Cross elasticity of demand
USA	Abdelwahab (1998)	Elasticities of mode choice probabilities and market elasticities of demand: evidence from a simultaneous mode choice/shipment-size freight transport model	The model chosen was a mixed discrete/continuous choice model of mode and shipment size. The mode choice component of the model was specified as a binary probit function. The data for the study was obtained from individual shipments of manufactured goods.	<b>All commodities:</b> Truck (-0.797 to -2.525) Rail (-0.908 to -2.489) <b>Food and tobacco:</b> Truck (-1.32 to -2.18) Rail (-1.32 to -2.34) <b>Textile and apparel:</b> Truck (-1.40) Rail (-1.59) <b>Chemicals, petroleum and coal:</b> Truck (-0.92 to 1.71) Rail (-1.05 to -1.96) <b>Rubber, plastic and leather:</b> Truck (-1.13) Rail (-1.23) <b>Primary and fabricated metal products:</b> Truck (-0.79 to -1.11) Rail (-0.90 to -2.48) <b>Electrical machinery and equipment, transport supplies and equipment:</b> Truck (-1.19 to -2.52) Rail (-1.16 to -2.15) <b>Stone, clay, glass and concrete:</b> Truck (-0.74) Rail (-0.95)	<b>All commodities:</b> Truck-rail (0.933 to 2.532) Rail-truck (0.904 to 2.425) <b>Food and tobacco:</b> Rail-truck (1.27 to 2.22) Truck-rail (1.20 to 2.33) <b>Textile and apparel:</b> Rail-truck (1.62) Truck-rail (1.46) <b>Chemicals, petroleum and coal:</b> Rail-truck (1.04 to 1.92) Truck-rail (1.07 to 2.00) <b>Rubber, plastic and leather:</b> Rail-truck (1.25) Truck-rail (1.28) <b>Primary and fabricated metal products:</b> Rail-truck (0.90 to 2.42) Truck-rail (0.93 to 2.53) <b>Electrical machinery and equipment, transport supplies and equipment:</b> Rail-truck (1.16 to 2.10) Truck-rail (1.19 to 2.19) <b>Stone, clay, glass and concrete:</b> Rail-truck (0.95) Truck-rail (0.98)

Country	Author	Title of article	Model	Modal share elasticity	Cross elasticity of demand
USA	Friedlaender and Spady (1980)	A derived demand function for freight transportation	The model derives an input demand equation from the firm's cost function. This model uses a firm's short run cost function compared to long run cost function	<p><b>All commodities:</b> Truck (-1.001 to -1.547) Rail (-1.681 to -3.547)</p> <p><b>Food:</b> Truck (-0.95 to -1.03) Rail (-1.569 to -4.009)</p> <p><b>Wood:</b> Truck (-0.145 to -1.71) Rail (-1.44 to -2.17)</p> <p><b>Paper, plastic and rubber:</b> Truck (-0.97 to -1.08) Rail (-1.68 to -2.06)</p> <p><b>Stone, clay and glass:</b> Truck (-1.00 to -1.02) Rail (-1.60 to -1.81)</p> <p><b>Iron and steel:</b> Truck (-1.05 to -1.09) Rail (-1.81 to -2.78)</p> <p><b>Fabricated metal:</b> Truck (-1.16 to -1.58) Rail (-2.16 to -8.65)</p> <p><b>Non electrical machinery:</b> Truck (-1.01 to -1.17) Rail (-1.98 to -2.76)</p> <p><b>Electrical machinery:</b> Truck (-1.07 to -1.31) Rail (-1.66 to -5.06)</p>	<p><b>All commodities:</b> Truck-rail (-0.164 to 0.032) Rail-truck (-0.672 to 1.55) Rail-truck (-0.145 to 0.066) Truck-rail (-0.002 to 0.03)</p> <p><b>Wood:</b> Rail-truck (-0.02 to -0.67) Truck-rail (-0.05 to -0.18)</p> <p><b>Paper, plastic and rubber:</b> Rail-truck (-0.009 to 0.03) Truck-rail (-0.004 to 0.02)</p> <p><b>Stone, clay and glass:</b> Rail-truck (0.00 to 0.03) Truck-rail (0.00 to 0.02)</p> <p><b>Iron and steel:</b> Rail-truck (-0.053 to 0.004) Truck-rail (-0.13 to 0.02)</p> <p><b>Fabricated metal:</b> Rail-truck (-0.05 to 1.55) Truck-rail (-0.05 to -0.16)</p> <p><b>Non electrical machinery:</b> Rail-truck (-0.01 to -0.08) Truck-rail (-0.01 to 0.01)</p> <p><b>Electrical machinery:</b> Rail-truck (-0.07 to 0.01) Truck-rail (-0.04 to 0.01)</p>

