

Understanding Transport Costs and Charges

Phase 2 – Social and environmental costs

A literature review on valuation methodologies

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Foreword

Effective transport interventions and policies are critical to allow the transport sector to operate efficiently, increase its productivity and minimise potential economic, environmental and social impacts. Irrespective of the policy priorities under which the transport sector operates, the need for quality transport data remains important for evidence-based transport evaluation and transparent policy-making.

Understanding the full costs of the different modes of transport will allow informed investment or mode-choice decisions to be made. Better utilisation of the transport system is important to support long-term economic growth and development.

The Understanding Transport Costs and Charges project follows on from the Surface Transport Costs and Charges (STCC) study released in March 2005. The STCC study provided some snapshot estimates of the total, average and marginal costs and charges associated with the road and rail networks for 2001-2002. The UTCC project aims to update this knowledge.

The UTCC project has adopted a two-phase process comprising:

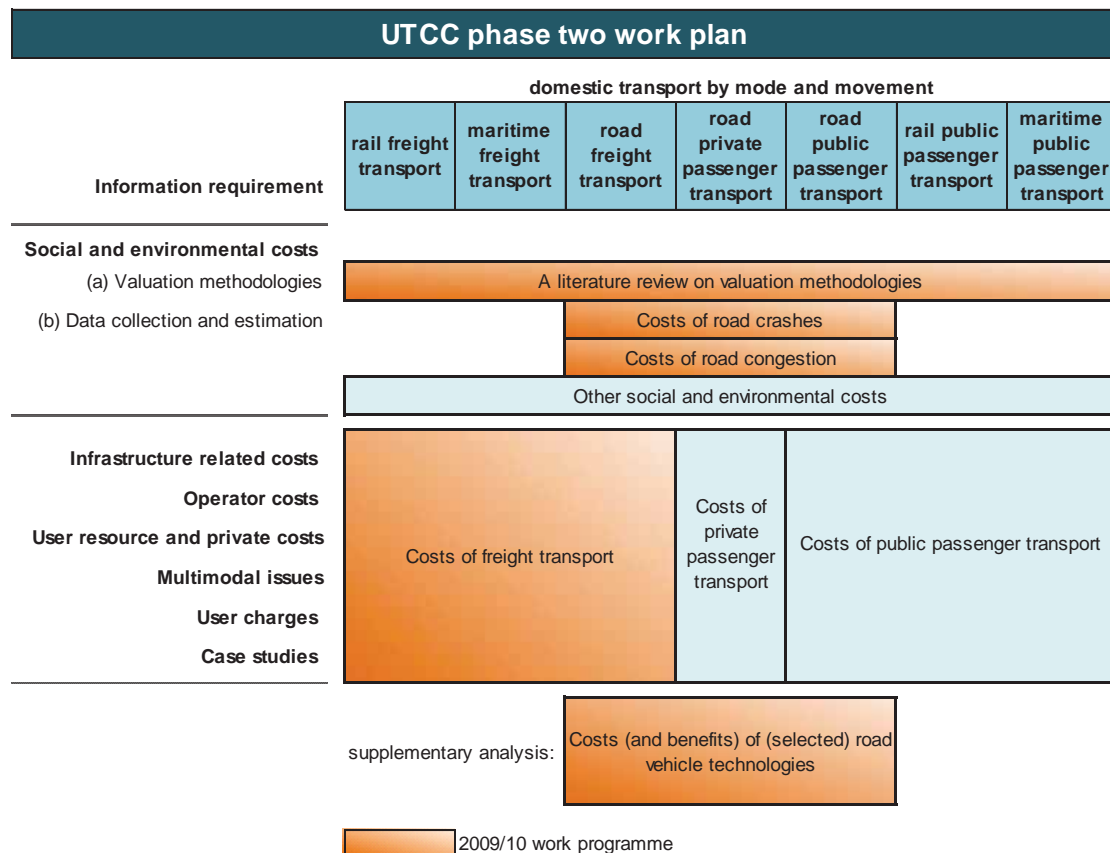
Phase One – a stock-take of the current domestic transport funding, charging and pricing arrangements for the road, rail and maritime transport sectors, and a gap analysis to identify transport costs and charges information needs.

Phase Two – data collection and estimation of costs and charges for the three modes.

Phase One was awarded to Hyder Consulting and a series of workshops and interviews was conducted to identify costs and charges information gaps and priorities. The consultation involved transport partners, transport modellers, policy professionals and transport industry groups. Phase One was completed in September 2008. The full and summary reports are available from the Ministry of Transport's website.

In early 2009, a project taskforce (made up of a Steering group, a project management team, working groups and the industry advisory group) was established to commence the work associated with Phase Two.

The Phase Two work plan can be summarised in the following diagram:



As part of the deliverables for Phase Two, the Ministry conducted this literature review on valuation methodologies for estimating social and environmental costs. This review will assist the quantification and valuation of the social and environmental costs of transport use by mode. An earlier version of this literature review was circulated to the project taskforce for discussion at a technical workshop convened in mid-May 2009.

This is the final version of the literature review. We trust you will find it useful.



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 Project Sponsor
 General Manager Road and Rail

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Disclaimer

This publication represents the opinions and research results of the author and the working group members but does not necessarily represent the views of the Ministry of Transport. While every effort has been made to ensure the accuracy of the material and the integrity of the analysis, readers should rely on their own skill and judgement in applying the information it contains to particular issues.

Executive summary

In this report, we have reviewed the methodologies, frameworks or approaches for valuing social and environmental costs, and recommended the best approaches to adopt given the inevitable time and resource constraints.

The topics of social and environmental impacts that we have covered include: road congestion; greenhouse gas emissions; harmful emissions; accidents; transport noise; and other social and environmental impacts. In each of these topics, we have also discussed briefly the rationale for collection and carried out a literature review on methodologies. We also looked at the current NZ practice and issues for collection.

Rationale

In terms of the policy context, estimation of the social and environmental costs of transport use is useful for three reasons:

- First, such information helps us to understand the current state of the social and environmental impacts and to analyse any trend or patterns.
- Second, such estimates are required to determine the potential benefits from mitigation. When social costs information is used together with estimates of other costs and benefits, policy makers can judge whether or not individual projects and programmes are worthwhile.
- Finally, understanding the marginal external cost is also important for understanding the extent to which pricing could bring about a better utilisation of the existing transport network, and mitigate the negative effects of transport use.

Due to the potential magnitude of their effects, this report focuses mainly on road congestion, greenhouse gas emissions, harmful emissions, accidents and the noise effects of transport use.

- Road congestion imposes significant social costs on the economy by lengthening average journey times, making trip travel times less predictable, and making vehicle operation less efficient (and results in increased emissions and the associated negative health impacts). Severe urban congestion increases the transport cost of freight and can affect the health status of commuters (e.g. stress-related illnesses). The previous study estimated that, in 2001/02, the total cost of congestion delays (compared to free-flow speeds) in New Zealand was \$1 billion.
- Human activities have an impact on the concentration of greenhouse gases in the atmosphere, primarily carbon dioxide from burning fossil fuels. The concentration of greenhouse gases has a direct influence on the climate and hence on global warming. The impacts from climate change can include (but are not limited to) increases in the frequency and intensity of extreme weather events, the altered spatial distribution of infectious disease vectors, increased

sea-levels and coastal erosion, changes in precipitation and biodiversity, and the progressive acidification of oceans. The transport sector contributes to around 20% of New Zealand's total greenhouse gas emissions.

- Apart from the emission of greenhouse gases, the use of fossil fuels in transport also produces harmful emissions. The effects of these emissions include chronic obstructive pulmonary disease, altered lung function and lung cancer, cardio-pulmonary and heart disease, and leukaemia. A previous New Zealand study estimated that transport emissions contributed to over 400 premature deaths (or approximately 45% from all sources), and over 500 cases of respiratory disease, annually. Some of these effects arise from the aggravation of existing respiratory and cardiac conditions. Therefore, the social cost of harmful emissions is significant.
- Over the last five years, on average, approximately 400 New Zealanders have been killed on our roads each year. The NZ Police also recorded another 2,500 people who were seriously injured and 13,000 people with minor injuries. Furthermore, each year around 40 people are killed and approximately 100 people are injured (reported numbers only), as a result of rail and maritime incidents. Transport injuries result in a significant medical burden, loss of life quality and economic loss to the economy.

Road congestion

- Congestion is commonly defined as the excess travel time relative to time in 'free-flow' conditions. However, this definition is not particularly useful for policy purposes as it would be too costly and inefficient to bring all traffic up to free-flow speeds at all times. A more appropriate approach is to compare congested situations with that at the economically most efficient level of traffic for the existing road network (the deadweight loss approach).
- Unit value of time (VOT), the value road users place on the time spent on travel, is an important input for determining the cost of congestion delays. In New Zealand, the Economic Evaluation Manual's (EEM) standard VOT savings are based primarily on a willingness-to-pay study conducted for the New Zealand Transport Agency in 2001/02.
- At present, the EEM uses different VOTs for public transport (PT) users and non-public transport users. However, there may be cause for doubting this approach (especially for commuting travel in urban cities). Many argue that the VOT for an individual should not differ due to the choice of transport mode. In 2008, the NZTA amended the EEM to include provision for travel time equity values for people changing to active and shared modes. It remains unclear whether or not equity values should also be used for more general applications.
- Journey time reliability is also an important component in determining the cost of travel delays, in particular the non-recurrent component. There are several measures of journey time variability. At present the EEM values reliability improvements in relation to the reduction in the standard deviation of journey time, using values per minute reduction in the standard deviation of: 0.8

minute of in-vehicle VOT for car and public transport: 0.9 minute for calculating the value of reliability based on a typical urban traffic mix; and 1.2 minutes in-vehicle VOT for commercial vehicles.

- Recommendations:
 - Value of time – The EEM’s VOT estimates should be utilised for the calculation.
 - Value of time for PT users – Two sets of estimates should be used to gauge the likely impact on the cost of congestion.
 - (1) The EEM’s estimates
 - (2) The same VOT for all passenger transport (private and public) modes.
 - Definition of congestion – The STCC’s definition (relative to free-flow conditions) should be used in the first instance. However, we should also adopt an alternate definition by using the congestion threshold approach and the deadweight loss approach (relative to the optimal level of congestion on the existing network). Applying the three approaches will give us a range of estimates to gauge the potential scale of the problem.
 - Journey time reliability – Two sets of estimates should be used to gauge the likely impacts:
 - (1) the mean-variance approach (one standard deviation compared to mean travel time)
 - (2) the 80th to 90th percentile compared to median travel time.

Greenhouse gas (GHG) emissions

- There are four common approaches to estimate the costs of GHG emissions. The carbon price approach measures mainly the potential Kyoto liability. The mitigation cost approach measures the costs of mitigation rather than the consequences. We could potentially obtain comparable estimates under the impact pathway approach and the benefit transfer approach. But the benefit transfer approach is not a stand-alone method, it simply utilises the findings of other methods.
- Ideally the impact pathway approach is the appropriate approach to use for valuing the environmental impacts of GHG. Unfortunately, the New Zealand-specific dose-response relationships have not been developed, so analysis in New Zealand is somewhat dependent on the dose-response relationships that have been calibrated for different populations.
- Currently the EEM uses \$40 per tonne (at 2004 dollars) of carbon dioxide (CO₂) to value the cost of GHG emissions; this equates to approximately 12 cents per litre of fuel. An alternative approach, as suggested in the EEM, is to value the cost at 4% of total vehicle operating costs for the default traffic composition.
- In terms of estimating the quantum of impacts, it is difficult to differentiate the impacts from transport alone due to the co-existence of several emission sources (such as household, industrial and agricultural emissions).

- There is also a difficulty with separating out the global and local emission sources as well as their impacts. For global emission effects, the impacts are not identical for different regions. There may be some initial benefits to parts of New Zealand for the production of agriculture and forestry products. These factors will need to be considered when using a benefit transfer approach to estimate the unit value of GHG effects.
- The Ministry of Economic Development (MED) estimated that, in the year 2001, transport contributed to nearly 14 million tonnes of carbon dioxide equivalent (CO₂e), with road transport contributing around 90% of CO₂e, followed by aviation (5%) and rail and maritime.
- For estimating the unit cost of climate change, we recommend using:
 - a benefit transfer approach to gauge the climate change impact
 - the carbon price to estimate the total carbon costs for reference purposes.

Harmful emissions

- There are three common approaches to estimating the costs of harmful emissions. The impact pathway approach only determines the impact patterns, while the contingent valuation approach can determine a unit value of mortality or morbidity. The benefit transfer approach could be used for determining either the impact patterns or the unit value of health effects.
- Ideally the impact pathway approach is the appropriate one to use for valuing the environmental impacts of harmful emissions. Unfortunately, the New Zealand-specific dose-response relationships have not been developed, so analysis in New Zealand is somewhat dependent on the dose-response relationships that have been calibrated for different populations.
- The EEM provides two valuation approaches for monetising harmful emission effects.
 - \$40 per person per year exposed per PM10 microgram/m³
 - a 0.101% increase in daily death rates for a one microgram per m³ increase in PM10.
- The STCC study adopted two variations of the benefit transfer approach in estimating the impact of air quality on human health. The first approach utilised Australian damage cost estimates (converted to NZ dollars and adjusting for differences in population density) and gave a total annual road transport air pollution cost of around \$440m. The second approach utilised a European dose-response function, an annualised value of statistical life and an average 14 years of life lost, and gave a total annual road transport air pollution cost of around \$480m. Both estimates are for 2001/02.
- The STCC report did not, however, look at the health effects of air quality on morbidity, which could add another 30% to the total.
- In terms of estimating the quantum of impacts, it is difficult to differentiate the impacts from transport alone due to the co-existence of several emission sources (such as household, industrial and agricultural emissions).

- Recommendations:
 - Adopt a benefit transfer approach (based on the latest NZ and Australian studies), in conjunction with revised energy consumption estimates, to estimate the impact of harmful emissions on human health.
 - In terms of the valuation of morbidity and mortality, the current value of statistical life established for the safety area (and a variation using a meta-analysis) will be utilised to derive the value per year of life lost.
 - In terms of updating the average number of life years lost due to harmful emissions, and the average age of those affected, NZ Health Information Services data will need to be collected.

Accidents

- The social costs of road crashes and the associated injuries include a number of different components: loss of life and life quality; loss of output due to temporary incapacitation; medical costs; legal costs; and property damage costs. Injury costs are classified into fatal, serious and minor injuries as reported by crash investigators.
- The cost of pain and suffering due to the loss of an unidentified life from a road crash is estimated by the amount of money the New Zealand population would be willing to pay for a safety improvement that results in the expected avoidance of one premature death (i.e. the willingness-to-pay-based value of statistical life, or VOSL).
- The VOSL was established at \$2 million in 1991. This has been indexed to the average hourly earnings (ordinary time) to express the value in current dollars. The updated VOSL is \$3.35 million, at June 2008 prices. The current VOSL is now very out-dated and is low by international standards. Therefore, a review is necessary.
- Due to a lack of data and information, each of the other social cost components (including loss of life and life quality) was estimated based on a number of studies conducted during the early to mid-1990s, and was updated for price changes by indexing it to a certain price index. Research commitment is required to update each of the social cost components based on more up-to-date information.
- Research is also required to collect better information on costs of property damage due to road, rail and maritime accidents. Estimates of the costs associated with damage to port infrastructure, carriages, wagons or vessels are currently not publicly available. However, some sample estimates could be obtained from ports or KiwiRail.
- The current estimates of social costs of road crashes and injury do not include costs of travel delays due to road crashes. The cost of travel delays includes additional travel time, additional fuel usage and potential loss of business opportunities. Investigation is necessary for assessing the impact of accident-induced delays on journey time reliability.

- The level of reporting is not the same across the country. The Ministry estimates the number of non-reported injuries based on data obtained from Traffic Crash Reports, the NZ Health Information Service's hospitalisation data, and the Accident Compensation Corporation's motor vehicle claims data. However, there is not enough information to determine whether reported and non-reported injuries of the same injury severity (i.e. fatal, serious or minor) should have the same average social cost per injury.
- Recommendations:
 - VOSL – Carry out a meta-analysis of WTP-based VOSL for overseas countries to obtain an alternative VOSL. Together with the existing value, this will provide a range of accident cost estimates.
 - Non-VOSL components – Due to the tight timeframe and resource constraints, it is recommended to focus on lost output and productivity component.
 - Valuing reported and unreported injuries – Continue with the existing approach but further collaboration with the health sector and the Accident Compensation Corporation should occur to improve such estimates in the longer term.

Noise

- There are four common approaches for valuing the impact of transport-related noise. The impact pathway approach only determines the impact patterns. The mitigation cost approach measures the costs of mitigation rather than the consequences. The hedonic pricing approach values the negative influence of road noise and vibrations on house prices. The benefit transfer approach could be used for determining either the impact patterns or the unit value of health effects.
- The EEM recommends that the noise effects should be assessed as 1.2% of the value of properties affected per dB of noise increase. In 2008, this was equivalent to \$3,924 per dB per property, and \$1,500 per dB per resident affected, based on a median house price of \$327,000 and average occupancy of 2.6 persons (NZTA, 2008). The EEM also recommends that a national median be applied in all areas, as there is no reason to suppose that noise is less annoying to those in areas with low house prices. For simplicity, this is also applied to any increase above existing ambient noise levels.
- The most important determinant of the cost of noise pollution is the size of the problem. During 2001 and 2002, the Ministry of Transport commissioned Sinclair Knight Merz (SKM) to develop a National Noise Impact Analysis Model (NNIAM) for building an inventory or quantitative model of noise emissions from road and rail sources in New Zealand. Further investigation is required to understand whether this model can be utilised and updated to help establish the baseline noise exposure at the regional or national levels.

- Recommendations:
 - Review the appropriateness of the Noise Depreciation Index (NDI) developed in LTPS-EE (1996) for current use
 - Adopt the STCC approach, with refined assumptions on noise thresholds and updated valuations as per the EEM to generate one set of estimates (for baseline comparison purposes)
 - Further investigate whether SKM's *National Noise Impact Analysis Model* can be utilised and updated to help establish the baseline noise exposure at the regional or national levels, and for estimating the costs of noise (hopefully to obtain an alternative set of estimates)
 - Due to time and resource constraints, vibration effects should be investigated outside the UTCC workstream.

1. Introduction

This working paper reviews the methodologies, frameworks or approaches for valuing social and environmental costs. This is the first of a series of working papers related to Phase Two of the Understanding Transport Costs and Charges (UTCC) project, and represents the first task required to complete the Social and Environmental Costs workstream. It is anticipated that a technical report will be completed for the data collection and estimation stage, which will include developing methods to quantify various impacts and apply the valuation methodologies in practice to estimate the costs.

The major purpose of this working paper is to recommend appropriate methodologies or approaches for valuing social and environmental costs, considering the time and resource constraints involved. It must be stressed that the intention is not to invent new methodologies, but to make appropriate improvements (from the STCC approach) and develop transparent frameworks using existing methodologies, where appropriate. Therefore, the recommended approach for a particular cost component does not necessarily represent the best approach to adopt, but the best approach given the time and resource constraints. In order to obtain the best estimate possible, where appropriate, we will recommend further research needed to inform the research community.

This paper is organised as follows. In the next section, we will discuss the assessment criteria and scope. Sections 2 to 7 will cover the six major groups of the social and environmental costs of transport. They are:

- Costs of congestion
- Costs of greenhouse gas emissions
- Costs of harmful emissions
- Costs of accidents
- Costs of transport noise
- Other social and environmental costs.

Each of Sections 2 to 7 will cover the following:

- Rationale for collection
- Literature review
- Current New Zealand practice
- Data requirements
- Questions for discussion
- Recommendations.

Section 8 discusses the interactions of effects and Section 9 covers the other social and environmental costs. Section 10 summarises the findings and recommendations. A summary of the main findings of NZIER's report entitled "*Externalities – Methods for Attributing Costs between Internal and External Components*" is provided in Appendix I. In Appendix II, we provide details of the working group members and the expert panel, and their contributions and areas of expertise.

2. Study scope

This literature review focuses on the valuation methodologies for estimating the social and environmental costs associated with domestic road, rail and maritime transport. While methods for estimating the quantum of the impacts are also important, they are typically constrained by the data available and often require the use of modelling tools. A detailed assessment of appropriate measurement methodologies will take place at the data collection and estimation stage.

2.1 Coverage

2.1.1 *Economic and financial costs*

For understanding the full costs of transport, we need to understand both the financial and non-financial costs. In economics, this is often referred to as the “economic cost” or “social cost”.

The exact cost components to be included under each social and environmental cost topic will depend on the nature of the impacts. For example, the social (or full) cost of congestion delays includes the value of time lost, vehicle operating costs and the costs of emissions. For environmental effects, the social cost includes climate change impacts (for greenhouse gas emissions), loss of environmental quality, health effects, and loss of life and life quality. The social cost of injuries includes the value of loss of life and life quality, the value of time lost, loss of output, medical and rehabilitation costs, legal and investigation costs, and property damage.

2.1.2 *Consequential and preventive costs*

Although the full cost of transport includes both the costs of preventive measures and the consequential costs, this literature review will focus on consequential costs only. Preventive costs (such as the costs associated with Police enforcement) will be covered under other UTCC workstreams.

2.1.3 *Internal and external costs*

It must be stressed that the social and environmental cost is not the same as externalities. In fact, externalities do not always refer to costs. There are also positive externalities from transport use (e.g. agglomeration benefits). However, positive externalities are not the subject of this review. Therefore, this review focuses on the negative externalities related to the social and environmental costs of transport use and does not cover infrastructure externalities, the costs road users impose on infrastructure providers.

For many policy decisions such as those relating to mitigation and intervention, it is important to know the size of the potential problem and the scope of any improvements, especially for safety analyses. To assess these, the total costs of any social and environmental impacts would be required. In other situations, what we are interested in would be the external costs road users imposed on others, and ways to

reduce them. Therefore, this literature review covers both the total (i.e. internal plus external) and the external costs of social and environmental impacts.

As identified in UTCC Phase One, the method for attributing social and environmental costs of transport use between internal and external components is of high priority¹.

For congestion, while individuals impose costs on everyone else, in aggregate terms, the majority of the costs of congestion are borne by all road users as a group (in terms of their travel time and vehicle operating costs). For environmental impacts, however, the majority of the costs are borne by society. Individual road users only bear a small portion of the costs. Within this subject area, the methodology for separating the accident costs internalised by road users from the external component is of particular importance.

Due to the complexity of the subject, the New Zealand Institute of Economic Research (2009) investigated this in detail for all the social and environmental cost components and the three transport modes. A summary of the main findings is provided in Appendix I.

2.1.4 *Average, total and marginal costs*

Average, total and marginal costs of transport use are useful for different purposes and are, therefore, required for wide-ranging policy development work.

- **Total and average costs of transport use** can help us to gauge the size of a transport problem and the potential benefits from mitigation. Average cost estimates are typically used together with incremental effects to generate estimates of incremental costs (or benefits from mitigation).

