

# **The implications of road investment November 2012**

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# Executive summary

The overall project objective was 'to provide improved evidence (potentially leading to improved modelling, monitoring and evaluation methods) on the implications of major road investments in New Zealand on various factors, including: travel demand, operational performance, environmental effects, emissions, road safety, development patterns and economic effects'.

To address this objective, the research adopted the following (high-level) methodology:

- Assess New Zealand (principally) and international evidence on the actual impacts and implications for all significant factors of major road investment projects in New Zealand.
- Assess the procedures used in New Zealand for the post-evaluation of major road projects, and draw conclusions on the strengths, weaknesses and priorities for improvement in current New Zealand post-evaluation procedures and practices.
- Compare the post-evaluation evidence, from selected New Zealand case studies, with the pre-appraisal forecasts of scheme impacts, and draw conclusions on the strengths, weaknesses and priorities for improvement in current New Zealand forecasting and (economic) pre-appraisal methods.

The research covered the following five topic areas in developing its conclusions and recommendations.

## **1 Travel behaviour - methods and impacts**

This area of the research addressed the impacts of changes in transport conditions on travel behaviour, with a primary focus on urban/metropolitan areas. It particularly examined the empirical evidence on 'induced' travel, given its importance in any assessments of the overall traffic, environmental and economic impacts of urban road system improvements.

Analyses of 11 major urban road schemes in various countries showed that corridor (screenline) traffic volumes increased, principally in the first year of use, by 3% to 12%. This was mainly due to a shift from public transport. A reversion to peak travel by 10% to 30% of road users was also noted. In the short term, generation of new trips appeared to be small. Significant travel time reductions were achieved in all cases, at least in the short term.

In the short term, the international evidence indicated that the elasticity of traffic volumes with respect to total travel times was relatively low (around -0.3), but much higher (around -0.6) in the long run, indicating that a significant proportion of the 'theoretical' time savings from road improvements would be eroded over time by the additional 'induced' traffic.

While this induced traffic does not invalidate the case for increases in road capacity, it suggests that such increases need to be examined with considerable care. Given the possibility of some form of direct road-use pricing being introduced in the future in New Zealand and given the considerable uncertainties in forecasting of traffic growth trends, there is a case for examining the effects on economic performance at the pre-appraisal stage in the event that such a pricing scheme were to be introduced.

Current transport modelling practices, in New Zealand and elsewhere, tend to be deficient in reflecting some of the behavioural changes that are significant in practice – including peak spreading/reversion to the peak, induced travel/new trip generation, and transport and land use interaction effects. The report makes a number of recommendations and suggestions for improvements to modelling procedures to overcome the current deficiencies in these areas.

## **2 Economic appraisal methods**

The research reviewed best practice methods for pre-appraisal of the economic efficiency and economic impacts of road (and public transport) projects. The findings and recommendations in this area are as follows:

- Current best practice cost-benefit analysis (CBA) of transport strategies does not allow for induced land use change, even though this could be a dominant effect of some schemes in the longer term. New Zealand authorities (led by the NZTA) should resource and target effort towards research to develop and improve (pre-) appraisal methodologies in this area.
- There is scope to refine and improve the procedures and conventions used in the appraisal of wider economic benefits. The report recommends greater facilitation for project sponsors, CBA practitioners and theorists to pool their experiences and thoughts on the development and application of wider economic benefits, and for the NZTA to issue supplementary guidance on how to estimate them.
- Computable general equilibrium (CGE) modelling is the leading method to pre-appraise project/programme impacts on national economic output. It may be particularly well suited to addressing a number of situations and issues in the New Zealand context. The case should be considered for developing a model capable of assessing scheme impacts on transport demand in the short, medium and longer term.

## **3 Social, environmental, health and safety effects – methods and impacts**

In this area, the research focused on:

- international evidence on the social, environmental and safety effects of road schemes
- current New Zealand monitoring/post-evaluation procedures and impacts of these effects
- proposals for improvements in New Zealand monitoring and post-evaluation of these effects.

It found that although significant research has been undertaken in New Zealand on various environmental areas (including air quality, noise and safety), the application of research knowledge to scheme monitoring and evaluation has been limited, and is often confined to compliance with Resource Management Act consent conditions. Some potentially significant effects are often omitted or unquantified, at both pre-appraisal and post-evaluation stages. The report recommends a more comprehensive approach covering all significant impacts should be adopted for future major roading projects.