Appendix B – International evidence on freight mode choice elasticities

Country	Author	Title of article	Model	Modal share elasticity	Cross elasticity of demand
Belgium	Beuthe et al (2000)	Freight transportation demand elasticities: a geographic multimodal transportation network analysis	The model computes the elasticity of 10 different categories of goods. The model works by minimising the generalised cost of transportation tasks defined by O-D matrices, assigns traffic flows to different modes and routes. Successive simulations with different costs allow the computation of elasticity values	<b>All commodities:</b> -0.58( SD truck)(T) -0.63(LD truck)(T) -2.06 (SD rail)(T) -1.54 (LD rail)(T) -1.06(SD truck)(TKm) -1.31(LD truck)(TKm) -1.77(SD rail)(TKm) -1.19(LD rail)(TKm)	<b>All commodities:</b> 2.26(SD)(T)(rail-truck) 0.08(SD)(T)(truck-rail) 2.13(LD)(T)(rail-truck) 0.14(LD)(T)(truck-rail) 2.99(SD)(TKm)(rail-truck) 0.11(SD)(TKm)(truck-rail) 1.92(LD)(TKm)(rail-truck) 0.67(LD)(TKm)(truck-rail)
Canada	Oum et al (1990)	A survey of recent estimates of price elasticities of demand for transport	The authors have reviewed 70 estimates of the price elasticity of demand for transport published in journal articles, estimates covering many different transport modes and market situations and employing various statistical methods and databases	<b>All commodities:</b> Truck (-0.7 to -1.10) Rail (-0.4 to -1.2) <b>Chemicals:</b> Truck (-1.00 to -1.90) Rail (-0.4 to -0.7) <b>Automobiles:</b> Truck (-0.5 to -0.7) Rail (-0.70 to -1.10) <b>Food:</b> Truck (-0.5 to -1.3) Rail (-0.3 to -1.0) <b>Coal:</b> Rail (-0.1 to -0.4) <b>Machinery:</b> Truck (-0.1 to -1.2) Rail (-0.6 to -2.30)	

Country	Author	Title of article	Model	Modal share elasticity	Cross elasticity of demand
				<b>Paper, plastic and rubber:</b> Truck (-0.3 to -1.1) Rail (-0.2 to -1.00) <b>Petroleum:</b> Truck (-0.5 to -0.7) Rail (-0.50 to -1.00) <b>Stone, clay and glass:</b> Truck (-1.00 to -2.20) Rail (-0.8 to -1.7) <b>Fertilisers:</b> Rail (-0.1 to -1.0) <b>Lumber, pulp and paper:</b> Truck (-0.1 to -0.6) Rail (-0.1 to -0.7)	
Europe	De Jong, Gunn and Ben Akiva (2004)	A meta-model for passenger and freight transport in Europe	The model was a meta model of passenger and freight transport in Europe. A meta model combines other models to create a single model. This model combined the results of five disaggregate national models of freight transport, two European transport models and four national models of freight transport	Truck -0.4 to -0.7 (TKm)	
Indonesia	Norojono and Young (2003)	A SP freight mode choice model	This article outlines a data collection approach and the development of a disaggregate mode choice model applicable to the analysis of freight shipper decision making. It focuses on	Truck -0.53  Rail -0.88	Truck-rail 0.42  Rail-truck 0.26