Total cost is typically made up of fixed and variable cost components. Therefore, average cost also includes both fixed and variable cost components. In theory, average cost per VKT is obtained by averaging the total cost for all road users across the total VKT of those users.

In practice, estimates of the average cost of transport use are typically generated using transport modelling tools and obtained by comparing the average cost (per VKT) between situations with different traffic flows. Average cost can be obtained for the traffic volume on a specific link (or corridor) during a specific time period, or for the network as a whole.

- Information on **marginal cost of transport use** is useful for informing pricing and charging-related policy decisions. When used together with the total cost estimates, forecasted demand and the factors affecting demand, we can derive estimates of the level of cost recovery from marginal cost-based pricing. In theory, the marginal cost of travel is obtained by taking the first-order derivative of the total cost of travel with respect to the quantity of travel. In the short run, i.e. at given levels of infrastructure and capacity, the marginal cost of transport use

¹ See section 6.2.1 of the UTCC Phase One report.

only includes the variable cost component. In the long run, costs that are defined as fixed in the short run will become variable and therefore form part of the long-run marginal cost. The distinction between short- and long-run marginal costs is relevant in the context of efficient charging.

In practice, calculation of the marginal cost of transport use is more complex and it is typically generated with the aid of transport modelling tools. The marginal cost of transport use can be obtained for the traffic volume on a specific link (or corridor) during a specific time period, or for the network as a whole.

2.2 Criteria for inclusion

Transport can result in a number of different social and environmental impacts. Some of these impacts are material, while others may have longer-term implications. However, not all these impacts can easily be quantified, identified or measured in monetary terms.

To help ensure our limited resources are used efficiently in the investigation, the following criteria have been developed based on earlier studies by Transit New Zealand (1992, 1993 and 1998):

- The potential **scale** of the effect – global, regional or local
- The potential **intensity** of the effect, considering the probability of occurrence and potential size of the impact
- The potential **duration** of the effect – temporary or permanent (irreversible)
- The **frequency** of the effect – ongoing or intermittent
- Any **cumulative effect** which arises over time or in combination with other effects, regardless of the scale, intensity, duration and frequency of the effect
- Affecting the long-term goal of **sustainable management** of natural and physical resources
- Associated with **trade-offs** against other social and environmental effects – e.g. the removal of lead from petrol has resulted in an increase in CO₂ levels emitted from vehicles
- Scope for improvement and suitable for **mitigation**
- A real **externality** cost or a transfer cost – i.e. is the cost incurred by those who are not involved in transport use?

Based on these criteria, the working group has assessed the relative size and scale of various social and environmental impacts. The results are discussed in the next section.

2.3 Inside scope

This review initially considered the following effects for all the three modes, as identified in the UTCC Phase One report (UTCC priority in brackets):

- Congestion (first priority)
- GHG emissions (first priority)
- Harmful emissions (first priority)
- Accidents (second priority)
- Noise (third priority)
- Other social and environmental effects:
 - Bio-security (fourth priority)
 - Run-off and water quality (fourth priority).

During the investigation process, the working group has also identified several effects that may warrant further investigation. These include:

- Other social and environmental effects:
 - Vibration
 - Spills
 - Operational discharges and waste disposal.
- Upstream and downstream effects – this refers to indirect costs of transport including energy production, vehicle production and maintenance, and infrastructure construction and maintenance
 - Upstream effects – energy production and infrastructure construction and maintenance
 - Downstream effects – end-of-life waste management.

Table 2.1 shows an initial assessment of the potential size and scale of various effects. The working group members believe that road transport would account for the majority of the mainstream social and environmental costs (congestion, accidents, emissions and noise impacts). This is likely to reflect the relatively high level of road transport use compared to other modes. However, for spills, water quality and bio-security, the working group members believe that the majority of such costs would fall under maritime transport.

In view of this initial assessment, this paper will cover in detail congestion, accidents, emissions and noise impacts. For other social and environmental cost items, we will discuss the information currently existing and recommend areas for further research.

Table 2.1: An initial assessment by the working group members of potential size and scale of social and environmental impacts

Social and environmental impacts	Scale of effects (Local, regional or global)	Transport mode (road, rail & maritime)	Potential intensity		Duration: Temporary or permanent	Frequency	With cumulative effects = Y	Effects on sustainable management	Interact with other effects	Scope for mitigation	Size of external effects	
			Chance of occurrence	Size of impact								
Congestion	Local	Road	H	M	temporary	intermittent		M	M	H	M	
		Rail & maritime	M	M				L	L	L	L	
Accidents	Local	Road	H	H	both	intermittent		L	L	H	H	
		Rail & maritime	M						M	M		
GHG emissions	Global	Road	H	H	permanent	on-going	Y	H	H	H	H	
		Rail & maritime		M				M	M			
Harmful emissions	Local *	Road	H	H	both	on-going	Y	H	H	H	H	
		Rail & maritime	M	M		intermittent		M	M	M		
Noise	Local	Road	H	H	both	on-going	Y	M	H	M	H	
		Rail & maritime	M	M	temporary	intermittent		L	M			
Vibration	Local	All modes	M	L – M	temporary	intermittent		L	L	L – M	H	
Run-off and water quality	Spills	Local *	Road & rail	L – M	M	temporary	intermittent	H	L	L	M	
			Maritime	M	H	both	intermittent		M	M	H	
	Operational discharges	Local *	Road & rail	L	L – M	temporary	on-going	Y	H	M	M	L
			Maritime	H	M	both	intermittent					M
Run-off	Local	Road & rail	M	M	temporary	on-going		H	M	M	M	
Bio-security and bio-diversity	Local *	Road	M	M	both	intermittent	Y	H	H	M	H	
		Rail	L	L					L	M	L	
		Maritime	H	H					H	M	H	
Upstream and downstream effects	energy production / infrastructure construction	Global	Road	H	both	on-going		M	M	M	H	
			Rail								L	M
			Maritime								M	H
	End of life disposal	Local *	Road	H	permanent	on-going		H	H	H	M	H
			Rail									L
			Maritime									M

An * Indicates the effect can be both local and regional for maritime transport.

L – Low; M – Medium; H – High.

Note: This table shows the subjective assessment by the working group members, who are technical or policy experts in related fields.

2.4 Outside scope

The following items are outside the scope of this workstream:

- preventive costs (to be covered under other UTCC workstreams)
- infrastructure and other operational externalities (to be covered under other UTCC workstreams)
- aviation transport
- social impacts (e.g. isolation) (not to be covered under the UTCC project)
- health benefits of transport use (not to be covered under the UTCC project)
- wider economic effects of transport use (not to be covered under the UTCC project).

Due to time and resource constraints, we have not investigated the following effects:

- Visual effects (including the temporary effect of construction and other effects on the quality of the landscape)
- Effects on physical landscape (e.g. on land stability and soil erosion)
- Cultural, spiritual, historic and Treaty of Waitangi effects, including archaeological effects
- Effects on recreation values (including loss of public open spaces such as parks, beaches and reserves)
- Lighting effects (e.g. vehicle headlights or street lights shining on to property)
- Community severance and local accessibility
- Community disruption/disturbance (particularly due to infrastructure construction work)
- Effects on land use and subsequent impacts on urban sustainability
- Effects on personal safety and security (except for accident risks)
- Effects on a range of transport-dependent industries.

The scale of the above effects is either difficult to ascertain, difficult to separate from other impacts, or unknown.

2.5 Valuation methodologies

2.5.1 *An overview of non-market valuation methodologies*

As most of the social and environmental costs are not directly measurable, these costs are typically estimated using non-market valuation methodologies. Examples of non-market valuation methodologies include the willingness-to-pay/accept approach, the impact pathway approach and the benefit transfer approach. These are discussed briefly below.

- **Willingness-To-Pay/Accept (WTP/WTA) Approach** – There are three accepted methods for the WTP approach. The first method involves either asking respondents directly about their willingness to pay for (or accept) a good or

services (or for the removal of a good or services). For example, *contingent valuation* is a typical *expressed WTP* (or stated preference) method, commonly used in the safety area. *Conjoint analysis* is another stated preference approach typically used in valuing travel time savings.

The second method involves asking respondents to trade off between alternatives so as to reveal their WTP. The *hedonic pricing approach* is an example of a revealed preference method.

The third approach is the *imputed WTP*, such as the *mitigation cost approach* (e.g. WTP to purchase safety equipment to reduce the risk). Under this approach, a WTP is imputed after the actual transaction of good and services.

The major merits of a WTP (or WTA) approach are the ability to use a survey to obtain estimates that reflect an individual's WTP for the costs and benefits of goods that are bought and sold in markets. The WTP/WTA methods are very flexible and can be tailor-made to cater for a range of non-market valuation situations, such as non-use, passive use and option values.

Although the WTP approach has been widely used, it is still subject to debate about its ability to measure individuals' WTP for safety and environmental quality. However, a lot of work has also been conducted to improve these techniques to make the results more valid and reliable, and better understand their strengths and limitations.

We shall briefly discuss the contingent valuation, revealed preference, hedonic pricing and mitigation cost approaches below.

- **Contingent valuation (CV) Approach** – This approach uses a survey to ask respondents directly about their WTP for specific safety or environmental improvements. Its major advantage is that this method has been widely used and results based on good quality surveys are generally more valid and reliable. Guria et al. (2003) noted that the major limitations of a CV method include:
 - presence of protest bid (non-responding, extreme low or high values)
 - difference in survey results from actual behaviour
 - payment vehicle (e.g. general taxes versus fuel taxes) may affect results
 - embedding effects – results not sensitive to the scale of the problem
 - ordering problems – results depend on the sequence of the questions.

- **Conjoint analysis**² – This approach is similar to the contingent valuation but, instead of asking about individuals' WTP, it asks people to make trade-offs between alternatives. This approach can be used to value the outcomes of an action as a whole, and allow respondents to make explicit trade-offs. Proponents prefer this approach because sometimes it may be easier for respondents to provide a ranking than provide a price. Its limitations include:

² Source of the discussion: [http://www.ecosystemvaluation.org/contingent choice.htm](http://www.ecosystemvaluation.org/contingent_choice.htm) (accessed 11 May 2009).

- the difficulty for respondents to accurately evaluate trade-offs
 - the lack of clear information regarding the behaviour behind the results
 - possible fatigue effects, especially if the number of attributes (and hence the comparisons to be made) is high
 - any disparity between the choices available to respondents and the factors individuals would consider
 - uncertainty with the translation of the results to monetary values.
- **Hedonic pricing approach**³ – This approach is used to estimate economic values for environmental impacts that directly affect market prices. It is most commonly applied to variations in house prices that reflect the value of local environmental attributes, such as noise pollution (e.g. Austroads, 2003; LTNZ, 2006; Austroads, 2009d).

The major advantage of this approach is that it is relatively straightforward and uncontroversial to apply, because it is based on actual market prices and fairly easily measured data. If the data are readily available, it can be relatively inexpensive to apply. If the data must be gathered and compiled, the cost of application can increase substantially.

However, this approach is limited to things that are related to housing prices. Also, it will only capture individuals' willingness to pay for perceived differences in environmental attributes, and their direct consequences. Thus, if people are not aware of the linkages between the environmental attributes and benefits to themselves or their property, the value will not be reflected in house prices.

- **Mitigation Cost Approach** – This is sometimes referred to as the '*Control or Avoidance Cost approach*'. This approach is based on the costs of mitigating or avoiding damage. This approach is relatively easy to measure and less data and resource intensive. It is therefore very useful when more detailed WTP studies are not viable. However, mitigation costs are not the same as consequential costs; the former is affected by the level of improvements required, which may cost more than the benefits of reduction. Further, the resulting estimates are not necessarily consistent with the social preference approach.
- **Impact Pathway Approach** – This is sometimes referred to as the '*Damage Cost approach*'. ExternE (2005) illustrated the principal steps of an impact pathway analysis as including the following:
 - Specification of the relevant technologies and pollutants
 - Calculation of increased pollutant concentrations in all affected regions
 - Calculation of the dose from the increased concentration, followed by calculation of impacts (damage in physical units) from this dose (using a dose-response function)
 - Economic valuation of these impacts by applying a unit value to the physical units.

³ Source of the discussion: http://www.encora.eu/coastalwiki/Hedonic_Evaluation_Approach and http://www.ecosystemvaluation.org/hedonic_pricing.htm (accessed 10 May 2009).

2.5.2 *Benefit transfer approach*⁴

When it is not possible to conduct a large-scale survey, or when there is a lack of data for applying the above methods, a **benefit transfer approach** may be used. In estimating the social cost of transport use, Austroads (2003), Quinet (2004) and Austroads (2009d) all applied a benefit transfer approach.

The benefit transfer approach operates by transferring values in some way from existing valuation studies to a target study of interest. This is done by transferring available information from studies already completed in another location, jurisdiction and/or context, with appropriate conversions to account for differences in population density and purchasing power parity, etc. For pollution impacts, the conversion should also take into account any differences in baseline pollution levels. There are four ways to perform a benefit transfer process⁵:

- transfer a single value without adjustment from a source study to a target site/area
- transfer a single value allowing for site differences
- adopt a benefit valuation function, allowing adjustment for a variety of site differences
- combine the results of several studies to generate a pooled model (or a meta-analysis) (e.g. Quinet, 2004).

The major advantages are that the benefit transfer approach is less costly to conduct, and can be estimated more quickly than undertaking an original study. It can also act as a screening method prior to determining whether to conduct a specific approach.

However, it may not be accurate unless site and location characteristics are the same between the origin study (typically European studies) and the application. It is only as accurate as the initial value estimates, and there are also issues with timeliness and how the estimates are converted to NZ values.

2.5.3 *Criteria for selecting an appropriate method*

It is difficult to determine the economic value of social and environmental effects because these raise questions about equity and validity. The selection of appropriate valuation methodologies/approaches will need to consider the following aspects:

- **Consistency** – it should be capable of being applied consistently across modes and over time, but note that achieving consistency does not necessarily imply the use of identical valuation estimates. The decision on these will need to consider data availability, the similarities and differences between modes, and the logic of their inclusion.

⁴ Source of the discussion: http://www.ecosystemvaluation.org/benefit_transfer.htm (accessed 10 May 2009).

⁵Source: CQ University of Australia, *A Systematic Database for Benefit Transfer of NRM Values in Queensland* <http://resourceeconomics.cqu.edu.au/FCWViewer/view.do?page=2598> (accessed 29 April 2009)

- **Reliability and validity** – the method needs to be acceptable to professional technicians and experts. The assumptions and value judgements used should be explicit.
- **Technical complexity** – we need to seek a balance between the theoretical and practical aspects.
- **Time and resource cost** – we need to consider limited financial and technical resources.

3. Congestion

This literature review will cover methodologies for estimating the total, average and marginal costs of road congestion, for both recurrent and non-recurrent delays, and briefly discuss what kind of analyses require the total, average and marginal cost estimates.

Congestion delays that are caused by operational deficits (e.g. signal failures causing delays for train services or the allocation of wharf spaces due to loading/unloading delays) are not counted as social and environmental costs but as operational externalities. They will be investigated under other workstreams. As congestion delays associated with rail and maritime transport occur mainly as a result of operational constraints, this literature review only covers road congestion.

Road congestion is typically defined as “*the excess travel time relative to time in ‘free-flow’ conditions*” (e.g. STCC, 2005). There have been some debates about the appropriateness of such a definition. We shall explore this further in this section.

The two main types of road congestion are recurrent and non-recurrent congestion. Recurrent congestion occurs regularly around the same locations on the network and, in the case of urban congestion, at around the same time periods. Such congestion is predictable to some extent, even if its day to day impact may vary. On the other hand, non-recurrent congestion is less predictable because it is caused by events that do not occur with any consistent pattern, such as incidents and road works.

Arguably non-recurrent congestion is more disruptive than recurrent congestion because it is difficult to predict and mitigate, whereas transport users can alter their travel plans to factor in recurrent congestion effects (Naudé and Tsolakis 2006). Goodwin (2004) also commented that “*the really costly effect of congestion is not the slightly increased average time, but the greater than average effect in particular locations and markets, and the greatly increased unreliability*”. In Canada, total recurrent and total non-recurrent congestion costs are approximately equal (iTRANS, 2006).

For brevity, unless otherwise indicated, we shall refer to road congestion as congestion throughout this section.

3.1 Rationale for collection

3.1.1 Policy context

Estimation of the costs of road congestion is useful for three reasons:

- First, such information helps us to understand the current state of congestion (by time and location) and to analyse any trends or patterns.

- Second, such estimates are required to determine the potential benefits from mitigation. When the costs of congestion are used together with estimates of other costs and benefits, policy makers can judge whether or not individual projects and programmes are worthwhile.
- Finally, understanding the marginal congestion costs is also important for understanding the extent to which pricing could bring about a better utilisation of the existing transport network, and mitigate the congestion effects from excess demand.

3.1.2 *Magnitude of impacts*

Road congestion imposes significant social costs on the economy by lengthening average journey times, making trip travel times less predictable, and making vehicle operation less efficient. Severe urban congestion increases transport costs of freight and can affect the health status of commuters (e.g. stress-related illnesses). The STCC (2005) estimated that the total cost of congestion delays (compared to free-flow speeds) in New Zealand in 2001/02 was \$1 billion.

The social costs of road congestion have been well examined in the literature (e.g. BTRE, 2007 and IMPACT, 2008) and include the following components:

- Increased travel time due to urban congestion, particularly at peak periods
- Increased journey time variability due to incidents or events (especially for freight transport)
- Increased vehicle operating costs (e.g. fuel consumption) due to increased start-stop requirements
- Increased emissions (and associated negative health impacts) due to increased fuel consumption
- A potential to increase the occurrence of minor road crashes and reduce road crash severity.

In per-vehicle terms, larger and heavier vehicles cause more congestion than smaller, lighter vehicles because they require more road space and are slower to accelerate. In the New Zealand Transport Agency's Economic Evaluation Manual (EEM), a truck is counted as 1.7 passenger cars if the terrain type is level, and as eight passenger cars for mountainous terrain⁶. The scaling values are commonly referred to as passenger car-equivalent units (PCUs) (BTRE, 2007 and EEM, 2008).

The three major factors that affect the magnitude of the costs of road congestion are:

- The definition of congestion costs (e.g. total cost of delays relative to free-flow traffic, or total cost of optimal delays based on existing network)
- Unit value of time by user type, trip purpose, time of day and location, etc.
- The component of wider impacts to be included in the valuation (e.g. costs to businesses and to non-car travellers, etc) on top of the usual generalised cost calculations.

In section 3.2, we shall discuss these factors in more detail.

⁶ For details, see Chapter A3-9 of Volume 1 of the EEM.

3.2 Literature review

To estimate the costs of congestion involves two distinct pieces of analysis. First, we need to measure the amount of delays borne by transport users. Second, we need to estimate the value users place on these delays, i.e. the valuation of time delays or time savings.

Quantification of the amount of delays is particularly important for estimating the total or avoidable⁷ costs of congestion. For this, we would require estimates of the distributions of vehicle kilometres travelled for different user groups, locations and times of day. The levels of accuracy and disaggregation of the congestion impacts will depend on data availability. Such analysis can be more complex than unit valuation methods and typically requires the use of transport modelling tools.

While this literature review intends to focus on methods for determining the unit values of various road congestion effects, it is impossible to talk about congestion costs without discussing how the amount of delays is determined. Therefore, this review also looks at typical approaches for quantifying such impacts.

For valuation of congestion delays, the focus of this section is the time cost component. We shall also look at the methodologies for estimating congestion-related values of travel time (VOT) and journey time variability. VOT is the value road users place on the time spent on travel. Journey time variability is about the unpredictable variation in journey times.

For effects on vehicle operating costs, the valuation methodologies will be based on actual or average costs by mode or vehicle characteristic. For environmental and safety impacts, the valuation methodologies would be based on those discussed under the respective sections.

3.2.1 Full costs of congestion

Two different calculations of the full costs of congestion have been used by the international research community for valuing congestion costs:

- (i) The first calculation is the **total costs of congestion delays**. The motivation for obtaining such an estimate is to determine the size of the congestion problem and the potential benefits of significant investment decisions (e.g. Quinet, 2004; Safirova et al., 2007; Bilbao, 2008). Since travel costs include dollar values for both the financial and non-financial components (including vehicle operating costs, time costs and health effects from emissions, etc.), unless otherwise indicated we refer to generalised costs throughout the following discussion.

Most studies of the total costs of congestion delays typically focus on the differences in travel costs between travel at congested and **free-flow speeds**.

⁷ The avoidable cost of congestion is a measure of a potential reduction in congestion costs from intervention. This will be discussed further in section 3.2.1.

The total cost calculation described above is analogous to obtaining a zero level of congestion with existing volumes of traffic on an optimal network rather than on the existing network. Such calculations are useful for comparing congestion levels across different urban areas and their trends over time. However, they are not particularly useful for policy purposes since it would be too costly and inefficient to bring all traffic up to free-flow speeds at all times (e.g. Goodwin, 2004; Safirova et al., 2007; BTRE, 2007; VTPI, 2009).

While there have been numerous studies on congestion problems, both domestically and overseas, there has not been a consensus view on when congestion technically begins. The literature shows that there are other ways to measure the total cost of congestion delays without necessarily comparing them with perfect 'free-flow' conditions. For example, iTRANS (2006) evaluates the cost of congestion by comparing current traffic conditions with a pre-determined **congestion threshold**.

The threshold represents the point at which congestion becomes apparent and is deemed unacceptable, and is typically based upon a percentage of the free-flow speed. iTRANS noted that the congestion threshold definition can vary according to local conditions (quantitative) and perceptions (qualitative), and should correspond to traditional level-of-service boundaries used to identify the need for new capacity in long-term transport infrastructure plans. In their analysis, iTRANS looked at a range of threshold values at between 50% and 70% of the free-flow speed, and estimated that the total recurrent and non-recurrent costs of congestion in Canada in 2000 would have increased by 50% simply by changing the threshold⁸.

A major disadvantage of using the congestion threshold approach is that the determination of the threshold is subjective. However, for the purposes of understanding the scale of the congestion problem, this approach is preferable to using the free-flow approach. Further, sensitivity analyses could be carried out to gauge the congestion effects at different threshold levels.

Once the level of congestion is determined, such an estimate is then multiplied through with the retrospective unit value of travel time costs to obtain the time cost component of congestion delays. Vehicle operation costs, health effects and other related costs are then added to yield the total costs of congestion delays.

The STCC (2005) estimated that the total cost of congestion delays (compared to free-flow speeds) in New Zealand in 2001/02 was \$1 billion. In Australia, the BTRE (2007) estimated that, in 2005, the annual congestion delay cost (relative to free-flow conditions) was A\$11 billion (including Sydney A\$3.9 billion, Melbourne A\$3.6 billion and Brisbane A\$1.4 billion, all estimates excluding the costs of travel time variability). It must be stressed that:

⁸ The total costs of congestion in Canada in 2000 were estimated at C\$4.4 billion with a 50% threshold, and C\$6.7 billion for a 70% threshold (of the free-flow speed).