## **4 Post-implementation review (PIR) procedures**

The research found that in New Zealand the current PIR procedures (instigated by NZTA) are:

- discretionary and informal, with no regulatory backing
- not currently integrated into the overall scheme development and implementation process
- confined to a limited number of impacts
- confined to small/medium-size projects
- usually undertaken between one and five years after scheme opening
- not made widely available
- not well utilised in terms of analysis of programme results and feedback to improve forecasting and pre-appraisal procedures.



The report includes a number of recommendations in each of these areas which would bring the NZTA procedures more into line with good practice internationally.

## **5 New Zealand post-evaluation case studies**

The research carried out post-evaluation case studies of selected New Zealand road projects completed in recent years, to make recommendations on improvements in processes to facilitate future post-evaluations.

The five medium-size schemes (cost range \$30m – \$360m) assessed were: Auckland northern motorway extension (ALPURT B2), Auckland northern busway, Auckland southern motorway ramp signalling, Tauranga Harbour link and Wellington inner city bypass.

The research discovered the following:

- The outturn costs for four of the schemes were within  $\pm 10\%$  of the prior estimates: for the other scheme, the costs were substantially lower than the estimate.
- There was no clear evidence of short-term induced travel. In the case of the (ALPURT B2) toll road, the extent of traffic relief to the old (by-passed) route was significantly lower than forecast.
- Travel times for general traffic in the corridors affected were reduced for four of the schemes, with the reductions generally reflecting the size of the scheme. There was no evidence in changes in travel time reliability (variability).
- The Auckland northern busway scheme appeared to have been successful in reducing bus travel times, increasing PT use in the corridor, and significantly reducing peak period car use. No monitoring of modal effects was undertaken in the other cases.
- Only one of the five schemes appeared to result in significant reductions in crash costs. In general, pre-appraisal forecasts of crash reductions were not achieved: this appears to be an aspect on which crash forecasting methods would warrant review and greater attention should be given to safety aspects at scheme assessment report stage.
- No monitoring or post-implementation estimates of vehicle operating cost changes, associated fuel consumption or greenhouse gases were undertaken for any of the case studies.
- For all five schemes, the estimates of shorter-term transport benefits (travel times, vehicle operating costs, crash costs) at the post-evaluation stage were within c.20% of the pre-appraisal estimates for this period (noting that no attempt was made in the post-evaluation work to re-estimate the benefit stream over future years). This indicates reasonably good predictive accuracy.

## Abstract

The objective of this research (undertaken in 2010–12) was to provide improved evidence (potentially leading to improved modelling, monitoring and evaluation methods) on the implications of major road investments in New Zealand on significant factors including travel demand, operational performance, environmental effects, emissions, road safety, development patterns and economic effects.

The research methodology involved:

- Assessing New Zealand (principally) and international evidence on the actual impacts and implications for all significant factors of major road investment projects.
- Assessing the procedures used in New Zealand for the post-evaluation of major road projects, and drawing conclusions on the strengths, weaknesses and priorities for improvement in current New Zealand post-evaluation procedures and practices.
- Comparing the post-evaluation evidence, from selected New Zealand case studies, with the pre-appraisal forecasts of scheme impacts, and drawing conclusions on the strengths, weaknesses and priorities for improvement in current New Zealand forecasting and (economic) pre-appraisal methods.

Conclusions and recommendations were developed covering five main topic areas: travel behaviour; economic appraisal; social, environmental, health and safety effects; post-implementation review procedures; and lessons from New Zealand post-evaluation case studies.

# 1 Introduction

## 1.1 This project

This research project on the implications of road investment was undertaken for the NZ Transport Agency by consultants Ian Wallis Associates Ltd (principally Ian Wallis, Don Wignall and Chris Parker). The overall project objective was:

*to provide improved evidence – potentially leading to improved modelling, monitoring and evaluation methods – on the implications of major road investments in New Zealand on various factors, including: travel demand, operational performance, environmental effects, emissions, road safety, development patterns and economic effects.*

## 1.2 The New Zealand transport policy context

The New Zealand government's current<sup>1</sup> objectives and priorities for the New Zealand land transport sector are set out in the *Government policy statement on land transport funding 2012/13 – 2021/22* (GPS). The GPS specifies three priorities for the sector, namely: economic growth and productivity, road safety and value for money.