Appendix B – International evidence on freight mode choice elasticities

Country	Author	Title of article	Model	Modal share elasticity	Cross elasticity of demand
			the choice between rail and road in Java, Indonesia. The model indicates that safety, reliability and responsiveness are major attributes influencing rail/road freight mode choice		
Australia	Kells (1997)	Effect on road and rail demand of increased mass limits for heavy road vehicles	An econometric analysis was undertaken to estimate the impact of proposed changes to heavy vehicle mass limits on the demand for road and rail freight along six major Australian transport corridors	Truck -0.77	NA
Australia	MM Starrs (2005)	Effect of truck charges on rail	Literature review	Truck short haul (-0.5 to -0.7)* Truck long haul (-0.9 to -1.1)* *Values obtained by review of Australian sources	Rail-road (short haul)* 4.03 to 7.54 Rail-road (long haul)* 0.61 to -0.75 *Values obtained by review of Australian sources
Australia	Meyrick and Associates (2006)	Rail freight price elasticities	Literature review	Rail -0.7 to -0.9	NA
Australia	BITRE (2009)	Road and rail freight: competitors or complements?	Intercapital freight studies	Truck -0.46  Rail -1.66	Truck-rail 0.58  Rail-truck 1.04
Australia	BTRE (1999)	Competitive neutrality between road and rail	A freight transport logistic substitution model is estimated over the long run (1971-1995) using road as the base mode of transport. The model essentially keys off movements in the price competitiveness of road, rail and sea modes relative to each other		Rail-truck -0.90

**Table B.2 Willingness-to-pay for valuations of freight time and reliability savings**

Title	Reference	Value of freight time	Reliability	Notes
Godskunders Varderingar	Transek (1990)	20 SEK/hour and shipment (Road) 6 SEK (rail/wagon)	60 SEK/wagon(1% increase in the frequency of delays) (same day arrival) 40 SEK/wagon (next day arrival)	The estimated models are formulated in terms of percentage changes for each explanatory variable. Interpretation of calculated unit prices are unclear
Godskunders Transportmedelsval	Transek (1992)	30 SEK/hour and shipment (lorry)	280 SEK (1% unit reduction in late arrival) (same day arrival) 110 SEK (next day arrival)	The estimated models are formulated in terms of percentage changes for each explanatory variable. Interpretation of calculated unit prices are unclear
Value of time in freight transport	Kurri et al (2000)	\$1.53/ton and hour (road) \$0.1/ton and hour (rail)	Value of delay: \$47.47/ton and hour (road) \$0.50/ton and hour (rail)	The interpretation of delay variable is not clear
A disaggregate model of the demand for intercity freight	Winston (1981)	US\$125–\$1187/ shipment and day (road) US\$490/shipment and day	\$299–\$4110/shipment and day (rail) \$404/shipment and day (road)	
The value of freight transport: A cross country comparison of outcomes	de Jong et al (1995)	1999 US\$33/shipment and hour (Germany) US\$40–43 (Netherlands) US\$34 (France)		Variables are measured in percentage terms and not in absolute terms.
Valuation of travel time savings and predictability in congested conditions for highway user-cost estimation	Small et al (1999)	US\$144–\$193/shipment and hour	US\$373 (reducing 1 hour of schedule delay)	Most parameter estimates related to reliability were either insignificant or had the wrong sign. The reasons could be a small sample or respondents having problems in understanding the questions related to reliability.

**Table B.3 Perceived importance of freight transport attributes**

Title	Reference	Commodities	Reliability	Time	Flexibility	Frequency	Damage	Cost
Logistics managers stated preferences for freight service attributes	Danielis et al (2005)	Food, tobacco, chemicals and fibres	1				1	
		Metals, minerals and paper						1
Analysing qualitative attributes of freight transport from stated orders of preference experiment	Beuthe and Bouffioux (2008)	Minerals, fertilisers and agricultural products	1	1	1			
		High value goods			1		1	
		Metals						1
Modelling preferences and stability among transport alternatives	Maier et al (2002)		1					
Evidence on shippers' transport and logistics choice	Bolis and Maggi (2002)		1	3	5	4		2
A SP freight choice model	Norojono and Young (2003)		1	2	1			4
Freight mode choice and adaptive SPs	Shinghal and Fowkes (2002)		1			1		
Service priorities in international logistics	Semeijn (1995)		1	2				3
Service priorities in small and large firms engaged in international logistics	Pearson and Semeijn (1999)		1	2				3