- international comparisons must be treated with caution since different countries are different in many respects – unit value of time, population profile, land-use patterns, the availability and quality of public transport services, etc.
 - the above congestion cost estimates are not directly comparable with measures of the real economy, such as Gross Domestic Product, because these estimates include intangible and non-financial components.
- (ii) A second calculation is what Australia's Bureau of Transport and Regional Economics (BTRE) called the 'avoidable cost of congestion' (BTRE, 2007). This calculation looks at the **deadweight losses (DWL)**⁹ associated with a particular congestion level. This gives a measure of how much total social costs could be reduced if traffic volumes were reduced, given the existing network.

The DWL is measured by the area under the marginal social cost curve and above the demand curve, comparing the current quantity of travel with that of the optimal level (or area under PQA in Figure 3.1). The corresponding total cost of congestion delays (compared to free-flow conditions) is the area under the marginal cost curve, less the generalised costs at free-flow conditions (or the area under TPC in Figure 3.1).

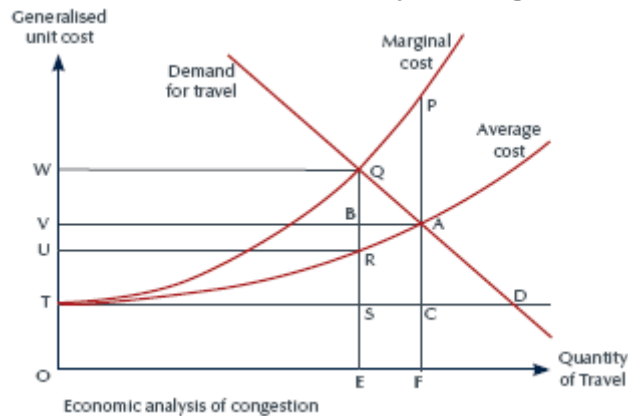
The DWL approach does not aim to estimate the cost of congestion at free-flow conditions, but at the economically most efficient level of traffic for the road network (iTRANS, 2006 and BTRE, 2007). Therefore, as can be seen from Figure 3.1, the DWL estimate is smaller than the estimated total costs of congestion (compared to free flow speeds).

The most efficient level of traffic is defined as that at which the generalised cost equals the marginal social cost (rather than the average cost). This is the equilibrium level at which road users also consider the cost of extra delays imposed on others in their travel decisions. There are several ways to achieve this. The most often discussed means is the use of congestion pricing or charging. However, an investigation of the merits of various travel demand management interventions is not part of the scope of this project.

The DWL approach is the most theoretically sound approach for understanding the full costs of congestion. The data requirement for this method includes estimates of the generalised cost of marginal delay caused by an additional vehicle entering the traffic stream, taking into account the speed-flow relationship of each road segment, and the price elasticity of travel demand.

⁹ In economics, deadweight loss is a measure of the welfare lost due to an inefficient allocation of resources. A loss of economic efficiency occurs when the equilibrium supply of, and demand for, a good or service is not Pareto optimal. In the presence of external cost, transport users would tend to demand a higher than the socially optimal level of a good or service, because they do not consider the resulting external cost in their decision-making process.

Figure 3.1: Basic economic theory of congestion costs



Source: BTRE (2007)

3.2.2 Average and marginal costs of congestion

When valuing the costs of congestion, we also need to consider the purpose of the analyses to determine whether it is the total, average or marginal costs that are relevant to the policy questions we are trying to address.

- The total and **average cost of congestion delays** (compared with either free-flow speeds or a congestion threshold) can help us to gauge the size of the congestion problems and the potential benefits from mitigation. Total cost is typically made up of fixed and variable cost components. Therefore, average cost also includes both fixed and variable cost components.

In theory, the average cost of congestion delays (per VKT) is obtained by averaging the total generalised cost of congestion delays for all road users across the total VKT of those users.

In practice, estimates of the average cost of congestion delays are typically generated using transport modelling tools, and are obtained by comparing the average cost (per VKT) between congested situations and less- or uncongested situations (depending on whether we are comparing the base situations with free flow conditions, or with certain congestion thresholds). The average cost of congestion delays can be obtained for the traffic volume on a specific link (or corridor) during a specific time period or for the network as a whole.

- **The marginal cost of congestion delays** is useful for informing congestion charging-related policy decisions (e.g. Quinet, 2004; Safirova et al., 2007; and Bilbao, 2008). Such information is also required for estimating the full costs of congestion using the deadweight loss approach.

In theory, the marginal cost of travel is obtained by taking the derivative of the total cost of travel with respect to the quantity of travel. Therefore, the marginal cost of congestion delays is the difference in the marginal cost of travel between congested and marginally less congested conditions.

In the short run, i.e. at a given level of infrastructure and capacity, the marginal cost of congestion only includes the variable cost component. In the long run, costs that are defined as fixed in the short run will become variable and therefore form part of the long-run marginal cost. The distinction between short- and long-run marginal costs is relevant in the context of efficient charging.

In practice, calculation of the marginal congestion cost is more complex and it is typically generated with the aid of transport modelling tools. In STCC (2005), the marginal cost of congestion per VKT equals the difference in the total cost of congestion between the existing traffic volume and a marginally-reduced traffic volume, and divided by the corresponding change in VKT.

The marginal congestion cost can be calculated on a link-by-link basis or over the network as a whole (Safirova et al., 2007). Estimates for a link-by-link approach do not account for any interaction between traffic congestion on different links on the network. Safirova et al. (2007) discussed two methods for adjusting network effects. Both methods require the use of transport modelling tools to adjust the distribution of traffic to take into account the congestion effects of one link on other links of the network.

The choice of estimation approach will depend on the uses made of such estimates. Safirova et al. (2007) concludes that the link-by-link method can be used to compute region-wide average levels of marginal congestion costs for determining aggregate policies. For localised policies, Safirova et al. (2007) recommends that a network approach would be more appropriate.

3.2.3 *Valuation of travel time costs*

Time is a limited resource. Both the consumer and labour-leisure trade-off theories suggest individuals do value their time when allocating their time budgets between work, leisure and other activities (e.g. consumption). As travel time also affects utility (or disutility), there is also a value placed on travel time. However, the value of travel time varies, not only with individuals but also with activities, the timing of trips and the value of the next best use of the time.

Value of travel time (VOT) is the value road users place on the time spent on travel. In the context of transport evaluation, VOT is typically used to estimate the potential benefits of a reduction in travel time. VOT is also used in valuing congestion delays, by multiplying through the congestion effects with the retrospective unit value of travel time costs.

The **willingness-to-pay (WTP)** based approach is typically used to determine VOT. Transport Canada (2008) discussed the two main WTP approaches; they are the 'revealed preference' approach and the 'stated preference' approach. Under the revealed preference approach, VOT is derived based on surveying road users on situations that have been identified where people appear to exercise a choice between two activities that incur different costs but save time. Under the stated

preference approach, VOT is derived based on surveys that ask road users to indicate their preferences for hypothetical travel cost and time alternatives. The stated preference approach was used to determine the VOT used in the Economic Evaluation Manual (EEM) (IWA, 2007b).

For trucks operating in congested conditions considerable lost time can result, leading to increased costs for driver wages (often absorbed by the driver) and fuel, and lost vehicle productivity. These differences are implicitly accounted for in the EEM's VOT estimates by vehicle and road user type.

3.2.4 *Journey time reliability*

International literature has found that road users often value the cost of unpredictability and unreliability of journey time higher than the average travel time of a journey (e.g. Bates et al., 2001; Goodwin, 2004).

To estimate the value of journey time reliability, it is necessary to first determine trip variability. Broadly speaking, there are two major types of delay that affect travel time variability – unexpected schedule delays and non-recurrent travel delays.

The effects of unexpected schedule delays are affected, not only by the probability but also by the duration, of such delays. For certain trip purposes, late arrivals can have significant consequences (e.g. missing a connecting flight) and result in additional costs to users. On the other hand, adding buffer time to journeys will add costs to users, especially if the buffer time is high (e.g. for journeys requiring interchanges). There will also be disutility (e.g. stress and anxiety) associated with increased waiting time.

Non-recurrent travel delays (e.g. road crashes) can affect car users, as well as the on-time performance of scheduled services, because these delays are unpredictable. Depending on the expectation of such variability, road users may add buffer times to ensure they arrive on time.

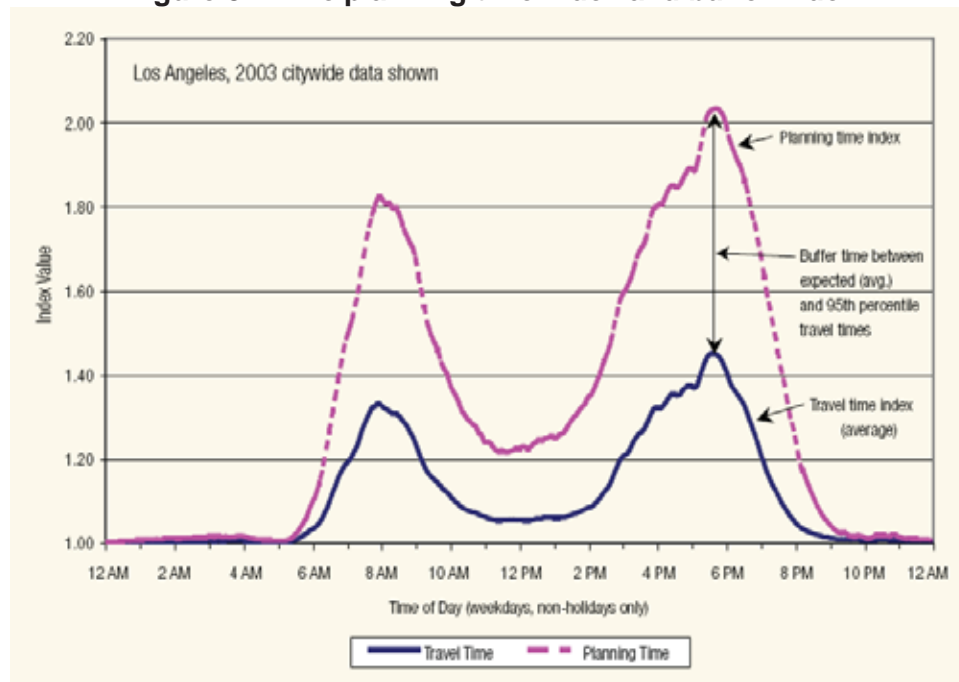
There are several measures of travel time reliability: the travel time index, planning time index and buffer index are three examples (e.g. FHA, 2006; TRB, 2008; CUTR, 2009). The travel time index simply refers to the indexed average travel time. The planning time index refers to the *total travel time* that should be planned for the trip when an adequate buffer time is included (FHA, 2006 and CUTR, 2009). Buffer time is the *additional time* allowed to ensure arrival on schedule most (e.g. 95%) of the time (FHA, 2006 and iTRANS, 2006). The relationships between the planning time index, the buffer index and the travel time index (average travel time indexed to one for free-flow period) are tabulated in Figure 3.2.

Furthermore, Warffemius (2005) identified three methods that have been used for deriving reliability performance indicators: (1) standard deviation against average travel time (also known as the mean-variance approach) (e.g. BTRE, 2007); (2) the difference between an 80th or 90th percentile and the median travel time; and (3) the number of minutes arriving early or late.

The most commonly-used approach is the mean-variance approach. This involves obtaining the difference between free-flow trip variability and the estimated average trip variability for various time periods, vehicle types and locations. BTRE (2007) noted that, while most studies are based on one standard deviation (approximately the 68th percentile) in travel time, engineering definitions of trip variability are commonly based on the 85th percentile (or 1.44 standard deviations).

Several international studies (e.g. Lam and Small, 2001 and CUTR, 2009), however, recommended the use of a range between the 80th and 90th percentiles (rather than one standard deviation) as a measure of travel time variability, and the median (rather than the mean) for travel time distribution. CUTR (2009) noted that the median (i.e. the 50th percentile) is the preferred measure of travel time distribution, especially when the travel time distribution is skewed (it is left-skewed if arriving late occurs more often than arriving early). Furthermore, van Lint et al. (2008) showed that the use of both the width and the skew of the travel time distribution can provide a more robust estimate of variability.

Figure 3.2: The planning time index and buffer index



Source: FHA (2006)

(http://www.ops.fhwa.dot.gov/publications/tt_reliability/long_descriptions/Figure4.htm)

In New Zealand, the EEM uses one standard deviation from mean travel time as the standard travel time variability measure. To correct for a likely overestimation of the changes in journey time reliability for a specific project (since, in many cases, a project evaluation will consider a defined area which does not represent the full length of most journeys), the EEM also provides adjustment factors of between 30% (intersection model or individual passing lane model) and 100% (regional model), depending on the transport network model's coverage.

To determine the value of journey time reliability, we need a unit value of travel time reliability. For a detail discussion on the subject, please refer to Lam and Small (2001), TRB (2008), Vincent (2008) and UCTR (2009). Listed below are some factors that can affect its value:

- Flexibility of arrival/departure time
- Probability of delays
- Expected duration of delays
- Trip purposes
- Demographic and socio-economic factors (e.g. income).

The definition of journey time reliability can affect the valuation methodology to use. There are three common modelling approaches for valuing trip variability – the mean delays model, the variance delays model and the scheduling model (Bates et al., 2001; Noland and Polak, 2002; Vincent, 2008; and CUTR, 2009). The choice of these approaches will depend on how reliability is defined. The first two approaches can be used for different modes and movements but the scheduling approach is only appropriate for scheduled travel.

The three models differ by the factors that enter the utility function. In the mean and variance delays models, utility is a function of the expected delays (mean delays model), or the standard deviation in delays (variance delays model). For modelling scheduled services using either the mean delays or the variance delays model, the scheduled travel time is typically added to the utility function. In the scheduling approach, utility is a function of expected travel time and variables (schedule delay early or late, and penalty for late arrival) that affect disutility. To obtain the monetary valuation of reliability, a cost variable is typically included in the utility function discussed above. From the trade-off between different attributes (such as travel time and its variability) and economic measures, the marginal rate of substitution between wealth and reliability can be estimated to form the basis for determining the value of reliability.

In New Zealand, a willingness-to-pay survey was conducted in 2001/02 (Beca, 2002) to estimate various benefit parameter values, including reliability. Unfortunately, due to the uncertainties associated with their results for journey time reliability, Beca (2002) recommended the adoption of the UK findings instead. As a result, the EEM values reliability improvements in relation to the reduction in the standard deviation of journey time, using values per minute reduction in standard deviation of 0.8 minute of in-vehicle VOT for car and public transport, and 1.2 minutes in-vehicle VOT for commercial vehicles (Beca, 2002, p. 1-7). The EEM also includes a factor of 0.9 for calculating the value of reliability based on a typical urban traffic mix (EEM volume 1, 2008, p. A4-13).

On the other hand, CUTR (2009) recommended a factor of 0.8 for ordinary circumstances, and up to 3 for non-flexible arrival/departure constraints, relative to the in-vehicle VOT. The latter is comparable with the NZ stated preference survey results of Vincent (2008) of three to five times the in-vehicle VOT. These factors are not directly comparable with the EEM value of 1.2 because they apply to the average

minute of lateness, whereas the EEM's factors apply to the standard deviation of delays.

To gain an indication of the size of journey time reliability in terms of understanding the full cost of congestion delays, BTRE (2007) obtained the total cost of trip variability due to congestion by multiplying the trip variability by the corresponding VKT and a "relevant vehicular value of time", and found that including the total cost of trip variability due to congestion added around 25% to the total. The NZTA found that, on average, the increase is about 10%¹⁰.

There are a few residual problems that require further research:

- The issue of double counting – if the unpredictable part of the congestion delays is valued separately, should we ignore this part of the delays when we value the costs of congestion delays?
- Measure of travel time distribution – there is a need to choose between the mean-variance approach (i.e. standard deviation compared to average travel time); or the difference between an 80th and 90th percentile and the median travel time.
- Vincent (2008) versus Beca (2002) – there is a need to investigate whether the results from Vincent (2008) can be used.

3.2.5 Other components

Apart from the vehicle operating costs, time costs and health effects from emissions, severe congestion and the unreliability of journey time also affect the costs of businesses for not meeting trip schedules.

The potential impacts of congestion on businesses include reductions in market accessibility; increases in costs of inventory; restrictions on location decisions, and even reductions in the economies of scale (e.g. Sankaran et al. 2005 and BTRE, 2007). As the effects vary on a case-by-case basis, they are difficult to predict or estimate. Therefore, the EEM does not currently include such effects. However, BTRE (2007) noted that "*some studies suggest that these broader economic costs to business could be comparable in size to the direct travel costs due to congestion*".

We shall investigate these further in other UTCC workstreams (e.g. under the costs of congestion or the costs of freight transport workstreams).

¹⁰ Source: Personal communications with Sandy Fong of the NZTA.

3.3 NZ practice

3.3.1 The EEM's value of time estimates

Unit value of time (VOT), the value road users place on the time spent on travel, is an important input for determining the cost of congestion delays. The Economic Evaluation Manual's (EEM's) standard values of time (VOT) savings (summarised in Table 3.1) are based primarily on a willingness-to-pay study conducted for the New Zealand Transport Agency (then Transfund New Zealand) in 2001/02 (Beca, 2002). To obtain WTP estimates by trip purpose or user type, the WTP responses have been weighted or rescaled for the distribution of annual trip distances for the selected trip type for each person in the sample, the number of trips they made, their incomes and trip lengths. For details, see chapter 5 of Beca (2002).

Table 3.1: Values for transport user, vehicle and freight time in dollars per hour (\$/h) (all road categories; all time periods – July 2002 prices (note))

Vehicle occupant	Work travel purpose	Commuting to/from work	Other non-work travel purposes
Base values of time for uncongested traffic (\$/h)			
Car, motorcycle driver	23.85	7.80	6.90
Car, motorcycle passenger	21.70	5.85	5.20
Light commercial driver	23.45	7.80	6.90
Light commercial passenger	21.70	5.85	5.20
Medium/heavy commercial driver	20.10	7.80	6.90
Medium/heavy commercial passenger	20.10	5.85	5.20
Seated bus and train passenger	21.70	4.70	3.05
Standing bus and train passenger	21.70	6.60	4.25
Pedestrian and cyclist	21.70	6.60	4.25
Maximum increment for congestion (\$/h)			
Car, motorcycle and commercial vehicle driver	3.15		2.75
Car, motorcycle and commercial vehicle passenger	2.35		2.05
Base values for vehicle and freight time (\$/h)			
Passenger car	0.50		
Light commercial vehicle	1.70		
Medium commercial vehicle	6.10		
Heavy commercial vehicle I	17.10		
Heavy commercial vehicle II	28.10		
Bus	17.10		

Note: The EEM's inflation adjustment factor for updating the above estimates to July 2008 prices is 1.19 (or +19%) – see Appendix 12 of the EEM volume 1.

Source: New Zealand Transport Agency's Economic Evaluation Manual

The EEM assumes that total travel time savings comprise base travel time benefits arising from an improved flow of traffic, reduced traffic congestion and improved trip

reliability. Base values for travel time in uncongested traffic conditions are provided in the EEM per vehicle type, and for work, commuting and other non-work trip purposes. An increment is also provided for the base values to take account of congestion. Base values are provided for vehicle occupants and for freight time.

Seated bus and train passengers have the lowest VOT for commuting to and from work and other non-work travel purposes. These passengers have a VOT of around 60%-80% of car drivers and passengers for commuting trips, and 45%-60% for non-work travel trips. IWA (2007a)¹¹ analyses the following reasons behind this observation:

- **Uses of travelling time** – as people travelling on PT services (particularly on train) may use travel time for reading, listening to music and working with a laptop computer etc., the willingness to pay for these users may be lower because people see PT services as more pleasant and less onerous compared to driving or as a car passenger (e.g. Austroads, 2009a). IWA dismissed this explanation as a major determinant by citing the research findings of a UK study in which the bus users were found to have a higher value than car users, and the values for the rail mode are generally the lowest. In NZ, standing passengers and non-motorised users do have higher WTP values (for commuting and non-work travel) than seated passengers, indicating possible linkages with the uses of travel time and the stress associated with a particular mode.
- **User characteristics** – the surveyed sample have younger age groups, more female respondents, students and part-time workers, and lower average income earners for the public transport users' group compared to car drivers and the general population. IWA estimated that the income difference may result in a reduction of VOT by around 20%.
- **Self-selection effect** – this asserts that people with high WTP would tend to use car as it is a faster mode than PT. IWA believes this *“is likely to be an important factor (maybe the dominant factor) behind the observed VOT relativities”*.

Given the perverse impact of lower travel time values applied to a modal shift project, the NZTA amended the EEM to include provision for travel time equity values for people changing to active and shared modes. In Chapter A4-2 of the EEM (Volume 1), it says:

“Lower travel time values are not used when evaluating the benefits of activities that encourage a change from car or motorcycle driver to shared or active modes.

The travel time values pertaining to the original mode (where these values are higher) should be adopted for proposals that have a high proportion of mode switching. This includes activities which have the primary objective of changing modes or maintaining mode share.”

¹¹ IWA – Ian Wallis Associates Ltd

Travel time values combining passenger and commercial (including freight) occupants, and vehicle types for standard traffic compositions, are also provided in the EEM (see Table 3.2). To obtain the combined WTP, the estimates were weighted according to the proportion of trip distances or trips. For details, see chapter 5 of Beca (2002). These composite values of travel time are also provided for different road types (urban arterial, urban other, rural strategic and rural other) for different times of the weekday (they are especially detailed for urban arterial roads) and weekends.

Table 3.2: Composite values of travel time and congestion in dollars per hour (\$/h) (all occupants and vehicle types combined – July 2002 prices (note))

Road category and time period	Base value of time (\$/h)	Maximum increments for congestion (CRV \$/h)
Urban arterial		
Morning commuter peak	15.13	3.88
Daytime inter-peak	17.95	3.60
Afternoon commuter peak	14.96	3.79
Evening/night-time	14.93	3.68
Weekday all periods	16.83	3.79
Weekend/holiday	14.09	4.26
All periods	16.27	3.95
Urban other		
Weekday	16.89	3.82
Weekend/holiday	14.10	4.32
All periods	16.23	3.98
Rural strategic		
Weekday	25.34	4.23
Weekend/holiday	19.21	5.22
All periods	23.25	4.39
Rural other		
Weekday	24.84	4.24
Weekend/holiday	18.59	5.23
All periods	22.72	4.40

Note: The EEM's inflation adjustment factor for updating the above estimates to July 2008 prices is 1.19 (or +19%) – see Appendix 12 of the EEM volume 1.

Source: New Zealand Transport Agency's Economic Evaluation Manual

3.3.2 The STCC approach

The STCC estimated the costs of congestion in four types of situation:

- Recurrent congestion in three main centres (Auckland, Wellington and Christchurch)
- Recurrent congestion in other urban centres
- Recurrent congestion on the inter-urban state highway network
- Non-recurrent congestion.

In each case, congestion was valued by applying the EEM's VOT savings. The STCC study also includes an allowance for an increase in vehicle operating costs in urban situations.