The GPS also encompasses goals, consistent with the National Infrastructure Plan (July 2011), to improve journey times and reliability, reduce severe congestion, improve road safety, improve accessibility by other modes and increase energy efficiency. The GPS also refers to various short- and medium-term impacts that the transport investment programme is intended to achieve, including reducing adverse environmental impacts and contributing to positive health outcomes.

The NZTA is the government's land transport funding agency, with responsibility for the allocation of government funding (raised principally from petrol taxes and road user charges) to operate, maintain and improve the country's land transport system. A substantial proportion of its funding is allocated to road improvement (capital) projects.

The current NZTA (2012) *Statement of intent 2012–15* (SOI) describes NZTA's contribution to delivering the government's policies and expectations for the land transport sector and for the economy as a whole. The NZTA intends to achieve desired long-term outcomes and impacts, as set out in figure 1.1.

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<sup>1</sup> It should be noted that a range of different policies have applied to the transport sector over the past decade.

**Figure 1.1 NZTA desired long-term outcomes and impacts**

OUR CORE FUNCTIONS	PLANNING THE LAND TRANSPORT NETWORK	INVESTING IN LAND TRANSPORT	MANAGING THE STATE HIGHWAY NETWORK	PROVIDING ACCESS TO AND USE OF THE LAND TRANSPORT SYSTEM
Our desired long-term impacts	<p><i>Desired long-term outcome:</i> an efficient transport system that supports high levels of economic productivity, provides strong international connections for freight, business and tourism, and meets international obligations. We will contribute to this outcome by working towards achieving:</p> <ul style="list-style-type: none"> <li>› better use of existing transport capacity</li> <li>› more efficient freight supply chains</li> <li>› a resilient and secure transport network</li> <li>› easing of severe urban congestion</li> <li>› more efficient vehicle fleets.</li> </ul> <p><i>Desired long-term outcome:</i> an accessible and safe transport system that contributes positively to the nation's economic, social and environmental welfare. We will contribute to this outcome by working towards achieving:</p> <ul style="list-style-type: none"> <li>› reductions in deaths and serious injuries from road crashes</li> <li>› more transport mode choices</li> <li>› reduction in adverse environmental effects from land transport.</li> </ul>			

Source: NZTA (2012, p19)

## 1.3 Project scope and focus

To address the overall project objective (refer section 1.1), the project focused on:

- 1 assessing the New Zealand (principally) and international evidence on the actual impacts on all significant factors (discussed below) of major road investment projects, and their implications, in the New Zealand context
- 2 assessing the procedures used in New Zealand for the post-evaluation of major road projects, and drawing conclusions on the strengths, weaknesses and priorities for improvement in current New Zealand post-evaluation procedures and practices
- 3 comparing the post-evaluation evidence from selected New Zealand case studies with the pre-appraisal forecasts of scheme impacts, and drawing conclusions on the strengths, weaknesses and priorities for improvement in current New Zealand forecasting and (economic) appraisal methods.<sup>2</sup>

Hence the research involved the review (and potential improvement) of New Zealand and international evidence, procedures and practices for both post-evaluation and pre-appraisal of major road schemes, in the light of the actual evidence of scheme impacts. Such research is central to the development of improved procedures for the pre-implementation forecasting of scheme impacts, and hence the 'value for money' that planned schemes are likely to deliver against the range of government objectives and priorities. Despite the importance of this topic, the extent of high-quality research in the field is surprisingly limited, both in New Zealand and internationally, particularly in regard to post-evaluation of the impacts of major schemes. The case for extensive further road investment in New Zealand, in order to meet strategic objectives and targets, is very dependent on having better information on the impacts of such investments across the whole range of impact areas and evaluation criteria.

<sup>2</sup> Throughout this report we have used the following terminology: **pre-implementation** to refer to the situation and activities undertaken prior to the decision to proceed with a road scheme; **post-implementation** to refer to the situation and activities undertaken once the scheme is in use. We also use the terms **pre-appraisal** and **post-evaluation** to refer specifically to the pre/post assessment processes, usually focusing on economic effects but often having a wider scope.