## B1 References

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## Appendix C: Glossary

AA	New Zealand Automobile Association
ANZSIC	Australia – New Zealand Standard Industrial Classification
ARC	Auckland Regional Council (now replaced by Auckland Council)
ATIS	advanced traveller information systems
BITRE	Bureau of Transport, Infrastructure and Regional Economics, Australia
ca	circa
Carrier	A person or company who, in a contract of carriage, undertakes to perform or to procure the performance of carriage of goods by rail, road, water or air or by a combination of such modes
Commercial transport	Transport of the goods of a third party for hire or reward
Consignee	The person who receives the cargo or freight
Cross-docking	Goods from various suppliers are received and unloaded at one side of the dock, sorted to destination consignees and reloaded to outbound transport at the other side of the dock with minimum intermediate storage
DAE	Deloitte Access Economics
DTS	Domestic Travel Survey (New Zealand)
EAM	Economic appraisal manual (National Roads Board 1986)
EEM	<i>Economic evaluation manual</i> (NZ Transport Agency 2010)
Effectiveness	Measures the amount or degree of accomplishment in proportion to size of the task
Efficiency	A productivity measure of the response achieved in relation to a stimulus applied, used in particular for economic efficiency in relation to economic benefits obtained for resource costs applied.
FCL	Full container load: container holds goods for one consignee
FED	fuel excise duty
Freight	cargo or goods carried by commercial transport – road freight, sea freight, air freight
Freight charge	charge made for carriage of goods, sometimes abbreviated to freight
Freight forwarder	A person or company who books end-to-end transport arrangements on behalf of a client, usually for international transport involving more than one transport mode and carrier.
FTL	full truck load: truck holds goods for one consignee
GPS	global or geographic positioning system
HCV	heavy commercial vehicle
ICT	information and communications technology
INCA	incident cost benefit analysis
ISO	International Standards Organisation
ITS	intelligent transport systems
IVS	International Visitor Survey
Land transport	transport by land based modes – road and rail
LCL	less than container load: goods for more than one consignee packed in an ISO container
LCV	light commercial vehicle
Logistics	The part of the supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customers' requirements.

LTL	less than truck load: truck holds goods for more than one consignee
MCV	medium commercial vehicle
MoT	Ministry of Transport, New Zealand
MPL	marginal productivity of labour
NLTP	National Land Transport Programme (New Zealand)
NRCA	National Road Carriers Association
NZBEC	New Zealand Classification by Broad Economic Categories
NZHC	New Zealand Harmonised Classification
NZHTS	New Zealand Household Travel Survey
NZVOC	New Zealand Vehicle Operating Cost (model)
Own account transport	Carriage of goods owned by a person or company in that person or company's own transport vehicles; also referred to as ancillary transport meaning ancillary to the main business of the person or company; also referred to as 1st party logistics 1PL
OXERA	Oxford Economic Research Associates
PAT	preferred arrival time
PED	petrol excise duty
PEM	<i>Project evaluation manual</i> (Transfund NZ 1997)
RoRO	roll-on roll-off
RP	revealed preference
RTAs	regional transport authorities
RTF	Road Transport Forum
RUC	road user charges
SH	state highway
Shipper	person or company who consigns the cargo or freight, usually the owner; also called the consignor
SP	stated preference
Supply chain	the sequence of activities from supply of raw materials to industry, through secondary delivery of inputs to the manufacturer , to final delivery of finished products to consumers
surface transport	all transport modes excluding air; in the context of this research surface transport has not included pipelines, conveyors and ropeways
TDM	traffic demand management
teu	twenty foot equivalent unit, equivalence measure for ISO shipping containers
Transport Agency	New Zealand Transport Agency
TREIS	Traffic Event Information System (NZ Transport Agency)
van/devan	pack/unpack containers (also stuff/unstuff)
v/c	volume/capacity
vehicle	a mechanical contrivance used for the transport of goods or persons, and includes road vehicles, vessels and aircraft
VoT	value of time
VMS	variable message signs
WTP	willingness to pay