In the STCC, the levels of congestion for the three main centres were derived using the regional/district transport models. Three model runs were performed for each city and time period (peak and inter-peak):

- (i) the base model that describes the 2001 traffic conditions
- (ii) a variation of the base model with 5% of trips uniformly removed (for Wellington, an extra model run with a 1% change was also carried out)
- (iii) a model run with no congestion – this was done by “*running the model with a reduced number of trips and factoring up the model outputs such as VKT to match the original trip matrix*” (see the STCC report for details).

The STCC (2005) calculates the total, average and marginal costs as follows:

- the average cost of congestion per VKT equals the difference in the average cost per VKT from congested and uncongested model runs (i.e. the difference between model (i) and model (iii))
- the total cost of congestion per VKT equals the average cost of congestion multiplied by the total VKT
- the marginal cost of congestion per VKT equals the difference in the total cost of congestion between model (i) and model (ii), divided by the corresponding change in VKT.

For congestion on the inter-urban state highway network, estimates were based on the NZ Transport Agency's (then Transit NZ's) passing lane model. For other congestion, only indicative estimates were made. The STCC also includes an adjustment for induced traffic effects, which vary with the degree of congestion.

3.3.3 Review of the STCC – areas for improvement

IWA (2007b) reviewed the STCC and recommended that the following improvements should be made with regard to estimating the costs of road congestion:

- *review the total cost approach for main urban centres*
- *revisit the approach/methodology for estimating non-recurrent congestion, in light of:*
 - *more recent NZ work*
 - *international analyses*
 - *evidence from NZ Traffic Management System monitoring*
- *consider, and undertake as appropriate, new model runs for the three main urban centres*
- *review whether estimates for Auckland adequately allow for peak spreading*
- *review whether more refined estimates of ‘secondary’ effects could be made, and develop/apply methodology if applicable*
- *undertake additional analyses (model runs, etc) to examine marginal (externality) congestion costs in selected key corridors within Auckland, Wellington and Christchurch.*

As many of these recommendations are not related to methods for valuing congestion, they will be addressed at a later stage when we commence the data collection and estimation process.

3.4 Major issues with valuing congestion delays

We have identified the following issues with valuing congestion delays:

- **Comparison speed values** – It is unclear when congestion actually starts. When quantifying congestion delays, should we compare with free-flow conditions or a less congested benchmark speed (e.g. a percentage of free-flow speed)?
- **Peak-spreading** – There are uncertainties around modelling how demand shifts from peak periods to shoulder or inter-peak periods. IWA (2007b) also recommended reviewing whether the Auckland model adequately allows for peak spreading.
- **Issues with the unit value of time** – At present, the EEM uses different VOTs for public transport (PT) users and non-public transport users. However, there may be some doubt about why this should be the case (especially for commuting travel in urban cities). Many argue that the VOT for the same person should not differ due to the choice of transport mode.

For values that are based on willingness to pay, there may be regional differences because the amount people would be willing to pay may depend on the level of tolerance. For example, people in Auckland may be more conditioned to congestion than people living in smaller cities. Also, people in

provincial cities may have less tolerance of delays because they occur less frequently for them.

As noted in IWA (2007a), for equity reasons the United Kingdom, United States and Sweden adopt the same values across all modes. In NZ, the current EEM values for PT users are lower than those for car users. As noted by IWA (2007a), car travel is significantly faster than public transport (PT) travel for most urban trips, and it could reasonably be expected that (for any given income level) those people with higher values of time (in the context of a particular trip) would tend to use a car, and those with lower values to use PT. But such a valuation would encourage car users away from PT use.

In 2008, the NZTA amended the EEM to include provision for travel time equity values for people changing to active and shared modes. It remains unclear whether equity values should also be used in more general applications.

- **Recurrent and non-recurrent congestion** – we need a better definition of recurrent and non-recurrent congestion, especially when estimating the costs of journey time variability/reliability, to avoid double counting.
- **Value of travel time and congestion costs** – when calculating the full costs of transport use, we need to differentiate the values of general travel time and congestion costs, to avoid double counting.

3.5 Data requirement

For estimating the unit cost of congestion delays, a benefit transfer approach is not recommended because different countries may define congestion differently, and there are also other inter-country differences such as population profiles and urban development.

However, irrespective of the approaches used, estimating the costs of congestion requires a number of inputs which cannot be easily measured in physical terms. These include:

- (i) **Value of time** – VOT is required for translating time losses and/or reduced reliability and comfort into monetary units (IMPACT, 2008). Value of time can differ markedly depending on income levels, mode of transport and travel purpose.
- (ii) **Speed-flow relationships** – As noted in IMPACT (2008) these describe the effects of an additional vehicle on the transport system, and thus on the costs to other users and to society. Speed-flow relationships depend on infrastructure characteristics, topography, weather conditions, the network arrangement, available travel alternatives, regulations (speed control, ramp metering, etc.) and driving habits. Thus, local evidence should be used if available.
- (iii) **Demand elasticities** – These describe the likely reactions of users in relation to changes in generalised costs (IMPACT, 2008). Elasticities of demand are

dependent on local conditions as they directly describe the alternatives of users, inducing the replacement of trips by other activities.

- (iv) **Congestion threshold** – This is required only when comparing a predetermined threshold (as opposed to free-flow conditions) with current traffic conditions to estimate the congestion level.
- (v) **Quantum** – One source of data is the NZTA's congestion index, including the standard deviation of travel time. This is done for Auckland, Wellington, Christchurch and Tauranga only. Such information may be useful for quantifying journey time reliability. On the other hand, regional transport models will be useful for estimating the quantum of congestion delays.
- (vi) **Level of disaggregation** – For policy purposes, VOT estimates by purpose of travel, transport mode, location, time periods, and vehicle and movement type are likely to be required.

3.6 Feedback from workshop consultation

Q1: Should we adopt the EEM's VOT and the congestion increment values to estimate the costs of road congestion? If not, is there another approach that could be adopted given the time and resource constraints?

- Most workshop participants agreed the EEM's VOT should be used in the first instance.
- Some commented that the unit value of time should not differ for congestion, but there should also be a factor for reliability.
- One of the transport economists/industry experts commented that the length of time saved will also affect the unit value and there may be a threshold below which the value is close to zero.
- Another transport economist/industry expert suggested the Ministry develop a distribution of WTP values and obtain a combined VOT by transport task (which is made up of a weighted average of VOT), as opposed to user type.

Q2: The EEM's VOT for PT is lower than for other modes. Should we also apply the same VOT for all passenger travel to gauge the likely impact on the cost of congestion?

- We have received mixed feedback on this. While some have indicated their support for using a consistent VOT for PT and non-PT users for all passenger travel, others supported another approach. One of the entities would also like to see different values by PT mode (rail, ferry versus bus).
- One of the transport economists/industry experts commented that, by using differential values, there is a risk of distortion in policy development because a change in availability/capacity of a specific mode will affect the mix of users and also the income distribution for that mode.

Q3: Should we apply different congestion thresholds (in addition to comparing traffic level with free-flow conditions) to obtain a range of congestion cost estimates?

- We have received mixed feedback on this. While some were opposed to the adoption of a congestion threshold (when deriving the total costs), as such a selection would be subjective, others thought it was a good idea to obtain a range of estimates.
- Some participants also commented that small time savings should have a low or zero value.

Other comments received

- The freight user group and the trucking industry recommended including business costs (e.g. cost of inventory and other logistic costs) as part of the costs of congestion delays.

3.7 Recommendations

3.7.1 *Approaches for the UTCC*

- (i) **Valuation methodology** – The EEM’s VOT estimates should be used for the calculation.
- (ii) **Value of time for PT users** – Two sets of estimates should be used to gauge the likely impact on the costs of congestion.
 - (1) The EEM’s estimates
 - (2) The same VOT for all passenger transport (private and public) modes.
- (iii) **Definition of congestion** – The STCC’s definition (relative to free-flow conditions) should be used in the first instance. However, we should also adopt an alternate definition by using the congestion threshold approach and the deadweight loss approach (relative to the optimal level of congestion on the existing network). Applying the three approaches will give us a range of estimates to gauge the potential scale of the problem.
- (iv) **Journey time reliability** – Two sets of estimates should be used to gauge the likely impacts:
 - (1) the mean-variance approach (one standard deviation compared to mean travel time)
 - (2) the 80th to 90th percentile compared to median travel time.
- (v) **Operational congestion** – Congestion associated with rail and maritime operations should be included under other workstreams, e.g. the ‘Costs of freight transport’ workstream.

3.7.2 *Long-term research needs*

- (i) When carrying out a follow-up willingness-to-pay study to determine VOT in the future, the study should attempt to improve our understanding of the VOT for PT users versus non-PT users.

4. Greenhouse gas emissions

This section covers a range of environmental impacts caused by greenhouse gases. Greenhouse gas (GHG) emissions refer to gases in the atmosphere that absorb and emit radiation within the thermal infrared range; they include carbon dioxide, methane and nitrous oxide (IPCC, 2007).

4.1 Rationale for collection

4.1.1 *Policy context*

Estimation of the costs of greenhouse gas emissions is useful for three reasons:

- First, such information helps us to understand the current state of greenhouse gas emissions by transport mode and analyse any trend or patterns.
- Second, such estimates are required to determine the potential benefits from mitigation. When the costs of greenhouse gas emissions information are used together with estimates of other costs and benefits, policy makers can judge whether individual projects and programmes are worthwhile.
- Finally, understanding the marginal (external) costs is also important for understanding the extent to which pricing could bring about a better utilisation of the existing transport network and mitigate the greenhouse gas emission effects from transport use.

4.1.2 *Magnitude of impacts*

Human activities have an impact on the concentration of greenhouse gases, primarily carbon dioxide from burning fossil fuels, in the atmosphere. The concentration of greenhouse gases has a direct influence on the climate and hence on global warming.

The impacts from climate change have been widely documented and debated. They can include (but are not limited to) increases in the frequency and intensity of extreme weather events, altered spatial distribution of infectious disease vectors, increased sea-levels and coastal erosion, changes in precipitation and biodiversity, and the progressive acidification of oceans (IPCC, 2007).

The International Panel on Climate Change says that it is virtually certain that New Zealand's climate will warm during this century. This will be likely to cause extreme events such as heatwaves, droughts and floods to become more frequent and intense, resulting in substantive environmental, social and economic costs.

Greenhouse gas emissions in the transport sector are relevant in this regard, as the sector contributes about 20% of New Zealand's total greenhouse gas emissions. This estimate excludes any upstream and downstream effects.

4.2 Literature review

4.2.1 Estimating the social cost of GHG emissions

There are four common approaches by which a cost estimate can be assigned to GHG emissions (e.g. Infrac/IWW, 2000; Austroads, 2003; ExternE, 2005; and Austroads, 2009d):

- **Carbon price approach** – This approach uses the market price of emission units (as they are traded on international markets) to estimate the cost of GHG emissions. To some extent, it is linked to the cost of mitigation because its value will increase as the cost of mitigation increases (as the demand for carbon credits will increase). Emission trading provides a means for offsetting the level of emissions from domestic and international markets. Applying the carbon price to the emission quantum will provide the total market price of GHG emissions.

Carbon price is also used to estimate New Zealand's obligation under the Kyoto Protocol ('the Kyoto liability'). The unit cost of carbon for assessing the Kyoto liability is based on the expected carbon price value (at €10 or NZ\$ 23.43 per tonne, at March 2009 prices¹²). The Kyoto liability is calculated based on the difference between the estimated emission quantum and the emission allowance for New Zealand to obtain the emission reduction deficit¹³. In other words, the Kyoto liability only values the emission levels above the 1990s level. As such, the resulting total will be lower than the total cost of GHG emissions.

The carbon price approach does not provide estimates of the full costs of climate change effects from GHG emissions.

- **Impact pathway approach** – This is sometimes referred to as the '*Damage Cost approach*'. It combines the physical impacts of climate change with estimates of the economic impacts resulting from them (Austroads, 2009d and Litman, 2009). Under this approach, a *dose-response function* or *damage cost function* is derived for assessing changes in the levels of damage as emission levels change. This approach aims to evaluate a range of climate change impacts including the effects of sea level rise, extreme weather events and impacts on human health, agriculture, water resources and ecosystems. Theoretically, this is the preferred approach as it attempts to measure the full costs from climate change. However, due to the uncertainties in the damage assessments and the sensitivities of the various assumptions used, the results are usually subject to high uncertainties.
- **Mitigation cost approach** – This is sometimes referred to as the '*Control or Avoidance Cost approach*'. This focuses on expenditures on mitigation,

¹²This is an estimation of the likely price the New Zealand Government could expect to pay per unit, if it was to meet its Kyoto liability through the Kyoto Flexibility Mechanisms i.e. purchasing emission units on to the international market. Source: <http://www.treasury.govt.nz/government/liabilities/kyoto> (accessed 8 May 2009).

¹³The Kyoto agreement commits New Zealand to reducing its average net emissions of greenhouse gases over 2008-2012 (the first commitment period of the Kyoto Protocol) to 1990 levels or to take responsibility for the difference.

abatement, replacement, restoration or avoidance. Mitigation cost estimates depend significantly upon the emission reduction targets selected. The Infrac/IWW study uses an emission reduction target of 50% (as recommended by the IPCC), whereas other studies are based on reduction targets specified in the Kyoto Protocol. However, New Zealand's target is to reduce "its average net emissions of greenhouse gases over 2008-2012 (the first commitment period of the Kyoto Protocol or CP1) to 1990 levels"¹⁴. Austroads (2003) states that the use of mitigation/control costs can result in significantly higher unit cost estimates than that of using a damage costs approach, as the cost of mitigation will increase over time, as diminishing marginal return starts to kick in.

- **Benefit transfer approach** – This is commonly used in assessing the social cost of climate change (e.g. Austroads, 2003; Quinet, 2004; Austroads, 2009d). For a brief description of this method, including its advantages and disadvantages, please refer to Section 2.5.2.

Please note that the estimates obtained from these approaches are not directly comparable because they measure different things. The carbon price approach measures mainly the potential Kyoto liability. On the other hand, the mitigation cost approach measures the costs of mitigation rather than the consequences. We could potentially obtain comparable estimates under the impact pathway approach and the benefit transfer approach, but the benefit transfer approach is not a stand-alone method, it simply uses the findings of other methods.

4.2.2 *Total, average and marginal costs*

The total costs of greenhouse gas emissions are obtained by summing all related costs (e.g. medical costs and damage to environment) by location or road user type.

The average cost of greenhouse gas emissions per vehicle or passenger kilometre travelled (VKT or PKT) is obtained by averaging the total cost for all (or a group of) road users across the total VKT or PKT of those users.

In theory, the marginal cost of travel is obtained by taking the derivative of the total cost of travel with respect to the quantity of travel. For estimating the marginal cost of greenhouse gas emissions, a practical approach would be to look at the incremental impact of changing greenhouse gas levels by a small percentage. Once the impact is estimated, we can then apply the same unit costs to estimate the marginal cost for each component.

¹⁴ Source: <http://www.treasury.govt.nz/government/liabilities/kyoto> (accessed 8 May 2009).

4.3 NZ practice

4.3.1 *The EEM's estimates*

Currently the Economic Evaluation Manual (EEM) uses \$40 per tonne (at 2004 dollars) of CO₂ to value the cost of GHG emissions; this equates to approximately 12 cents per litre of fuel. An alternative approach, as suggested in the EEM, is to value the cost at 4% of total vehicle operating costs for the default traffic composition (NZTA, 2008).

The \$40 figure was updated from the \$30 recommended in the LTPS-EE (1996), which was derived from the lower end of a range (US\$9 to US\$197 per tonne in 2000 dollars) of studies reviewed in the IPCC's 1995 Second Assessment Report (Clarkson and Deyes, 2002).

4.3.2 *The STCC approach*

The STCC report used a damage cost figure of \$25 per tonne of CO₂ to value the social cost of GHG emissions. This is an estimate of the expected carbon price as published by the NZ Treasury at that time.

With regard to the quantum of GHG emissions, the STCC used the estimates of transport greenhouse gas emissions by mode obtained from the Ministry of Economic Development's Greenhouse Gas Emission Report and their global warming potential (GWP) factors to convert various emissions to CO₂ equivalents (CO₂e) for different transport modes.

The Ministry of Economic Development (MED) estimated that in the year 2001 transport contributed to nearly 14 million tonnes of CO₂e, with road transport contributing to around 90% of CO₂e, followed by aviation (5%), rail and maritime¹⁵.

4.3.3 *Review of the STCC – areas for improvement*

IWA (2007b) reviewed the STCC and recommended that the estimates of environmental costs could be improved further by:

- *employing up-to-date NZ data sources*
- *exploring the relationships between the average and marginal costs for each component*
- *further disaggregating the assessments by vehicle type and characteristics*
- *more in-depth appraisal of the environmental costs associated with the rail mode.*

¹⁵ MED is currently reviewing the diesel use estimates to resolve some anomalies in attributing diesel consumption between transport and other uses. It is possible that MED might have over-attributed the amount of diesel use by transport in the past by as much as 20%. Hence, the total quantum of transport emissions could have been overstated by up to 10%. The MED review should be completed by mid-2010.

As many of these recommendations are not related to methods for valuing environmental costs, they will be addressed at a later stage when we commence the data collection and estimation process.

4.4 Major issues with valuing GHG emissions

- (i) Ideally the *impact pathway approach* would be the appropriate approach to use for valuing the environmental impacts of GHG. Unfortunately, the New Zealand-specific dose-response relationships have not been developed, so analysis undertaken in New Zealand is somewhat dependent on the dose-response relationships that have been calibrated for different populations.
- (ii) In terms of estimating the quantum of impacts, it is difficult to differentiate the impacts from transport alone due to the co-existence of several emission sources (such as household, industrial and agricultural emissions).
- (iii) There is also a difficulty with separating out the global and local emission sources as well as their impacts. For global emission effects, the impacts are not identical for different regions. As noted in the IPCC report (2007), there may be some initial benefits to parts of New Zealand in the production of agriculture and forestry products. These make it difficult to apply a benefit transfer approach.

4.5 Data requirement

- *The mitigation cost approach* is not a measure of consequential costs, it is a measure of preventive costs which should be collected as part of another UTCC workstream.
- The data requirements for analysing transport GHG emission effects on human health using the *impact pathway approach* include the following:
 - information on the existing concentrations
 - determining a NZ threshold (above which health effects occur)
 - measures of the exposure of humans to emissions
 - measures of the dose-response relationships between the exposure and health effects
 - NZ-specific willingness-to-pay or accept contributions to mitigating their effects.
- However, given the tight timeframe, the *impact pathway approach* is not feasible. Therefore, a *benefit transfer approach* (i.e. based on international findings and adjusted to the NZ context) could be used instead. To do so, the following information will be required:
 - baseline concentrations
 - population characteristics (health status, age & density, etc.)

- price index and income (e.g. gross domestic product, purchasing power parity and inflation index).

4.6 Feedback from workshop consultation

Q1: Given the time and resource constraints, it appears that the use of a benefit transfer approach is appropriate. Are there other alternatives?

- The majority of the attendees agreed that the benefit transfer approach is preferable. However, some questioned the validity of applying overseas research.
- Some questioned whether the task should rest with the Ministry for the Environment rather than the Ministry of Transport.
- No other approaches were suggested by the attendees.

Q2: The carbon price does not represent the total social cost of climate change. Therefore, this can only be used to estimate the total carbon costs for reference purposes. Do you agree?

- We did not obtain a consensus on this.
- Some attendees thought the carbon price was the official value used by the Treasury and therefore should also be used in this analysis.
- Others objected to this practice because the carbon price approach only attempted to estimate the emission liability, not the true costs of emissions.

Q3: In terms of quantum, apart from the MED's Energy Greenhouse Gas Emissions Report, are there any other sources of emission or energy use data, especially for the rail and maritime areas?

- The attendees were not aware of other data sources.

Other comments received

- There was a comment that information on the cost of emissions would be redundant since the emission trading scheme should be able to help mitigate greenhouse gas emissions.
- A small number of attendees would like some clarification on the potential use of emissions information.

4.7 Recommendations

4.7.1 Approaches for the UTCC

For estimating the unit cost of climate change, we recommend using

- a benefit transfer approach to gauge the climate change impact
- the carbon price to estimate the total carbon costs for reference purposes.

4.7.2 Long-term research needs

- (i) To investigate the scope of carrying out a New Zealand-based *Impact Pathway Analysis* to understand the dose-response relationship in New Zealand. This includes the data requirements and other specifications that are required for completing such a survey.
- (ii) To investigate the scope for improving the estimates of GHG emissions associated with the rail and maritime sectors.

5. Harmful emissions

Harmful emissions usually refer to air pollutants or substances in the air, other than GHG, that can cause harm to humans, animals and the environment. Harmful emissions include: sulphur oxides; nitrogen oxides; volatile organic compounds, and particulate matter (HAPiNZ, 2007). This paper only focuses on the effects on human health.

5.1 Rationale for collection

5.1.1 *Policy context*

Estimation of the costs of harmful emissions is useful for three reasons:

- First, such information helps us to understand the current state of harmful emissions by transport mode and to analyse any trends or patterns.
- Second, such estimates are required to determine the potential benefits from mitigation. When information on the costs of harmful emissions is used together with estimates of other costs and benefits, policy makers can judge whether or not individual projects and programmes are worthwhile.
- Finally, understanding the marginal (external) costs is also important for understanding the extent to which pricing could bring about a better utilisation of the existing transport network, and mitigate the harmful emission effects from transport use.

5.1.2 *Magnitude of impacts*

The effects of air pollution are well discussed in the literature (e.g. MOT, 2002; HAPiNZ, 2007; Austroads, 2009d) and include the following:

- chronic obstructive pulmonary disease (such as chronic bronchitis, emphysema, and some forms of asthma)
- altered lung function and lung cancer
- cardiopulmonary disease
- heart disease
- leukaemia.

HAPiNZ (2007) estimated that transport emissions contribute to over 400 premature deaths (or approximately 45% from all sources), and over 500 cases of respiratory disease, annually. Some of these effects arise from the aggravation of existing respiratory and cardiac conditions. Therefore, the social cost of harmful emissions is significant.

5.2 Literature review

5.2.1 *Estimating the health impacts of air pollution*

As noted in the literature (e.g. Austroads, 2003; ExternE, 2005; Austroads, 2009d), there are three broad approaches for valuing the health impacts of harmful emissions.

- **Impact pathway approach** – This approach is widely used (e.g. Infrac/IWW, 2000; ExternE, 2005; Sawyer et al., 2007). As noted in Austroads (2009d), “the main advantage of this approach is that it allows for site specific marginal external costing, especially in the valuation of localised impacts”. However, this approach only determines the impact patterns on human health; other information on unit costs will be required in order to obtain an economic valuation of the impact. For a brief description of this method, including its advantages and disadvantages, please refer to Section 2.5.
- **Contingent valuation** – This is not as popular as the impact pathway approach for valuing the health impacts of harmful emissions. This involves asking respondents for their willingness to pay for an environmental service that aims to improve air quality (e.g. Pratt, 2002, cited in Austroads, 2009). For a brief description of this method, including its advantages and disadvantages, please refer to Section 2.5.
- **Benefit transfer approach** – This is commonly used in assessing the social cost of the health impacts of harmful emissions (e.g. Austroads, 2003; Quinet, 2004; Austroads, 2009d). For a brief description of this method, including its advantages and disadvantages, please refer to Section 2.5.

Please note that the estimates obtained from these approaches are not directly comparable because they measure different things. The impact pathway approach only determines the impact patterns, while the contingent valuation approach can determine a unit value of mortality or morbidity. The benefit transfer approach could be used for determining either the impact patterns or the unit value of health effects. But the benefit transfer approach is not a stand-alone method, it simply utilises the findings of other methods.

5.2.2 *Total, average and marginal costs*

The total costs of harmful emissions are obtained by summing all related costs (e.g. health-related medical costs and damage to the environment) by location or road user type.

The average cost of harmful emissions per vehicle or passenger kilometre travelled (VKT or PKT) is obtained by averaging the total cost for all (or a group of) road users across the total VKT or PKT of those users.

In theory, the marginal cost of travel is obtained by taking the derivative of the total cost of travel with respect to the quantity of travel. For estimating the marginal cost of harmful emissions, a practical approach would be to look at the incremental impact of changing the harmful level by a small percentage. Once the impact is estimated, we can then apply the same unit costs to estimate the marginal cost for each component.

5.3 NZ practice

5.3.1 *The EEM's estimates*

The EEM provides two valuation approaches for monetising harmful emission effects:

- \$40 per person per year exposed per PM10 microgram/m³ (mathematically, this equates to \$40 × PM10 concentration × population exposed). This valuation is based on the results of US and French contingent valuation studies (see chapter A9-7 of the EEM, Volume 1)
- a 0.101% increase in daily death rates for a 1 microgram per m³ increase in PM10 (mathematically, this equates to 0.001 × ΔPM10 concentration × population exposed × normal death rate × value of life)¹⁶

5.3.2 *The STCC approach*

The STCC study adopted two variations of the benefit transfer approach in estimating the impact of air quality on human health.

The first approach utilised Austroads (2003) damage cost estimates, converting them to NZ dollars (it appears that the prevailing exchange rate was used at the time), and adjusting for differences in population density. These give the average cost factors (per vehicle kilometre travelled) by population density group. This approach produces a total annual transport air pollution cost of around \$440m.

The second approach utilised ExternE's dose-response relationship. The report concluded that the adjusted result was equivalent to 200 premature deaths with

¹⁶ The source of the formula was not given in the EEM.

exposure to transport emissions as a possible contributor. This is half of the impact estimated in MOT (2002).

To translate the impact of premature deaths to cost, the STCC annualised the VOSL to yield the value of a statistical life year lost (assessed at 6% discount rate). After considering an average 14 years of life lost, the report gives total annual traffic-related air pollution costs. This methodology is also commonly used in many environmental analyses (e.g. ExternE, 2005 and HAPiNZ, 2007). This approach produces a total annual transport air pollution cost of around \$480m.

The STCC report also disaggregated these costs by vehicle type, based on vehicle kilometre distributions.

The STCC report did not, however, look at the health effects of air quality on morbidity. According to HAPiNZ (2007), consideration of such impacts could add another 30% to the total cost mentioned above.

5.3.3 *Review of the STCC – areas for improvement*

IWA (2007b) reviewed the STCC report and recommended improvements to be made to estimating environmental costs. These were discussed in Section 4.3.3.

5.4 Major issues with valuing the health impacts of air pollution

- (i) Ideally the *impact pathway approach* is the appropriate one to use for valuing the environmental impacts of harmful emissions. Unfortunately, the New Zealand-specific dose-response relationships have not been developed, so analysis in New Zealand is somewhat dependent on the dose-response relationships that have been calibrated for different populations.
- (ii) In terms of estimating the quantum of impacts, it is difficult to differentiate the impacts from transport alone, due to the co-existence of several emission sources (such as household, industrial and agricultural emissions).

5.5 Data requirement

- The data requirements for analysing transport GHG emission effects on human health, using the *impact pathway approach*, include the following:
 - information on the existing concentration
 - determining a NZ threshold (above which health effects occur)
 - measures of exposure of humans to emissions
 - measures of the dose-response relationships between exposure and health effects
 - NZ-specific willingness-to-pay or accept contributions to mitigating their effects.

- However, given the tight timeframe, the *impact pathway approach* is not feasible. Therefore, a *benefit transfer approach* (i.e. based on international findings and adjust to the NZ context) could be used instead. To do so, the following information will be required:
 - baseline concentrations
 - population characteristics (health status, age & density, etc)
 - purchasing power parity.

- In terms of the valuation of morbidity and mortality, the current value of statistical life established for the safety area (and a variation using a meta-analysis) can be used to derive the value per year of life lost, as was done in the STCC report and HAPiNZ (2007). The data requirements for determining the value per year of life lost include:
 - The average number of life years per person lost due to harmful emissions
 - the average age of those affected by harmful emissions
 - the discount rate.

5.6 Feedback from workshop consultation

Q1: Given the time and resource constraints, should we use:

(1) the findings of HAPiNZ (2007), with revised energy consumption levels; and
(2) a benefit transfer approach (e.g. the Austroads (2009d) approach, which is equivalent to the STCC approach which used Austroads (2003) as its basis)

to produce two sets of estimates?

- Most attendees supported the use of the same VOSL for safety (the current one and a variation using a meta-analysis) and environmental impacts to ensure consistency in valuing the reductions in life or life quality due to different impacts.

Q2: In terms of quantum, the Ministry for the Environment published an emission inventory report in 2003. This was based on emission inventory studies carried out by regional councils for most of the larger urban areas of New Zealand. Are there any other (newer) data sources that can be used for this project, e.g. a council's emission inventory?

- The attendees were not aware of other data sources that could be used.

Q3: In terms of the valuation of morbidity and mortality, the current value of statistical life (VOLS) established for the safety area (and a variation using a meta-analysis) can be used to derive the value per year of life lost, as was done in the STCC study and HAPiNZ (2007). Do you have any information to help update the average number of life years lost due to harmful emissions and the average age of those affected?

- Most attendees supported the use of the same VOSL for safety (the current one and a variation using a meta-analysis) and environmental impacts to ensure consistency in valuing reductions in life or life quality due to different impacts.
- There was a comment about the validity of the approach taken by the health profession in valuing a Quality Adjusted Life Year (QALY) based on VOSL. The view was that the value per QALY is unlikely to be the same for all ages, and over time. It was recommended that further research into this area was necessary.
- The attendees were not aware of data sources on the average number of life years lost due to harmful emissions and the average age of those affected.

5.7 Recommendations

5.7.1 *Approaches for the UTCC*

- (i) Use the findings of HAPiNZ (2007) and a benefit transfer approach (Austroads, 2009d), in conjunction with revised energy consumption estimates, to produce two sets of estimates.
- (ii) In terms of the valuation of morbidity and mortality, the current value of statistical life established for the safety area (and a variation using a meta-analysis) will be used to derive the value per year of life lost, as was done in the STCC study and HAPiNZ (2007).
- (iii) In terms of updating the average number of life years lost due to harmful emissions, and the average age of those affected, we need to collect data from the NZ Health Information Service.

5.7.2 *Long-term research needs*

- (i) To investigate the scope of carrying out a New Zealand-based *Impact Pathway Analysis* to understand the dose-response relationship in New Zealand. This includes the data requirements and other specifications that are required for completing such a survey.
- (ii) To investigate the scope of improving the estimates of harmful emissions associated with the rail and maritime sectors.

6. Accidents

The term “accidents” used in this paper refers to:

- Road crashes which occurred on public roads, resulting in deaths, injuries or damages to property. Road crashes occurring on private property, such as farm lands and car parks, are not part of this study.
- Rail incidents (e.g. derailments and level crossing collisions) which occurred on the rail network, resulting in deaths, injuries or damages to property.
- Maritime incidents (e.g. capsizing of a vessel) which occurred within New Zealand’s territorial waters, resulting in deaths, injuries or damages to property.

6.1 Rationale for collection

6.1.1 Policy context

Understanding the social cost of accidents is important for a range of policy analyses. For example, it will inform the following work currently being conducted by the Ministry of Transport and other transport agencies:

- (i) **Safer journeys (Road Safety Strategy to 2020)** – this requires better social cost information on road injuries and crashes. As safety analysis concerns average and overall risk, both the internal and external components of the social cost are important. This information is also important for the development of safety rules and legislation.
- (ii) **Rail safety strategy** – proposed actions for 2008-2011 include research into the social cost of rail accidents (including at level crossings and trespassing). The social cost items to be investigated include injury costs, schedule delays (freight and passengers), and infrastructure costs (including damage to wagons etc.).
- (iii) **Maritime safety** – Maritime NZ, along with the Ministry, is responsible for the maritime safety area. Any information that can help improve the estimates of the social cost associated with casualties will assist maritime safety policy assessment.
- (iv) **Walking and cycling-related policies** – Social cost information (this includes injury risk and negative health impacts from exposure to pollution) related to walking and cycling would be useful for assessing walking and cycling-related policies.

6.1.2 Magnitude of impacts

Over the last five years, on average, approximately 400 New Zealanders have been killed on our roads each year. Alongside them another 2,500 people have been seriously injured and 13,000 people suffered minor injuries. These are based on Police crash reports. According to the Accident Compensation Corporation, each year there are a total of 43,000 new motor vehicle-related claims (note that the majority of ACC claims are related to minor injuries).

The annual total social cost of road injuries (including an allowance for under-reporting) is estimated at approximately \$3.7 billion¹⁷. This estimate includes the values of loss of life and life quality, loss of output, medical, property damage and legal costs (also see section 6.3.1).

On the other hand, the annual trauma resulting from rail and maritime incidents is somewhat smaller. Each year around 40 people are killed as a result of these incidents, and approximately 100 people are injured (these are the reported numbers only; the level of under-reporting for these modes is unknown). The annual social cost of reported rail and maritime injuries (excluding the associated property-damage costs) is approximately \$140 million.

In summary, transport injuries result in a significant medical burden, loss of life quality, and loss to the economy. In terms of the social cost of injuries, the total for road, rail and maritime transport amounts to nearly \$4 billion. It must be stressed that the social cost estimates are not directly comparable with measures of the real economy, such as Gross Domestic Product, because the social cost estimates include intangible and non-financial components.

6.2 Literature review

6.2.1 Valuation of accident costs

Estimations of the non-VOSL consequential cost of accidents are generally more straightforward than valuing the loss of a life, and are usually based on historic and average data using the resource costs approach and other predictive analytical frameworks. These will be investigated in detail at the data collection and estimation stage.

This review focuses on the approaches for valuing the loss of a life or the value of statistical life (VOSL) used in the international literature. The most commonly-used approaches include the following:

- **Human capital approach** – This approach focuses on the net output an individual produces over a productive life. Therefore, the value of a life lost due to premature death is the discounted stream of future earnings of that individual, after deducting the estimated reduction in future consumption of the same individual. For injuries, no adjustments to future consumption would be required.

¹⁷ Ministry of Transport (2009), *The Social Cost of Road Crashes and Injuries: June 2009 update*.

The human capital approach suffers from a large number of limitations. Miller and Guria (1991) and Austroads (2009b and 2009c) discussed the following:

- Failing to reflect society's views about the importance of safety
- Undervaluing children due to discounting effects
- Undervaluing those who are not likely to be in the labour force (e.g. housewives and the elderly)
- Undervaluing minorities and female road users as they tend to have lower average incomes
- Exclusion of socio-economic characteristics (e.g. education and occupation, etc)
- Ignoring loss of life and life quality, pain and suffering.

Due to these limitations, many international jurisdictions (including NZ) have moved away from the human capital approach. Austroads (2009b) recently recommended the willingness-to-pay approach should be adopted in Australia.

- **Willingness-to-pay based VOSL** – This is generally related to the amount of money a person is willing to pay for a safety improvement or to avoid a safety deterioration.

There are several variations of the WTP approach, namely contingent valuation, hedonic pricing and revealed preference. The WTP approach can overcome the limitations of the human capital approach (Miller and Guria, 1991; Austroads, 2009b). It also enables the individual to value small changes in the probability of injury or death that could be gained from a road safety intervention. The WTP approach is also recognised as a theoretically sound method for valuing life and aversion to death and injury (Austroads 2009b and 2009c).

The limitations of the WTP-based VOSL are typically associated with the quality of the questionnaires, which could potentially affect the quality of the estimates, and the existence of high WTP outliers (e.g. Guria et al., 2003) which mean the median and average estimates will be dependent on the level of trimming conducted.

- **Willingness-to-accept based VOSL** – This is generally related to the amount of money a person is willing to be paid to accept some deterioration in safety, or to be compensated for the absence of a safety improvement. This method is more appropriate for assessing the increased costs due to an increase in risk. Guria et al. (2003) estimated that the WTA-based VOSL is between three and five times that of its WTP-based counterpart.

In view of the above, the WTP-based VOSL is the preferred approach for the UTCC project.

6.2.2 *External cost of accidents*

A simple definition of externality is that “the cost or benefit experienced by an individual due to the action of another individual is called an externality”. Therefore, externality concerns the behaviour of others.

Most crashes cause externalities. Even when a crash does not cause any injury to road users, there could be travel delay costs to the general public and costs of property damage to those involved (other than the driver who took a risk and caused the crash, as that cost would be internalised by the driver).

There are a few issues with road safety risk that make it difficult to determine the extent to which it can be internalised via economic instruments:

- The risk associated with other drivers cannot be identified in advance
- The risk associated with other drivers varies across a range of factors, such as skills, experience, levels of concentration, and other driving behaviours.
- Apart from the driver factors, there are other factors influencing the outcome (randomness in risk, vehicle factors and road factors).

The costs of road/rail accidents are likely to be external to rail, as they are imposed by the road vehicle involved.

On the other hand, for maritime incidents the external cost components include the damages to the environment and water quality if such incidents involve fuel spillages.

The methods for assessing the above have been investigated by the NZIER and summarised in Appendix I.

6.2.3 *Total, average and marginal costs*

The total costs of accidents (and injuries) are obtained by summing all related costs (e.g. loss of output, legal and court costs, medical costs and property damage) by location or by other characteristics.

The average social cost of accidents per vehicle or passenger kilometre travelled (VKT or PKT) is obtained by averaging the total cost for all (or a group of) road users across the total VKT or PKT of those users.

In theory, the marginal cost of travel is obtained by taking the derivative of the total cost of travel with respect to the quantity of travel. For estimating the marginal cost of accidents, a practical approach would be to look at the incremental impact of changing greenhouse gas levels by a small percentage. Once the impact is estimated, we can then apply the same unit costs to estimate the marginal cost for each component.

The above also applies to rail and maritime accidents/incidents.

6.3 NZ practice

6.3.1 *The MOT's estimates*

The Ministry of Transport estimates and updates the social costs of road crashes and injuries every year. The latest update was the June 2009 update.

The social costs of a road crash and the associated injuries include a number of different components: loss of life and life quality, loss of output due to temporary incapacitation, medical costs, legal costs, and property damage costs. Injury costs are classified into fatal, serious and minor injuries, as reported by crash investigators.

The cost of pain and suffering due to the loss of an unidentified life from a road crash is estimated by the amount of money the New Zealand population would be willing to pay for a safety improvement that results in the expected avoidance of one premature death (i.e. the willingness-to-pay-based value of statistical life, or VOSL).

The VOSL was established at \$2 million in 1991. This has been indexed to the average hourly earnings (ordinary time) to express the value in current dollars. The Ministry of Transport updates the Social Cost of Road Crashes and Injuries annually. The updated VOSL is \$3.5 million, at June 2009 prices. Based on several international and New Zealand studies on the VOSL, the average loss of life quality for permanent impairment due to a serious or a minor injury were estimated to be 10% and 0.4% of the VOSL, respectively. These values also include the loss of productivity caused by long-term impairment (see Miller and Guria, 1991; Guria, 1993a).

As decided by the Government in 1991 (NZ Gazette notice 4983), the same VOSL for a fatality has been used in estimating the loss of life and life quality component of the social cost across all three transport modes (land, maritime and aviation). This practice has also been extended to non-fatal injuries.

6.3.2 *The EEM's estimates*

Currently the EEM adopts the estimates of the social cost of road crashes and injuries developed by the Ministry of Transport as the base values. The NZTA also develops specific reporting multipliers to estimate the social cost by speed zone and road user type.

6.3.3 *The STCC approach*

The STCC adopted the social cost of road crashes and injuries established by the Ministry of Transport.

6.3.4 Review of the STCC – areas for improvement

IWA (2007b) reviewed the STCC study and recommended that the following improvements be made with regard to estimating accident costs:

- *Further investigate evidence on the externality component of accident costs in the NZ situation:*
 - *first principles reconsideration*
 - *in-depth literature review/expert discussions*
- *Further investigate the evidence on marginal accident costs in congested situations:*
 - *NZ data/analyses*
 - *in-depth literature review/expert discussions*
- *Review the treatment of costs for road/rail accidents (between the road and rail sector analyses).*

Regarding the first aspect, the Ministry has commissioned the New Zealand Institute of Economic Research (NZIER) to investigate this in detail for all the social and environmental cost components and the three transport modes. A summary of this research is given in Appendix I.

As the other two aspects are not directly related to the valuation methodologies, they will be investigated further when we commence the data collection and estimation stage. Regarding the costs for road/rail accidents, the total and average costs should be based on the costs accrued to the mode involved. For external costs, such costs are likely to be external to rail as they are imposed by the road vehicle involved.

This literature review will focus mainly on the methods for valuing the costs of accidents.

6.4 Major issues with estimating the cost of accidents

We have identified four major issues associated with the valuation of accident costs:

- (i) The current **value of statistical life** (based on a 1990/91 survey) is too out-dated and therefore a review is necessary. The current value of \$3.5 million (at June 2009 prices) is lower than what NZ society would be willing to pay 10 years ago, and is also low by international standards (see Table 6.1). One plausible approach is to adopt the benefit transfer approach (possibly based on a meta-analysis as discussed in section 2.5.2) to obtain an alternative value for NZ.

Table 6.1: International comparison of value of statistical life

	Year	VOSL in foreign currency (note 1)	PPP(2008) (note 2)	NZ \$m
New Zealand	2008		1.567	3.35
	2001			2.55
United States (note 3)	2008	US\$5,800,000	1.000	9.09
Austria	2004	Euros 2,500,000	0.881	4.45
Norway	2005	NOK 26,500,000	9.401	4.42
Holland	2006	Euros 2,400,000	0.879	4.28
United Kingdom	2005	£1,430,000	0.653	3.43
Sweden	2001	SEK 17,510,000	9.274	2.96
Ireland	2002	Euros 1,690,000	0.941	2.81
Finland	2005	Euros 1,750,000	0.989	2.77
Germany	2003	Euros 1,160,000	0.851	2.14
France	2005	Euros 1,160,000	0.911	2.00
Italy	2005	Euros 920,000	0.866	1.67

Notes:

- 1 Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan
- 2 Purchasing Power Parity for 2008 sourced from http://stats.oecd.org/wbos/Index.aspx?datasetcode=SNA_TABLE4
- 3 Private correspondence with Larry Blincoe of the Department of Transport, United States.
- 4 Ideally we should first convert all estimates to the value of a common year first, prior to converting to NZ dollars. This raises a question regarding the choice of inflator. For indicative purposes, the estimates in NZ dollars are obtained by first converting the foreign currency to US currency using the 2008 PPP values and then to NZ dollars.

- (ii) Due to a lack of data and information, each of the **other social cost components** (including loss of life and life quality) was estimated based on a number of studies conducted during the early to mid-1990s, and was updated for price changes by indexing to a certain price index. Research commitment is required to update each of the social cost components based on more up-to-date information.
- (iii) Research is required to collect better information on the **costs of property damage** due to road, rail and maritime accidents.

Estimates of the costs associated with damage to port infrastructure, carriages, wagons or vessels are not publicly available at present. However, some sample estimates could be obtained from ports or KiwiRail.

Estimates of the repair costs due to rail incidents are recorded by KiwiRail Group. For the three years to 2007/08, the total repair cost for rail incidents was estimated at \$32.6 million¹⁸.

¹⁸ Source: Personal communication with Thomas Davis of KiwiRail Group.

- (iv) The current estimates of the social cost of road crashes and injuries do not include the **cost of travel delays** due to road crashes. The cost of travel delays includes additional travel time, additional fuel usage and the potential loss of business opportunity. NZIER (1999)¹⁹ did not find any workable methodology for estimating accident-induced travel delays. Based on the relativity found in the United States, NZIER (1999) estimated the average travel delay cost per crash would be negligible (between \$60 and \$175 per crash, in 1998 dollars), although it could be quite high for a small proportion of crashes (e.g. a crash that occurred at peak travel times on a busy motorway). A re-investigation is necessary for assessing the effect of accident-induced delays on journey time reliability.
- (v) The level of reporting is not the same across the country. The Ministry estimates the number of non-reported injuries based on data obtained from Traffic Crash Reports (TCR), the NZ Health Information Service's (NZHIS) hospitalisation data and the Accident Compensation Corporation's (ACC) motor vehicle claims data. However, there is not enough information to determine whether **reported and non-reported injuries** of the same injury severity (i.e. fatal, serious or minor) should have the same average social cost per injury.

6.5 Data requirements

The Ministry of Transport updates each year the average social cost per road injury and road crash by severity, road type, vehicle movement and region. Social cost estimates, with an adjustment for the level of non-reporting, are published by the Ministry. Subject to the problems and issues associated with the social cost estimates (discussed above), further breakdowns by a range of factors (e.g. by vehicle type, specific locations and road user types, etc) can be made as long as the corresponding crash data are available.

Regarding rail and maritime transport, the Ministry maintains a record of rail injuries (through the NZ Transport Agency), and Maritime NZ maintains a record of water-related injuries and drowning statistics.

Injury statistics for the three modes are also published in the Transport Monitoring Indicator Framework on the Ministry's website²⁰.

To address the issues discussed under section 6.4, specific data requirements (irrespective of modes) include:

- (i) **VOSL** – for a meta analysis, we need to collect the following information:
- various international WTP-based VOSL estimates
 - information about the risk in question (nature and magnitude)

¹⁹ NZIER (1999) "The social cost of accident-induced traffic delays: Review of literature and options for estimation", Report to the Land Transport Safety Authority, Wellington.

²⁰ <http://www.transport.govt.nz/ourwork/TMIF/Pages/default.aspx>

- population characteristic data, such as mean income and mean age
- data on exposure (vehicle kilometres travelled)
- price levels and national income (e.g. purchasing power parity, gross domestic product and inflation rate, etc).

(ii) **Non-VOSL components** – to update the other cost components based on actual cost data will be a time-demanding task. It may be prudent to focus only on areas that can be resolved within the timeframe of this workstream.

We believe that priority should be given to **lost output and productivity**. To estimate these, the following data will be required:

- Gender and age-specific data (including injury mix, labour participation rates, average income, average time off work due to injury, and estimates of future consumption)
- Other data including expected future GDP growth.

For medical costs, any revision will require data and expertise from the health sector to allocate common costs between the transport sector and the general health sector. Specific data requirements include hospitalisation data, ACC data and insurance data. Given the timeframe for this workstream, we recommend further analysis should be undertaken outside the UTCC project.

For property damage costs, clear information gaps remain with the rail and maritime sectors. Some of the base data can be collected from the corresponding industries (e.g. repair costs as a result of accidents) and the insurance industry.

(iii) **Costs of travel delays due to accidents (road, rail and maritime)** – To re-investigate the approach used by NZIER (1999), the following data will be required:

- frequency
- time of day
- location
- duration
- the split of vehicle involvements (private car versus commercial light and heavy vehicles).

(iv) In order to find any differences in the average social cost of motor vehicle injuries between **reported and non-reported injuries**, two important analyses are:

- *Matching of the Accident Compensation Corporation's (ACC's) data with the NZ Health Information Service's (NZHIS's) hospital data and Traffic Crash Report (TCR) data using their diagnosis information* – District Health Boards and the NZHIS have cost weight estimates by diagnosis. Together with the TCR and ACC data, cost weight information could be used to detect any material difference between the hospital treatment costs for reported and non-reported events. However, this analysis will not

improve our understanding of the costs associated with non-hospitalised injuries.

- *Reclassifying injuries by injury severity scale (as opposed to fatal, serious and minor only) and estimating the associated loss of life and life quality values* – As the social cost of road injuries is dominated by the loss of life and life quality, the current injury severity classification is too crude to distinguish between reported and non-reported injuries. A re-classification (e.g. based on diagnosis information) will help identify any differences in the distribution of injury severity between reported and non-reported injuries. Further work will be required to determine the value of loss of life and life quality by injury severity scale.

The above exercises require resource commitments from the Ministry of Transport, NZHIS and ACC. Due to the timeframe of the UTCC project, any work on this should be treated as a separate exercise.

6.6 Feedback from workshop consultation

Q1: Should we also adopt the benefit transfer approach (based on a meta-analysis) to obtain an alternative VOSL for valuing the loss of life and life quality component of accident costs?

- Most attendees supported the use of a meta-analysis to obtain an alternative VOSL estimate.

Q2: What is the best way to update various non-VOSL social cost components? Should we continue with the Ministry's existing approach? Should we investigate the possibility of using a benefit transfer approach in this case?

- While attendees did not comment on the methodologies, most agreed that loss of output was an important factor that should be investigated further, along with the revision of the VOSL estimate (since the current VOSL includes some loss of output from permanent incapacitation).
- Attendees thought that property damage costs for rail and maritime incidents and the costs of travel delays due to road crashes would be quite high, and therefore this information should be collected.

Q3: How should we address the issues with valuing reported and unreported injuries, given the time and resource constraints?

- We have obtained mixed feedback on this. Some attendees suggested carrying out a sensitivity analysis on this by using differentiated values.

Q4: What is the best way to estimate the frequency and duration of delays due to accidents?

- There was a suggestion to carry out an extension of the international literature review undertaken by NZIER in 1999, and conduct a small survey to gauge the size of such impacts.

Other comments received

- There was a suggestion to also look at the cost of perceived safety risk, and the adverse impact on travel decisions due to severe incidents (such as a serious rail crash).

6.7 Recommendations

6.7.1 *Approaches for the UTCC*

- (i) **VOSL** – Carry out a meta-analysis of WTP-based VOSL for overseas countries to obtain an alternative VOSL. Together with the existing value, this will provide a range of accident cost estimates.
- (ii) **Non-VOSL components** – Due to the tight timeframe and resource constraints, it is recommended to focus on lost output and productivity component.
- (iii) **Valuing reported and unreported injuries** – Continue with the existing approach but further co-ordination with the health sector and the Accident Compensation Corporation (ACC) should be established to improve such estimates in the longer term.

6.7.2 *Long-term research needs*

- (i) Develop a work programme (involving ACC and NZHIS) on the following issues discussed in section 6.4:
 - a. **the medical cost component**
 - b. **the valuation differences between reported and unreported injuries.**
- (ii) Collect information on **property damage costs** for rail and maritime
- (iii) **The cost of travel delays due to accidents** – further in-depth literature review is required to obtain such estimates.

7. Noise pollution

There are different sources of transport noise pollution. For road transport, there is general traffic noise²¹ (i.e. the constant hum of vehicles using roads in large towns and cities); noise caused by individual vehicles²², such as noisy car exhausts or truck engine brakes; and infrastructure construction-related noise. For rail transport, there is noise created by trains using the rail network, as well as that caused by loading/unloading of containers at depots, etc. For maritime transport, there is noise created by vessels when sitting at port; noise caused by individual vessels in shipping lanes and when calling at port, such as engine noise, and noise caused by loading/unloading of containers at ports, etc.

In this exercise, our focus is the localised noise pollution associated with general road traffic noise, and port and rail operations. The majority of these noise effects are external, as the majority of those affected typically live near major road or rail corridors and ports. In terms of the size of the impact, the coverage of road traffic noise is much wider than that of rail and port noise. Therefore, we would expect much of the effect on human health (the noise effect on animals is not the subject of this work) to come from road traffic noise. However, in terms of localised noise pollution, rail and port noise can have a significant effect on those who live near to rail tracks and depots as well as ports.

The following noise sources are not the subject of this study:

- Noise inside a vessel, vehicle or train. These noises can affect individuals' levels of comfort and have noise-related health effects.
- Noises from infrastructure construction or maintenance work.

7.1 Rationale for collection

7.1.1 Policy context

The estimation of the costs of harmful emissions is useful for three reasons:

- First, such information helps us to understand the current state of localised noise pollution associated with general road traffic noise, and port and rail operations, and to analyse any trend or patterns.
- Second, such estimates are required to determine the potential benefits from mitigation. When information on the costs of noise pollution is used together with estimates of other costs and benefits, policy makers can judge whether or not individual projects and programmes are worthwhile.

²¹ The time average level A-weighted sound pressure level or $L_{Aeq(24h)}$ unit is established as the preferred metric for the assessment of road traffic noise in New Zealand. Source: Standards NZ, 2009.

²² L_{Amax} is the criterion for assessing individual vehicles.

- Finally, understanding the marginal (external) costs is also important for understanding the extent to which pricing could bring about a better utilisation of the existing transport network and mitigate the localised noise pollution effects from transport use.

7.1.2 *Magnitude of impacts*

Transport noise can cause a range of impacts on people and communities, from general interference with everyday activities through to more significant health issues. The following impacts of noise pollution have been discussed in the literature (e.g. National Health Committee, 2003; LTNZ, 2006; Standards NZ, 2009):

- impaired communication (speech interference)
- impaired school and work performance
- annoyance and stress-type responses such as depression and aggression
- acute and long-term noise exposure activates the nervous and hormonal systems, leading to increased blood pressure, and increased heart rate and the narrowing of blood vessels, and therefore aggravates heart disease and hypertension
- hearing impairment
- sleep disturbance, which will impact on daytime functioning and lead to mood effects.

These psychological, functional and physiological disturbances can result in substantial health effects and the associated medical costs and loss of output and productivity. This also causes amenity issues.

Sounds which are audible to people range from the threshold of hearing at 0 dB to the threshold of pain at levels over 130 dB (Brüel & Kjær 1984). Noise above 65 dBA²³ is highly undesirable. More specifically, the World Health Organisation (WHO) recommends maximum noise levels of ≤ 30 dBA in sleeping areas. For outdoor living areas, in residential areas, exposure levels should not exceed 50–55 dBA. Some local planning authorities include design levels and performance standards in local plans, but considerable variation exists. Table 7.1 summarises the average sound levels for different locations and activities.

The level of road traffic noise generated depends on traffic volume, traffic speed, traffic composition, road gradient and pavement texture. The spread of traffic noise can be influenced by the distance from the source of the noise to the reception point (e.g. residual housing), road profile (elevated, depressed or at grade), the surrounding areas between the source of noise and the reception point, the presence of screening and the weather conditions (e.g. LTNZ, 2006; Standards NZ, 2009).

²³ dBA is an abbreviation for the A frequency weighted decibel as per IC651, a scale of sound measurement which emulates the human auditory response.

Table 7.1: Sound scale

Activities/locations	dBA
Hearing threshold	0
Very calm bedroom	30
Library	40
Conversation	60
Street	70
Vacuum cleaner	80
Hearing damage from long term exposure	Approx. 85
Traffic noise on major road (at 10 m distance)	90
Jackhammer (at 1 m distance)	100
Aircraft takeoff (300m distance)	120
Hearing damage during short term effect	Approx. 120
Threshold of pain	130

Data source: LTNZ, 2006 and http://en.wikipedia.org/wiki/Sound_level#Sound_pressure_level

For the maritime area, port noise can be a major problem for ports located near residential areas, since ports tend to operate for very long hours (some operate 24 hours a day, 7 days a week) and have a number of noise emission sources (e.g. the crashing noise from cranes and fork-lifts picking up and placing containers, engines revving/whirring, voices on loud speakers, and horns).

The number of people exposed to road traffic, particularly in urban areas with higher population densities, leads to road traffic being the most common source of transport noise. In 1996, it was estimated that between 6.7% and 17.8% of households are exposed to a noise level L_{eq} (24h) of over 60 dBA (LTPS-EE, 1996, p. 36).

7.2 Literature review

7.2.1 Valuation of transport noise impacts

As noted in the literature (e.g. LTPS-EE, 1996; LTNZ, 2006; Austroads, 2009), there are three general approaches for valuing transport noise impacts:

- **The mitigation cost approach** – this is sometimes referred to as the ‘*Control or Avoidance Cost approach*’. It is based on the costs of mitigating or avoiding damage. The costs associated with land use and transport planning (e.g. zoning decisions) could be used as a measure of avoidance cost of noise pollution. But this approach is difficult to implement and there are many factors affecting land use decisions.

The mitigation approach, on the other hand, focuses on the cost of reducing the noise exposure of adjacent residential buildings to limit noise to a pre-determined threshold (typically between 50 and 65 dBA, depending on the location).

LTNZ (2006) noted that there are three technical options for mitigation, namely dealing with noise at the source, controlling the transmission of noise, and decreasing noise at the receiving end. Due to the variations in approach, the mitigation costs can vary substantially.

The mitigation for road noise may include the use of the latest noise-reducing road surface materials, various forms of noise barrier, a house noise insulation upgrade (e.g. double glazing), and an earth bund (LTPS-EE, 1996; LTNZ, 2006). Other measures include vehicle noise standards, and speed and traffic reduction measures. The mitigation options and costs are summarised in Tables 7.2 and 7.3 (reproduced from Standards NZ, 2009).

Mitigation for rail may include better management of rolling stock (e.g. the use of improved brake technology), railway line design (e.g. the use of sound absorptive rail-track beds) and, to a lesser extent, improved land use and planning (LTNZ, 2006).

To mitigate port noise, the Port of Napier and Port Nelson are offering financial assistance to neighbouring residences for sound insulation.

For Port Nelson, householders in existing 'noise-affected properties' are entitled to financial assistance from the Nelson City Council (owner of 50% of Port Nelson), from between 50% of the cost of sound insulation to 100% of the costs, or property purchase, depending on the noise levels (Nelson City Council, 2008). Other mitigation options adopted by Port Nelson that minimise noise at source include:

- Controlling the use of loudspeaker systems during night-time
- Relocating loading operations
- Improving storage facilities
- Changes in operational procedures
- the uptake of technology to quieten forklifts and other noisy generators or equipment.

In Napier, for houses receiving a long-term average of 68 decibels of port noise or more, the Port of Napier (mainly owned by the Hawke's Bay Regional Council) will pay all sound insulation costs²⁴ (between \$20,000 and \$100,000 per house). The Council will spend \$250,000 a year until all homes are insulated. Where the level is 65 to 67 decibels the port will pay 60 per cent, but the homeowner's contribution will be capped at \$20,000.

- **Hedonic pricing approach** – this approach values the negative influence of road noise and vibration on house prices. The hedonic pricing approach is a revealed

²⁴ Source: <http://www.stuff.co.nz/dominion-post/news/hawkes-bay/2367460/Port-to-pay-for-sound-proofing> (accessed 30 April 2009).

preference approach using a surrogate market for valuing intangible goods. As noted in LTPS-EE (1996), the hedonic pricing approach ‘fails to separate real resource effects from intra-community transfers’ and therefore ‘may overstate externality costs’.

- **Impact pathway approach** – this approach requires assessment of the negative impacts of noise pollution on health or illness, and deriving from that the value of the impacts. However, it is difficult to value the welfare losses of illness, and some of the effects are not valued at market prices. This is the most data intensive approach and is likely to be subject to high uncertainty.
- **Benefit transfer approach** – This is commonly used in assessing the social cost of noise impacts (e.g. Austroads, 2003; Quinet, 2004; Austroads, 2009d). For a brief description of this method, including its advantages and disadvantages, please refer to Section 2.5.2.

Table 7.2: Road noise mitigation options (Source: Standards NZ, 2009)

Option	Description
Vehicle noise emission regulations	The Ministry of Transport develops policy for regulations for sound emitted from vehicles. These regulations are administered by NZTA.
Traffic management	Speed limits or traffic calming measures can be used to reduce vehicle speeds, and travel demand management can be used to reduce vehicle numbers. Reducing vehicle speed or numbers can reduce traffic noise levels, although significant changes are needed to have an appreciable impact.
Low noise road surfaces	Different road surfaces have different noise characteristics associated with tyre-road interaction. ‘Low-noise surfaces’ have been utilised for many years and their development is continuing.
Road alignment	Removal or attenuation of traffic noise can be effectively achieved in the early stages of design by modifying route selection, horizontal/vertical alignment and gradient. However, these options can be expensive and are generally only available for new roads.
Driver education/behaviour	In many situations, noise disturbance is caused by peak-noise events, which are often related to driver behaviour and individual vehicle noise. Creation of quiet zones, signage, and traffic calming can assist noise reduction.
Noise propagation	The specific and changing environment that a road passes through impacts on the propagation path of noise. Noise reduces with distance from a road, and soft ground and natural barriers such as hills can reduce noise.
Noise barriers and bunds	Barriers and bunds work by interrupting the ‘line-of-sight’ path of noise between the source and receiver. Barriers and bunds generally need specific design to provide the required noise reduction and can have other effects such as visual impacts.
Building design and layout, building relocation	Effects of traffic noise can be managed within a site using a number of site specific approaches. These include the design and layout of buildings on the site, or possibly the re-location of existing buildings.
Voice amplification	In sensitive environments such as classrooms, traffic noise can be managed to some extent by using a voice amplification system to increase the sound level of the teachers’ voices.
Acoustic insulation	Indoor noise levels in protected premises and facilities can be reduced by modifying the design of new buildings and altering existing buildings to enhance the acoustic insulation provided by the building envelope. However, noise in outdoor areas is not altered, and there are ventilation considerations.

**Table: 7.3 Indicative road noise mitigation costs – 2008
(Source: Standards NZ, 2009)**

Structural mitigation			
Noise mitigation category	Subcategory	Indicative cost / Unit	Unit
Low noise road surface	OGPA	\$20.00 ³	sqm
	SMA	\$25.00 ³	sqm
Noise barrier - 2m	timber	\$200.00	linear m
	concrete	\$300.00	linear m
	polycarbonate	\$800.00	linear m
Noise barrier - 3m	timber	\$333.00	linear m
	concrete	\$500.00	linear m
	polycarbonate	\$1,333.00	linear m
Noise barrier - 4m	timber	\$466.00	linear m
	concrete	\$700.00	linear m
	polycarbonate	\$1,866.00	linear m
Noise barrier - 5m	timber	\$600.00	linear m
	concrete	\$900.00	linear m
	polycarbonate	\$2,400.00	linear m
Noise bund	non-struct recycled earth	\$10.00	cubm
	non-struct imported earth	\$25.00	cubm
	structural recycled earth	\$15.00	cubm
	structural imported earth	\$30.00	cubm
Building modification mitigation			
Noise mitigation category	Subcategory	Indicative cost / Unit	Unit
Acoustic insulation	dwelling	\$15,000.00	Unit
Educational premises	Teacher voice amplification system	\$1,000.00	Room

³ Differential cost relative to grade 2 chip seal.

Please note that the estimates obtained from these approaches are not directly comparable because they measure different things. The impact pathway approach only determines the impact patterns. The mitigation cost approach measures the costs of mitigation rather than the consequences. The hedonic pricing approach values the negative influence of road noise and vibration on house prices. The benefit transfer approach could be used for determining either the impact patterns or the unit value of health effects.

7.2.2 *Total, average and marginal costs*

The total costs of noise pollution are obtained by summing all related costs by location or road user type.

The average cost of noise pollution per vehicle or passenger kilometre travelled (VKT or PKT) is obtained by averaging the total cost for all (or a group of) road users across the total VKT or PKT of those users. However, this measure is of limited use.

In theory, the marginal cost of travel is obtained by taking the derivative of the total cost of travel with respect to the quantity of travel. For estimating the marginal cost of noise pollution, a practical approach would be to look at the incremental impact of changing the noise level by a small percentage. Once the impact is estimated, we can then apply the same unit costs to estimate the marginal cost for each component.

7.2.3 *Noise and vibration*

Although there is a link between noise and vibration, the effects are very much site specific and apply in situations such as roads or railways near historic buildings, and to road construction in densely-populated urban areas (NZTA, 2008). In general, the number of dwellings exposed to significant vibration should be quite small. However, for hospitals, the vibration impacts could have significant results if they affect the operation of sensitive equipment.

7.3 **NZ practice**

7.3.1 *The STCC approach*

The STCC study applied the cost factor estimated in LTPS-EE (1996).

Due to the lack of a generalised noise mapping baseline (above which transport noise costs will be incurred) for assessing existing exposure levels against relative traffic volumes, the STCC study used an approximation approach to estimate the marginal cost of transport noise. This method is outlined as follows:

- Assume the proportion (15% was assumed) of the national population exposed to noise levels above a pre-determined threshold (a 60 dBA level was used).
- Assume the threshold correlates with a certain level of traffic volume (20,000 vehicles per day was used).
- The first two assumptions give an affected population of 215,000 households.
- Assume an average house value of \$200,000 (mainly urban).
- Using the Noise Depreciation Index (NDI) developed in LTPS-EE (1996), the STCC study assumed an NDI of 0.5 corresponds to the depreciated value of \$3,000 per house.

- The above give a total depreciated value of \$645 million, and the annualised cost was \$101 million, using the same discount rate as LTPS-EE of 6.4% (p. 38 of LTPS-EE).
- Divide \$101 million by 38.6 VKT and obtain the marginal cost of 0.26c/VKT
- For urban traffic, the marginal cost was 0.61c/VKT, or 0.52c/km for cars and 2.62 c/km for trucks.

Regarding environmental costs, IWA (2007b) recommended several areas of significant weakness and uncertainty that warranted further research. The areas that are relevant to this workstream are summarised in Section 4.3.3.

7.3.2 *The EEM methodology*

After considering the results of international literature (e.g. a British survey and a Canadian survey), NZTA (2008) recommended that the noise effects should be assessed as 1.2% of the value of properties affected per dB of noise increase (0.6% multiplied by a factor of two to take into account effects not captured in the property values). Using the median house price of \$327,000 and occupancy of 2.6 persons, NZTA (2008) suggested a NPV cost of \$3,924 per dB per property and \$1,500 per dB per resident affected (\$410 per household or \$160 per person per year)²⁵.

NZTA (2008) also recommended that a national median be applied in all areas as there was no reason to suppose that noise was less annoying to those in areas with low house prices. For simplicity, this also applies to any increase above existing ambient noise levels. However, for highly sensitive areas such as schools and hospitals, NZTA (2008) mentioned that an appropriate site-specific survey (e.g. WTP survey) be carried out to determine a specific noise value for those situations.

7.4 Major issues with estimating the cost of transport noise

The most important determinant of the cost of noise pollution is the size of the problem. LTNZ (2006, p. 17) mentioned that, although “*a number of local authorities report that noise monitoring occurs as part of wider state of the environment reporting, but no national monitoring or data collection is undertaken*”.

During 2001 and 2002, the Ministry of Transport commissioned Sinclair Knight Merz (SKM) to develop a *National Noise Impact Analysis Model (NNIAM)* for building an inventory or quantitative model of noise emissions from road and rail sources in New Zealand. Further investigation is required to understand whether this model can be utilised and updated to help establish the baseline noise exposure at the regional or national levels.

²⁵ The EEM uses a real discount rate of 8% per annum.

7.5 Data requirements

To understand the full cost of transport noise to human health, the most appropriate approach is the *impact pathway approach*. The data requirement for such an analysis includes the following:

- information on the existing general road transport noise levels
- determining a NZ noise threshold (above which health effects occur)
- measures of exposure of humans to transport noise
- measures of the dose-response relationships between exposure and health effects
- NZ-specific willingness-to-pay or accept contributions to mitigating its effects.

However, given the tight timeframe, this approach is not feasible as it will require: (i) the development of a dose-response function for NZ, and (ii) a WTP/WTA survey to determine the unit cost. Alternatively, a *benefit transfer approach* (i.e. based on international findings and adjusted to the NZ context) could be used in place of a survey.

Other alternatives include the use of the *hedonic pricing approach* based on the STCC framework (with appropriate improvements in assumptions). The data requirement for a hedonic pricing approach includes:

- locations of noise-affected areas
- assumptions on the level of exposure
- assumptions on noise thresholds
- assumptions regarding the relationship between traffic volumes and noise levels
- data on average or median house values.

Both the *impact pathway approach* and the *hedonic pricing approach* require applying international findings to NZ data to some extent. Therefore, the following information will also be required:

- population characteristics
- vehicle mix and other traffic information
- price index and income level (e.g. purchasing power parity, gross domestic product and inflation index).

The mitigation cost approach is not a measure of consequential cost. It is a measure of preventive cost which should be collected as part of another UTCC workstream.

7.6 Questions for discussion

Q1: Road – Given the lack of information on the current level of transport noise exposure (% of total dwellings exceeding various noise levels), should we utilise the STCC approach (based on the *hedonic pricing approach*)? If so, are the STCC assumptions appropriate? Is there information/data to help refine the assumptions?

- Many attendees supported the utilisation of the NNIAM, as opposed to the STCC, approach, and applying the unit value of the EEM.
- Attendees were not aware of any data to help refine the assumptions.

Q2: Rail and port operations – is there any information that helps estimate the level of exposure?

- The NNIAM also includes rail.
- Attendees were not aware of any data to help refine the assumptions.

Other comments received

- Some argued that the social cost of transport-related noise pollution should not be high relative to other effects (such as congestion and safety), and therefore recommended against investment in time and effort on this subject. Therefore, they supported using the current EEM's approach and unit values.
- Some noted that the major issues included:
 - The characteristics of sound are difficult to determine (compared to the levels of sound)
 - The frequency and duration of noise pollution are sometimes more important than level of sound in determining the noise impacts on people.

7.7 Recommendations

7.7.1 Approaches for the UTCC

- (i) Review the appropriateness of the Noise Depreciation Index (NDI) developed in LTPS-EE (1996) for current use.
- (ii) Adopt the STCC approach with refined assumptions on noise thresholds and an updated valuation as per EEM to generate one set of estimates (for baseline comparison purposes).
- (iii) Further investigate whether SKM's *National Noise Impact Analysis Model* can be utilised and updated to help establish the baseline noise exposure at the regional or national level, and for estimating the costs of noise (hopefully to obtain an alternative set of estimates).
- (iv) Due to the time and resource constraints, vibration effects should be investigated outside the UTCC workstream.

7.7.2 Long-term research needs

- (i) Establish a data collection/estimation programme that would allow the sector to understand the extent of the issue. This should focus on areas where there is a significant noise source e.g. heavily-trafficked roads and significant areas of impact, such as major urban areas.
- (iii) To investigate the scope for carrying out a New Zealand-based *Impact Pathway Analysis* to understand the dose-response relationship in New Zealand. This includes the data requirements and other specifications that are required for completing such a survey.

8. Interactions of effects

There are interactions between various social and environmental effects, particularly with road congestion (see Table 8.1). Traffic congestion also has an adverse effect on fuel consumption and CO₂ emissions. Traffic speeds lower than 20 km/h cause a significant increase in fuel consumption and CO₂ levels emitted per vehicle-km. It has also been estimated that, for a 40-tonne articulated lorry, making 'two stops per kilometre leads to an increase of fuel consumption by roughly a factor of 3' (Piecyk and McKinnon, 2007).

Table 8.1: Interactions of effects

Category	Main effect	Other effects
Road congestion	Lost travel time	Increased environment costs from increased emissions
		Increase in vehicle operating costs
		Effects on accidents
Greenhouse gas (GHG) emissions	Climate change / global warming effects	Crop and building damages and other environmental impacts. Health impacts - Increased water-borne and vector-borne diseases due to global warming.
Harmful emissions	Health effects from air pollution	Lost output/productivity
Accident costs	Consequential costs associated with accidents	Travel delays due to accidents Lost output/productivity
Noise	Health effects from noise pollution	Multiplicative effects with vibrations (e.g. heavy trucks and trains)
Spills	Health effects from water pollution	Safety risk
Run-off and water quality	Health effects from water pollution	Biodiversity and biosecurity issues

9. Other social and environmental costs

9.1 Bio-security

The risks posed to New Zealand by both the introduction and spread of invasive aquatic species are considerable. Amenity values, recreational fishing, commercial fishing (including aquaculture) and coastal installations could all be impacted to varying degrees.

New Zealand is particularly concerned about marine pest organisms arriving by ballast water or fouling on the outside of hulls or structures. There are mandatory requirements for ballast water (mid-ocean exchange of all ballast water to be discharged in NZ waters at least 200 NM offshore). This applies to vessels and structures from outside the New Zealand Exclusive Economic Zone (EEZ), but other vessels are encouraged not to take ballast from one part of NZ to another unless it can be exchanged en route beyond 50 miles offshore²⁶.

New species might arrive in New Zealand waters attached to the hull or in the ballast water of commercial vessels, or indeed be introduced by a relatively small recreational vessel visiting from another country. Domestic maritime transport (commercial and recreational) plays a key role in the spread of such species around NZ once they have become established here.

The costs to New Zealand of the introduction and spread of invasive aquatic species are difficult to assess, but material related to two recent introductions will provide some insights about the risk and the potential scale of the problem²⁷.

- *Styela* (sea-squirt) was identified in Viaduct Harbour, Auckland in September 2005, and later at Lyttelton Harbour in October 2005. *Styela* originates from the north-west Pacific (Japan, Korea), and has become established in Asia, Europe, North America and parts of southern Australia. Fouling on vessels and marine equipment is considered the major means for its spread (internationally and domestically).

An Economic Impact Assessment carried out for Biosecurity New Zealand²⁸ in 2005 found that *Styela* had the potential to cause significant economic impacts. The primary impact would be on mussel farming, with lesser impacts expected on oyster farming and other forms of aquaculture. National impacts would vary according to the speed with which major aquaculture regions (Auckland-Waikato, Marlborough, and Nelson-Tasman) became infested. Minor additional costs were likely for a wide range of marine users needing to undertake additional anti-fouling. This was based on impacts on the aquaculture industry, and did not

²⁶ Maritime New Zealand's website http://www.maritimenz.govt.nz/biosecurity/bio_sec.asp (accessed 30 April 2009).

²⁷ Information source: personal communications with Mr. Allan Bauckham, Marine Biosecurity Programme Coordinator, Ministry of Agriculture and Forestry, Biosecurity New Zealand.

²⁸ NZ Institute of Economic Research (2005), "Sea squirt alert: Economic impact assessment of *Styela clava*", Report to Biosecurity New Zealand, Ministry of Agriculture and Forestry.

include unquantifiable environmental and conservation impacts. The cost of any ecological impacts of the organism was not assessed due to a lack of available information.

The potential impact over a 21-year period was estimated to fall in the range of \$13 million to \$240 million (present value²⁹), in 2005 dollars. This wide range reflected the lack of data on *Styela* behaviour in New Zealand, and uncertainty over the rate of its spread. The lower estimate was based on a scenario where *Styela* did not spread beyond its current range. Based on the known biology of *Styela*, Biosecurity New Zealand believes it is inevitable there will be further spread, and therefore it is likely that the impacts will fall into the middle or upper end of the range.

- *Sabella spallanzanii* (Mediterranean fanworm) was detected in Lyttelton Port in May 2008. It is likely that Mediterranean fanworm came into New Zealand through international vessel movements, via a ship's ballast water, or by attaching itself to a vessel's hull (biofouling), and would be spread within NZ by these means.

Mediterranean fanworm has the potential to have significant negative impacts on New Zealand's environment, economy, and social and cultural values. It is an invasive species with no known predators and an ability to thrive in a wide range of habitats. It may displace existing species, threaten high-value conservation and biodiversity areas, and foul port structures, vessels and aquaculture farms. It can become a nuisance to marine farmers and recreational and commercial fishers through the clogging and fouling of marine structures, fishing equipment and boats. High densities of this organism could impact on the commercial harvesting of species such as mussels, oysters and scallops.

Mediterranean fanworm poses a significant threat to high-value conservation and biodiversity areas such as marine protected areas, mātaihai reserves (regulated areas of customary managed Māori fishing grounds), and marine reserves. It may also impact on Māori kaitiaki (guardianship) values, customary fishing and species of value to Māori.

The lack of qualitative information on the impacts of Mediterranean fanworm means that a full cost-benefit analysis is not possible. However, Mediterranean fanworm has similar impacts to *Styela*, and the impact analysis for *Styela* (based on Canadian experiences, and modified for New Zealand circumstances) provides the best available quantitative assessment of the potential impact of *Sabella*.

²⁹ The analysis was based on a 10% discount rate (real).

9.2 Run-off and water quality

The effects of transport use on water quality can be classified into three major sources, namely spills (oil and chemicals), operational discharges, and run-off.

9.2.1 Spills

Spills are mainly a maritime issue due to the scale of the potential problem and the difficulty with containment. Although small spills do occur relatively regularly in road transport, the potential impact is usually smaller and is easily contained. Spills from rail rarely occur in New Zealand.

Road

Small spills from road transport occur regularly and can result in safety and environmental risks. There are also high clean-up costs involved and, when part of the network is closed for the clean-up, it will result in traffic delays or cause inconvenience to road users.

Spills may occur in two situations. Firstly, when a vehicle carrying chemicals, oil or another noxious liquid loses control or crashes and this results in the load falling or being spilled. The size of the spill, and hence the environmental impacts, will depend on the characteristics and the size of the load, the severity of the incident, and whether the load is sufficiently secured. Secondly, smaller spills of fuel from vehicles may occur as a result of a crash. While these spills may be small, the frequency of their occurrence means a sizeable impact on run-off and water quality.

According to the data provided by New Zealand Fire Service, over the three years to 2008 there were around 370 gas and chemical spills due to road transport accidents causing environmental effects. The majority (over 70%) of spillages resulted in gas and other liquid spills of less than 10 litres. It is likely that many of these incidents are associated with spills of fuel from vehicles as a result of a crash. On the other hand, over 10% of the spillage incidents resulted in gas and liquid spills of between 10 and 30 litres, with another 7-8% of between 30 and 250 litres. The remaining 10% of the spillage accidents are related to chemical spillages, with the majority being spills of less than 10 litres. Of the total, only 5 incidents (or 1%) resulted in spillages of over 1000 litres (of chemical, gas or other liquids).

Unfortunately, no information is currently available on the monetary loss due to the loss of goods; the costs of cleaning up and the environmental costs from these spills.

Rail

KiwiRail Group advised that there were two spills in the past four years. The first incident occurred at Southdown Station, where a locomotive struck a railway furniture maliciously placed between the rails and ruptured fuel tank. The cost of cleaning up, involving digging out ballast and dirt and separating out diesel, was over \$100,000. The environmental damages were unknown. The second incident occurred at Mill

Spill Picton, where milk leached through ballast into the Waitohi Stream and entered Picton Harbour. The prosecution fine was around \$40,000.

Maritime

Oil, chemicals and other noxious liquids are the major substances in maritime spills. In the event of an oil spill vessel operators should make all reasonable attempts to stop the discharge and prevent oil reaching the marine environment. Where possible oil should be contained and recovered from the water. Regional councils and Maritime New Zealand have spill response expertise and equipment, which will be activated as soon as a report of an oil spill is received.

Chemicals and other noxious liquid substances can present a hazard to the marine environment and to human health. The variety of such substances is wide, ranging from foodstuffs like vegetable oils and animal by-products like tallow, to a large number of synthetic chemicals. The environmental impacts vary but the principal hazards comprise bioaccumulation, aquatic toxicity, mammalian toxicity, irritation, corrosion and long-term health effects, tainting of sea food, physical effects on wildlife and benthic habitats, and interference with coastal amenities.

In the case of oil, New Zealand has well-developed spill planning and response arrangements that ensure that the social and environmental impacts are mitigated. In addition, the liability for pollution damage (including damage to third-party property) sits squarely with the spiller (the “polluter pays” principle). The assurance of payment is underwritten by requirements for larger ships to hold public liability insurance to cover their potential liability – that limit being prescribed in law on the basis of the size of the ship concerned.

In the case of noxious liquid substances, the framework is less well developed with no comprehensive planning and response arrangements in place. Policy work led by the Ministry has been done on the merits of such arrangements in the last two years, and more is planned in the near future. At the present time, however, the social and economic costs of any significant marine spills of this kind could be expected to be higher than they would be if such planning and response arrangements were in place. The current law, it should be acknowledged, already applies the polluter-pays principle to pollution damage from spills of noxious liquid substances³⁰. The fairly well-developed framework for dealing with marine spills provides opportunities to efficiently derive some measures of social and environmental cost. These include the accounts of the NZ Oil Pollution Fund, which finances, through a levy on ships carrying oil (cargo and fuel), the development of the New Zealand marine oil spill response capability. The accounts of the fund are accessible through Maritime NZ. MNZ also maintains a record of spill clean-up costs where these are funded by the OPF. While the fund covers all marine oil spills, coastal shipping’s levy contributions and clean-up costs may be disaggregated.

³⁰ In all cases, pollution damage covers both direct property damage (a fisher whose nets become fouled by oil, for example); economic loss (the fisher who cannot fish or the marine farmer who cannot harvest because the fishery is closed); interference with legitimate uses of the sea (including loss of amenities); and reasonable measures of environmental restoration.

Given that there is no record of significant spills with extensive third-party damage involving coastal ships in recent times, this is a cost category which awaits a realised risk. The probability of this occurring may be derived from MNZ's periodic risk assessment of marine oil spills.

Shipping has an extensive programme of pollution prevention involving ship design, the fitting and operation of pollution prevention equipment, operational procedures, and management systems. These are derived from international standards found in treaties developed under the auspices of the International Maritime Organisation. These standards are extended, to a greater or lesser extent, to ships in New Zealand domestic trade. The costs associated with these preventive measures are outside the scope of this paper.

9.2.2 Operational discharges and waste disposal

Road

There is a limited risk of operational discharges and waste disposal from road transport, with the exception of stock truck effluent disposal.

In New Zealand, there is a practical guideline for establishing stock truck effluent disposal sites to minimise environmental impacts. There is also an Industry Code of Practice (COP) for the Minimisation of Stock Effluent Spillage from Trucks on Roads. This COP provides information on how to reduce the amount of stock effluent falling on to roads and ensure voluntary and co-operative industry management of the issues.

Inappropriate stock effluent disposal can result in negative environmental impacts (e.g. run-off) and create road safety hazards (e.g. slippery roads and dirty windshields). There is insufficient information to determine the costs of such impacts at present.

Rail

There is a limited risk of operational discharges and waste disposal from rail transport.

Maritime

In shipping terms, operational discharges are those permitted harmful substances (oil, noxious liquid substances, sewage and garbage) that may be discharged into the sea under controlled conditions and in limited quantities. Coastal ships must meet these requirements, which are mostly derived from international standards. Where these standards are met, the social and environmental costs should be negligible.

Maritime NZ is currently researching the costs associated with discharges of sewage from ships, including coastal trading vessels. This is part of the rules contract for the current year, with a view to developing draft rules to give effect to international rules

for the prevention of pollution from sewage (Annex IV of MARPOL). The current New Zealand law for permitted discharges is significantly more permissive than the MARPOL sewage standard.

Maritime NZ is planning in 2009/10 to undertake an assessment of operational discharges of oil from ships in waters under NZ jurisdiction, including coastal ships. The aim is to quantify the amount of oil entering the New Zealand marine environment.

Work is also being done on garbage discharges, but focussed on fishing vessels, and on establishing (and dismantling) barriers to compliance with existing standards.

9.2.3 *Run-off*

The problems associated with run-off predominantly relate to road transport and, to a lesser extent, to rail transport. For maritime transport, this is covered under the spills and operational discharges and waste disposal section.

Transport produces a complex mix of various emissions that could affect the stormwater system. The following discussion has been derived mainly from Kennedy (2003)³¹. Table 9.1 reproduces a summary table in Kennedy (2003) that discusses the key sources contributing to general urban stormwater quality.

For road transport, the major contaminants include motor vehicles and their interactions with the road environment. Stormwater transports particulate matter containing high concentrations of contaminants, including a wide range of organic and semi-organic components. Many contaminants are present as a result of their emission from a number of sources associated with motor vehicles (such as tyres; brake pad wear; exhaust emissions; oil, grease and coolant losses, etc). Most road surfaces are constructed using bitumen, which contains some metal concentrations that will contribute to stormwater run-off.

According to Kennedy (2003), work in New Zealand using toxicity tests has shown that urban stormwater has chronic effects on the growth of freshwater algae. Further, urban stormwater testing has shown that a moderate proportion of all stormwater samples demonstrate toxicity to fish or invertebrate species. However, Kennedy noted that the degree of toxicity will vary between catchments and locations, depending upon other factors such as other sources and baseline concentrations.

Estimating the proportion of contaminants in stormwater derived from motor vehicles is complex, as it requires either an accurate estimate of the amount of contaminant emitted from vehicles, or an estimate of the amount of contaminant produced by other sources. Due to the number of different types of a particular component involved, there is considerable variation between countries and over time in contaminant emissions from motor vehicles.

³¹ Kennedy, P (2003), *The Effects of Road Transport on Freshwater and Marine Ecosystems*, Report to the Ministry of Transport, Wellington, New Zealand.

MWH (2007) successfully developed a GIS-based method for identifying and ranking sensitive receiving environments at risk from road run-off. The methodology incorporates the source-pathway-receptor risk concept to spatially link areas of high traffic intensity, run-off discharge routes and sensitive downstream environments potentially at risk. The tool can determine the relative contributions of pollution in road run-off from state highways and local roads, at the regional or national level. However, the tool does not provide information on the actual size of road run-off and therefore can only be used on a comparative, rather than absolute, basis for assessing road networks and their effects on receiving environments. It is possible that the model results could be used to gauge the potential risk of specific locations, and from there to derive possible environmental impacts and costs.

Table 9.1: Summary of key sources contributing to general urban stormwater quality (Adapted from Kennedy, 2003 which originated from ARC, 1992)

Source	Comment on Source
Motor Vehicles	Vehicle exhaust emissions, oil and lubricating losses, wear of vehicle body, tyre and brake wear.
Road Surface	Wear and breakdown of road surface including aggregate and other material used in base course and surface, bitumen, concrete and other materials used on road surface (e.g., marking paint).
Litter/Organic Debris	Wide variety of litter and debris of inorganic origin (metal, glass, plastic) and organic (food, paper, plant, litter and animal waste) origin.
Buildings	Corrosion and other weathering products from adjacent buildings including dry and wet losses. Includes losses such as Cu from Cu facings and gutters, roof runoff (paint fragments etc.,).
Construction	Building maintenance and construction produces a wide variety of inorganic dust and other debris (e.g., paint waste).
Soil	Wind and rain will transport fines in soils from adjacent areas onto roadways. Materials are typically silts, clays and sands with low organic content.
Rainfall	Atmospheric washout will contribute fine particulate material present in urban air. Sources will be site specific. A portion will be local and vehicle derived.

9.3 Upstream effects – infrastructure and environment

9.3.1 *Infrastructure quality*

In a study of the impacts of Brazilian highway conditions on fuel consumption and carbon dioxide (CO₂) emissions, Bartholomeua and Caixeta Filhob (2009) found that travel over well-maintained roads has environmental benefits over travel on poorly maintained roads, and there could be a 5% reduction in fuel consumption in the case of Brazil. In other words, poorly-maintained road surfaces can add to fuel consumption as well as emissions and other environmental costs.

9.3.2 *Infrastructure construction and maintenance*

As noted in Peploe and Dawson (2006), road construction material “may act more as a receptor, absorbing run-off contaminants, than as a source which liberates its own contaminants”.

To minimise the environmental impacts from infrastructure construction and maintenance, Peploe and Dawson (2006) caution that the following criteria will need to be considered:

- **Economic acceptability** – Blending and/or adding stabilising agents can reduce run-off, but sourcing (manufacture and transport) these may be costly, so high proportions of such components may make the project become uneconomic.
- **Sustainability** – The production, amendment and placement of the secondary material may help reduce environmental impacts, but we need to be clear that the secondary material is at least as sustainable as that which it replaces. At present, there is a lack of information for such assessment.
- **Similar long-term performance** – As with any new material, immediate success does not, of itself, presage lasting performance. There is a lack of evidence to prove longevity of substitutes since many tests are based on short-term tests.

9.3.3 *Parking facilities*

Provision of land or space for parking imposes environmental costs to society. These include reduced landscaping, farmland and wildlife habitat, increased impervious surfaces and related stormwater management costs. Litman (2009) states that the construction of parking facilities, particularly parking structures, consumes large quantities of energy and results in significant emissions of greenhouse gases from the production of concrete and steel. Ongoing operations and maintenance also require energy and materials that have environmental costs.

9.4 Downstream effects – End-of-life disposal of transport waste

Disposal of waste arising from the transport system can take many different forms. It includes disposal of used lubricating oil, batteries, waste tyres, vehicle or vessel parts or bodies, etc. With the increased level of transport use over time, the disposal of waste arising from transport use has also been increasing over time. Transport users and decision makers are increasingly aware of the issues associated with the sustainability of current waste disposal practices. However, the scale of the problem is difficult to quantify.

9.4.1 Road vehicle disposal

Vehicles continue to create costs at the end of their usable life by releasing a range of harmful substances to the environment. These environmental impacts are summarised in Table 9.2.

The costs created by end-of-life vehicles (ELV) vary greatly between jurisdictions, depending on the level of recycle and reuse taking place. In New Zealand, an early study of what happens to a car at the end of its useful life was conducted by Statistics NZ in 1998 (Tipping, 1998). This study looks at the environmental effects of end-of-life vehicle disposal and the disposal treatment of certain car parts in New Zealand.

More detailed studies of ELV treatment systems have been undertaken in other jurisdictions (Jeong et al., 2007), but comprehensive data can only be obtained from those where the industry is heavily regulated.. Although we have an established automotive recycling industry in New Zealand, it is not regulated by government. Individual operators are not legally required to hold a licence to dismantle a vehicle, and standard management practices are highly variable. This means that associated costs are specific to each operator, not generic to the industry.

Table 9.2: Summary of environmental impacts of end-of-life vehicles

Key Issue	Releases to Environment	Resource Loss/Waste
Dumped vehicles	Releases of fluids etc, disturbed water flows, pollution, vermin habitat etc	ELVs not entering the recycling stream
Poor practices at ELV recyclers	Releases to ground, air and water of ELV fluids, air-conditioning gasses etc	ELV fluids etc not recycled
Landfill contamination – fluids etc	Leaching of potentially polluting fluids etc in shredder flock at landfill sites	ELV fluids etc not recycled
Landfill contamination – heavy metals etc	Potential leaching of heavy metals, PCBs, PVC etc which may be contained in landfilled shredder flock	A small proportion of metals are not recycled through the shredders
Recycling of components		Limited reuse of ELV components
Waste volume and lack of material recycling	Release of potentially polluting substances Use of land for waste disposal	Waste volumes generated by shredder flock Limited recycling of non-metal portion of ELV materials

Source: Adapted from Department of Environment and Heritage (2002)

An ELV follows one of two pathways: treatment or abandonment. The number of ELVs entering the treatment system each year is not known. A reasonable estimate of the number of vehicles leaving the fleet can be obtained from deregistration data³², but using these figures assumes that all vehicles recorded as deregistered enter the ELV treatment system. A 2004 survey of local authorities showed that nearly 25,000 vehicles across the country are abandoned on public property each year³³. However, the majority of these vehicles are later recovered and also enter the ELV treatment system. Accurate figures of abandoned vehicles that do not enter the treatment system are currently unknown.

As noted in Tipping (1998) there are many components in a car that are of value, and vehicle recycling is not only a sound economic choice, but also an environmentally friendly one.

³² Each year approximately 150,000 to 160,000 light vehicles and around 3,000 to 3,500 heavy vehicles were recorded as being deregistered. Source: Ministry of Transport (2009).

³³ Cassells, Sue (undated), *Management of end-of-life vehicles: Lessons learned from Europe for the New Zealand Situation*, Massey University, Palmerston North, New Zealand.
<http://www.wasteminz.org.nz/conference/conferencepapers2005/Sue%20Cassells.pdf> (accessed 17 April 2009).

Advantages to vehicle recycling, as noted by Tipping (1998), include:

- Re-using recycled steel requires half the energy and a fraction of the water needed to make new steel from iron ore
- recycled material or parts may be cheaper
- reduced environmental impacts. as the amount of wreckage being dumped at landfills will reduce.

The recycling of many ELV components is commercially profitable. Approximately 70% of an ELV (by weight) is made up of ferrous metals, around 10% of nonferrous metals (such as aluminium, copper, lead, zinc), and the remaining 20% of non-metals such as plastic, rubber, glass and fluids (e.g. Tipping, 1998; Jeong et al., 2007; Cassells, undated). Ferrous metals are currently recycled. However, some of the remaining components are either toxic or have no recoverable economic value (see Table 9.3).

The process of recycling will still have some environmental impacts (since cleaning and dismantling parts requires the use of energy). On the other hand, the disposal of unrecoverable and non-recyclable components has high environmental costs.

Accurately quantifying New Zealand-specific ELV costs would be a difficult and costly process. Further investigation is needed to determine whether this cost can be feasibly quantified.

Table 9.3: Disposal and recycling of road vehicles

Items	Disposal and recycling
Waste vehicle/vessel bodies	<ul style="list-style-type: none"> ● Once the shell/carcass of the vehicle has had all saleable parts removed, any unsaleable or hazardous parts removed, and all vehicle fluids drained, the body of the car is flattened, crushed and shredded to produce scrap metals. ● A large amount of unwanted metal seating and glass still has to be disposed of at landfills.
Waste tyres	<p>There are a number of recycling, re-using and recovery options for tyres:</p> <ul style="list-style-type: none"> ● Retreading – A tyre casing in good condition can have new tread added and this delays tyre disposal. ● Crumbing – Tyres are shredded and the rubber granulated for use in other products such as sports surfaces, drainage materials, paints, retaining walls and asphalt for roads. ● Pyrolysis – Heating tyres without air so the gas, oil and carbon can be reprocessed. ● Incineration – Tyres are burnt to extract their energy value (for example, tyre-derived fuels can be used in cement kilns, pulp and paper mills and industrial boilers). ● Recycling for other uses (e.g. in the farming community). ● However, most tyres are disposed of at landfills.
Plastics	<ul style="list-style-type: none"> ● A car can contain as much as 25 types of plastic materials, many of which can be recycled or re-used. The extent to which plastics from scrapped vehicles are recycled and recovered is currently unknown.
Lead acid batteries	<p>The majority (approximately 90%) of car batteries are recycled. If a battery is recycled at a recycling plant, its environmental effects would be minimised.</p> <p>The recycling process is summarised as follows:</p> <ul style="list-style-type: none"> ● The acid is drained out and neutralised to produce water and sludge. The sludge is further treated, so that impurities can be removed. ● The plastic casing is crushed into plastic chips to recycle into new plastic battery casings. ● The lead and lead oxides from the battery are refined in a furnace to produce lead (of varying grades) and slag. The slag is further treated so that it is not hazardous and meets all environmental standards, and then dumped into the landfill. <p>Disposal of car batteries can pollute waterways, exposing the environment (air, land and water) to lead and sulphuric acid and resulting in a wide range of health effects.</p>
Used lubricating oil or other motor fluid	<ul style="list-style-type: none"> ● Can be recovered and re-refined but the re-refining process generates residues that will need to be dumped at landfills. ● Some residues could be used as a bitumen extender for roads but it is unclear whether such application is common.
Refrigerant gases	<p>These are currently dealt with in several ways:</p> <ul style="list-style-type: none"> ● Released into the atmosphere consciously (if not ozone depleting this is not illegal, but non-ozone depleting gases can create large quantities of greenhouse gases) ● Recaptured and sent for destruction in Australia (the ultra-high temperature facility for this purpose is in Melbourne) ● Recaptured and recycled for use in another vehicle.

Source: This table has been based mainly on Tipping (1998).

9.4.2 *Disposal of other maritime transport waste*

Disposal of maritime waste at sea (so-called dumping) may include end-of-life coastal vessels and dredged material from ports engaged in domestic trade.

Dumping standards in New Zealand are derived from the 1996 Protocol to the International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972, to which New Zealand is a party. A key principle of the protocol is the consideration of avoidance, re-use and minimisation of waste sources in order to minimise the amount of material that is required to be dumped at sea. Any waste must be sufficiently characterised to establish that it will not result in marine pollution – in other words, the environmental costs should be negligible.

In recent years, most end-of-life coastal ships have been sent to developing countries to be dismantled, with potentially significant social and environmental costs in those countries. These costs are a fruitful area for further research.

Internationally, moves are afoot to establish standards for ship recycling. A comprehensive treaty on this topic is to be concluded during the 2009 year.

9.4.3 *End-of-life rail wagon disposal*

Rail wagons have a much longer usable life than road-going vehicles. As rail wagons consist mainly of steel, end-of-life rail wagons have a positive value and are almost entirely recyclable. Some wagons are re-used in innovative ways such as farm bridges. End-of-life rail wagon costs are seen to be marginal³⁴.

³⁴ Conversation with Murray King, King-Small Associates, 17 April 2009.

9.5 Recommendations

9.5.1 *Approaches for the UTCC*

- (i) The total social costs of the environmental effects included in this section are relatively small compared to other effects (such as congestion and safety). Due to time and resource constraints, we do not recommend further research on any of the topics discussed above.
- (ii) The costs associated with spills and operational discharges appear to be material only for maritime transport. If this information is important for policy development, we should focus on collecting data that currently exists and those that are already being collected by Maritime NZ.

9.5.2 *Long-term research needs*

- (i) Further work may be warranted on the environmental impacts from infrastructure construction and maintenance. But this may need to be undertaken outside the UTCC workstream.
- (ii) Accurately quantifying New Zealand-specific ELV costs would be a difficult and costly process. Further investigation is needed to determine whether this cost can be feasibly quantified.

10. Summary and recommendations

10.1 Summary and discussion

In this report, we have reviewed the methodologies, frameworks or approaches for valuing social and environmental costs, and recommended the best approaches to adopt given the time and resource constraints.

The topics on social and environmental impacts that we have covered include: road congestion; greenhouse gas emissions; harmful emissions; accidents; transport noise; and other social and environmental impacts. For each of these topics, we have also discussed briefly the rationale for data collection and the current New Zealand practice, and carried out a literature review on methodologies.

Table 10.1 provides a summary of the valuation approaches, issues and data requirements by cost category and component.

Table 10.1: Summary of the valuation approaches, issues and data requirements by cost category and component

Category	Sub-components	Relevant valuation approach	Modal consideration	Valuation issues and other consideration	Data requirements
Road congestion	Travel time costs	<ul style="list-style-type: none"> Willingness-to-pay (WTP) Mitigation cost approach Deadweight losses approach Benefit transfer approach 	<ul style="list-style-type: none"> Congestions or delays for rail and maritime transport usually occur due to operational reasons. Hence, they will be included under the operator costs work stream. 	<ul style="list-style-type: none"> VOT by user type Speed-flow relationships Recurrent versus non-recurrent congestions 	<ul style="list-style-type: none"> Location-specific Demand elasticities Time of day Vehicle type Average speed Distance Accident data Data on other incidents and delays Fuel consumption
	Environment costs	See environmental costs		Speed-emission relationships	
	Vehicle operating costs	Travel activity-based method		Speed-fuel consumption relationships	
	Accidents	See accident costs		Speed-risk relationships	
Greenhouse gas (GHG) emissions	Climate change effects	Carbon charge approach	All modes	No direct link to consequential costs of climate change effects from emissions. Currently used to estimate Kyoto's liability.	<ul style="list-style-type: none"> Carbon charge based on Treasury's estimates Future changes Discount rate
		Impact pathway approach (Damage cost approach)	All modes	<ul style="list-style-type: none"> The coverage is very high, including crop & building damage and loss of biodiversity. Damage costs are difficult to establish. 	<ul style="list-style-type: none"> Coverage of cost components Information on cumulative effects Choice of discount rate
		Mitigation costs approach	All modes	<ul style="list-style-type: none"> Mitigation costs can be quite high depending on the reduction targets. Vary with the type of interventions adopted. 	<ul style="list-style-type: none"> Target to be achieve Interventions adopted Effectiveness of interventions Choice of discount rate
		Benefit transfer approach	All modes	<ul style="list-style-type: none"> Rely on the methods developed for different populations. Therefore, care should be taken to ensure transferability. 	<ul style="list-style-type: none"> Baseline concentration Population characteristics Price index and income

Table 10.1 (continued)

Category	Sub-components	Relevant valuation approach	Modal consideration	Valuation issues and other consideration	Data requirements
Harmful emissions	To determine impact patterns on human health	Impact pathway approach	<ul style="list-style-type: none"> Mainly affect major urban cities Air pollutants along rail routes, ports/harbours are complicated to allocate. For maritime, there are peculiar practices like incineration of garbage and fumigation of cargoes. 	<ul style="list-style-type: none"> Transferability of the 'dose-response relationship' for applying in NZ Different by age group, current health status and the level of exposure 	<ul style="list-style-type: none"> population characteristic & density & existing concentration Vehicle characteristics related information. Trip data (length, location, speed & mode etc)
	To quantify health impacts in monetary terms	WTP-based VOSL converting to value per life year lost.		<ul style="list-style-type: none"> Valuation of life years lost Choice of discount rate 	Age and gender information about those affected.
		Benefit transfer approach		<ul style="list-style-type: none"> See above 	<ul style="list-style-type: none"> See above
	Lost output	See accident costs		See accident costs	See accident costs
Accident costs	Loss of life, life quality and pain and suffering	<ul style="list-style-type: none"> Human capital (measures of productivity only) WTP-based Value of Statistical Life (VOSL) Meta analysis (or benefit transfer approach) 	<ul style="list-style-type: none"> Property damage cost specific to rail and maritime incidents needs to be established 	<ul style="list-style-type: none"> Estimates for most components are based on old studies (e.g. VOSL). New survey is outside the scope of the UTCC project. Therefore, a meta- analysis could be adopted. The level of externality is less well understood. 	For a meta analysis: <ul style="list-style-type: none"> need international estimates domestic data for applying 'benefit transfer approach'
	Lost output / productivity	Predicted based on historic and average data			Gender and age specific data including injury mix, labour participation, average income, average time off work, future GDP growth, estimate of future consumption (for fatal only).
	Medical costs, property damage and other costs	Resource costs approach			Hospitalisation data, ACC data, insurance data, etc
	Travel delays due to accidents	See congestion costs			Information on travel delays not collected.

Table 10.1 (continued)

Category	Sub-components	Relevant valuation approach	Modal consideration	Valuation issues and other consideration	Data requirements
Noise	Noise impact on health	Mitigation cost approach	All modes	Same as above	<ul style="list-style-type: none"> Same as above
		Hedonic pricing	Mostly road and to some extent rail. For maritime, it affects mainly ports located near residential areas (e.g. Napier and Nelson)	Baseline noise impacts currently unknown.	<ul style="list-style-type: none"> Noise exposure data Trip data (location, vehicle type, speed and mode)
		Impact pathway approach		Difficult to value annoyances.	
Run-off and water quality	Spills (oil & chemicals)	<ul style="list-style-type: none"> Clean up costs Insurance compensation 	<ul style="list-style-type: none"> For maritime the impact can be large due to the fuel volume involved. Relative small for road and rail. 	Financial costs only (based on actual)	<ul style="list-style-type: none"> Spills data Clean up costs data Insurance claims data
		<ul style="list-style-type: none"> Impact pathway approach Mitigation costs approach 		Depends on approach used. See above.	
	Operational discharges, waste disposal health impacts and other effects	<ul style="list-style-type: none"> Impact pathway approach Impact pathway approach 	Mainly for maritime	Difficult to get data	Disposal details: <ul style="list-style-type: none"> Type of discharges Volume Location
	Run-off	<ul style="list-style-type: none"> Impact pathway approach Mitigation costs approach 	Road and rail	<ul style="list-style-type: none"> Lack of data Difficult to separate effects from different sources and modes 	Details regarding pollutants <ul style="list-style-type: none"> Types & volumes Location Effects on environment & health

Table 10.1 (continued)

Category	Sub-components	Relevant valuation approach	Modal consideration	Valuation issues and other consideration	Data requirements
Bio-security and bio-diversity		Prediction model	Mainly for maritime, some effects for road	Difficult to get data	Details regarding pollutants <ul style="list-style-type: none"> • Types & volumes • Location • Effects on environment & health
Up and downstream effects	Upstream effects such as production of energy and infrastructure construction	Life cycle approach	All modes	Lack of data	<ul style="list-style-type: none"> • Energy source and mix • Energy requirement • Emission factors
	Downstream effects associated with end of life disposals of transport waste	End of life damage costs	All modes	Lack of data	<ul style="list-style-type: none"> • Substances to be disposed (non- recyclable) • Level of recycling taken place • Impacts of waste

10.2 Recommendations

This section summarises our recommendation regarding the approaches for estimating the social costs of road congestion, greenhouse gas and harmful emissions, accidents and noise.

10.2.1 Road congestion

- (i) Valuation methodology – The EEM’s VOT estimates should be used for the calculation.
- (ii) Value of time for PT users – Two sets of estimates should be used to gauge the likely impact on the costs of congestion:
 - (1) The EEM’s estimates
 - (2) The same VOT for all passenger transport (private and public) modes.
- (iii) Definition of congestion – The STCC’s definition (relative to free-flow conditions) should be used in the first instance. However, we should also adopt an alternate definition by using the congestion threshold approach and the deadweight loss approach (relative to the optimal level of congestion on the existing network). Applying the three approaches will give us a range of estimates to gauge the potential scale of the problem.
- (iv) Journey time reliability – Two sets of estimates should be used to gauge the likely impacts:
 - (1) the mean-variance approach (one standard deviation compared to mean travel time)
 - (2) the 80th to 90th percentile compared to median travel time.
- (v) Operational congestion – Congestion associated with rail and maritime operations should be included under other workstreams, e.g. the ‘Costs of freight transport’ workstream.

10.2.2 Greenhouse gas emissions

For estimating the unit cost of climate change, we recommend using:

- a benefit transfer approach to gauge the climate change impact
- the carbon price to estimate the total carbon costs for reference purposes.

10.2.3 Harmful emissions

- (i) Use the findings of HAPiNZ (2007) and a benefit transfer approach (Austroads, 2009d) (in conjunction with revised energy consumption estimates) to produce two sets of estimates.
- (ii) In terms of the valuation of morbidity and mortality, the current value of statistical life established for the safety area (and a variation using a meta-analysis) will be used to derive the value per year of life lost, as was done in the STCC and HAPiNZ (2007).
- (iii) In terms of updating the average number of life years lost due to harmful emissions, and the average age of those affected, we will need to collect data from the NZ Health Information Service.

10.2.4 Accidents

- (i) VOSL – Carry out a meta-analysis of WTP-based VOSL for overseas countries to obtain an alternative VOSL. Together with the existing value, this will provide a range of accident cost estimates.
- (ii) Non-VOSL components – Due to the tight timeframe and resource constraints, it is recommended to focus on the following revisions:
 - a. Lost output and productivity
 - b. Property damage costs (especially for rail and maritime).
- (iii) Valuing reported and unreported injuries – Continue with the existing approach but further co-ordination with the health sector and the Accident Compensation Corporation (ACC) should be established to improve such estimates in the longer term.

10.2.5 Noise

- (i) Review the appropriateness of the Noise Depreciation Index (NDI) developed in LTPS-EE (1996) for current use.
- (ii) Adopt the STCC approach, with refined assumptions on noise thresholds and an updated valuation as per the EEM, to generate one set of estimates (for baseline comparison purposes).
- (iii) Further investigate whether SKM's *National Noise Impact Analysis Model* can be used and updated to help establish the baseline noise exposure at the regional or national level, and for estimating the costs of noise (hopefully to obtain an alternative set of estimates).
- (iv) Due to the time and resource constraints, vibration effects should be investigated outside the UTCC workstream.

10.2.6 Other social and environmental costs

- (i) The total social costs of the environmental effects included in this section are relatively small compared to other effects (such as congestion and safety). Due to the time and resource constraints, we do not recommend further research on any of these topics.
- (ii) The costs associated with spills and operational discharges appear to be material only for maritime transport. If this information is important for policy development, we should focus on collecting the data that currently exists and those that are already being collected by Maritime NZ.

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Appendix I – A summary of NZIER’s paper on “Externalities – Methods for attributing costs between internal and external components”

This is a summary of the main findings of a report prepared by the New Zealand Institute of Economic Research (NZIER) on “*Externalities – methods for attributing costs between internal and external components*”, undertaken on behalf of the Ministry of Transport.

Study purpose

The aims of the study were to:

- *“Review and confirm the importance of being able to separate internal costs from externalities, in the context of estimating total, average and marginal costs of transport use. We shall also discuss and define the concept of internalisation”*
- *“Review relevant international literature, existing research, published practical guidance, published case studies, and other appropriate materials to determine the state of the art methods in achieving the above”*
- *“Recommend appropriate methodologies/approaches for attributing costs between internal and external components, considering data, time and resource constraints”*

Scope

The report discusses methodologies for identifying costs internalised by users of the transport system and external costs they impose on other users and the rest of society, in three areas: congestion, accidents and pollution, for the three modes of road, rail and maritime.

Definitions

The following are the definitions adopted by the NZIER:

- **Social cost** of transport use is the total cost to society including costs of accidents, congestion and environmental effects. This includes all direct and indirect costs and both tangible and intangible costs. The broad social cost of accidents includes value of loss of life and life quality, value of time lost, loss of output, medical and rehabilitation costs, legal and investigation costs, and property damage. The costs of congestion delays include value of time lost, vehicle operating costs and the cost of emissions. For environmental effects, the social cost items include climate change impacts, loss of environmental quality, and health effects, including loss of life and life quality.
- **Externality** is the cost or benefit part of the total cost or benefit that is not internalised. Broadly speaking, there are two forms of externality – technological and pecuniary externality. Pecuniary externalities occur through the effects on prices. Technological externalities occur when the action of one individual or firm affects the utility or profit of another individual or firm. This paper

does not cover pecuniary externalities. The external cost estimation can be at a particular point in time, or for a system in the short run or at the optimal flow level (e.g. road congestion).

- **Internalisation** – The cost internalised can be defined as the cost borne by the party who causes the effect. The idea of ‘internalising an externality’ is based on the view that individuals are reasonably rational and, if individual users are required to bear the full costs of their actions (‘internalisation’), they will make a decision to minimise their costs which, in turn, minimises the social costs.

Rationale

NZIER suggested the following rationale for separating between the internalised and external costs of social and environmental impacts:

- it facilitates policy development for managing externalities by identifying the size of the social and environmental impacts
- it assists the assessment of an optimal pricing system to mitigate external costs
- it assists the assessment of policy measures that aim to ‘internalise’ the externalities.

Congestion

Congestion for rail or maritime transport is typically related to capacity constraints relative to the demand for services. These can be classified as operational external costs and are outside the scope of this study. NZIER commented that, if congestion in rail and maritime transport is an important issue for policy development, a detailed methodology will need to be developed to estimate such effects, as well as to separating between the internalised and external components.

NZIER noted that the values of travel time and vehicle operating costs tend to increase monotonically with the level of traffic inflow, even for the situation where the speed-flow relationship is backward bending. In their opinion, it is more convenient to confine congestion costs to these components. For congestion-related accident and pollution effects, NIZER recommended considering their costs under those topics.

For road freight and road passenger transport, NZIER recommended that buses and trucks should be considered in terms of passenger car equivalent units³⁵, because they contribute more to traffic density and congestion than cars.

NZIER explained that, excluding the pollution and accident costs, the average private and marginal private costs of congestion per unit of traffic volume are the same. However, the marginal social cost (including both the cost to the individual and that to the rest of society) increases with traffic. The marginal external cost of congestion is the difference between the marginal social cost and the average (or marginal) private cost.

³⁵ As discussed briefly in section 3.1.2, passenger car equivalent units are the scaling factors that express non-passenger cars (e.g. trucks and buses) in terms of the number of passenger cars. It is a metric used to assess traffic-flow rates on the road network.

Accidents

The Value of Statistical Life in New Zealand is the value society is willing to pay (WTP) to reduce the risk of death so that one premature death is avoided. This value includes two components, the amount the concerned person and those closest to him/her are WTP and the amount the rest of society is WTP. NZIER asserted that the second component was always an external cost. In addition, certain costs that are borne by society (e.g. ACC) are also part of the external cost.

NZIER asserted that accident risk is internalised only if the user bears the costs of the consequences of accidents due to his/her actions. For road passenger transport, it is not obvious what proportion of the risk faced by passengers is considered by the driver. For estimation purposes, NZIER suggested the following segregation between internalised and external accident costs:

Table A1.1: Summary of internalised and external accident costs (extracted from NZIER, 2009)

Mode		Costs internalised	External costs
Road	Private vehicles	Cost of accidents suffered by the driver if driver does not take into account the risks to passengers OR	Cost of damages and injuries to others and society's share of the cost of driver's injuries
		Cost of accidents suffered by the driver and part of the cost of injuries suffered by passengers (if driver does take into account the risks to passengers)	Rest of the cost of accidents
	Public transport	Cost of accidents due to natural causes minus the cost borne by society	Cost of accidents due to natural causes borne by society
		Cost of accidents due to driver or vehicle factor minus the cost borne by society	All other costs of accidents
	Pedestrians and cyclists	Costs suffered by themselves due to accidents caused by natural causes and their own risk-taking behaviour	All other costs of accidents
Rail		Same as in road public transport	Cost of accidents due to driver or system fault
Maritime		Ship: Cost of accidents (due to natural causes) to the vessel and passengers minus the cost borne by society	Ship: Cost of accidents due to natural causes to the vessel and passengers borne by society
		Cost of damage to the ship and its property due to risk taking behaviour of the ship	All other costs
		Port: Negligible	All costs are external costs

Therefore, according to NZIER, there are two major factors for determining whether costs are internalised:

- i. whether the accidents occur due to natural causes or risk-taking behaviours
- ii. whether the drivers take into consideration the risks to their passengers.

On the other hand, society's share of the social cost of injuries to the driver and passengers is all external costs.

The report also discussed the situations when property damage costs and travel delays due to accidents are counted as external costs. In most situations, the principles described in Table A1.1 continue to apply.

Pollution

NZIER did not look at different pollution effects (e.g. noise versus greenhouse gas emissions) separately. They asserted that only a small fraction of the total cost of transport-related pollution is suffered by the user (i.e. internalised); the remainder of pollution costs are external costs.

Appendix II

Table A2.1: The Working Group

Organisation	Member	Field of specialisation
Ministry of Transport	Joanne Leung	Project Manager
	Michael Bealing	GHG and harmful emissions
	Oliver Lah	GHG and harmful emissions
	Melanie Hutton	Environment, vehicle
	Simon King	Environment, vehicle
	David Weinstein	Environment, maritime
	Joern Scherzer	GHG emissions
	Kerry Wood	Rail
	Iain McAuley	Road safety
	Stuart Badger	Vehicle fleet modelling
Maritime NZ	John Marshall	Environment, maritime
KiwiRail Group	Thomas Davis	Rail
NZ Transport Agency	Paul Clark	Congestion, EEM
	Rob Hannaby	Noise

Table A2.2: The Expert Panel

Organisation	Member	Field of specialisation
Ex-Ministry of Transport	Roger Toleman	STCC (2005) Project Manager
IWA Ltd (apology)	Ian Wallis	STCC (2005) main author
John Bolland Consulting	John Bolland	STCC (2005) investigator
NZIER	Dr Jagadish Guria	VOSL pioneer
Hyder Consulting	Nick Flack	UTCC Phase One investigator
Hyder Consulting	Chris Parker	Noise
Opus International	Peter Cenek	Freight transport efficiency
Scion Research	Barbara Nebel	Life Cycle Analyses