Consistent with the project objective and focus set out above, figure 1.2 provides a flowchart for the aspects that need to be addressed for a comprehensive research study covering all facets of the objective.

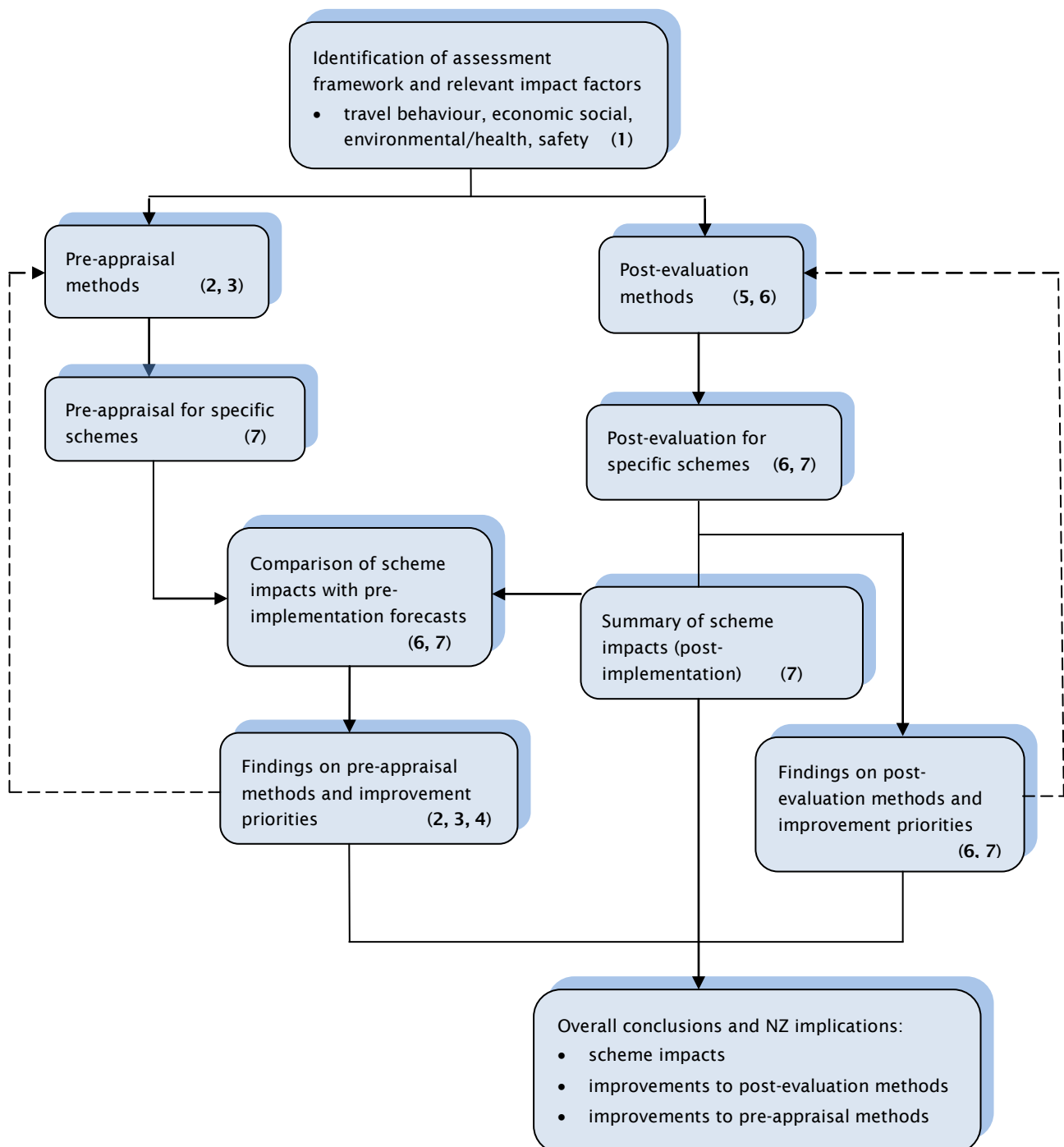
Key features of figure 1.2 include:

- Within the overall assessment framework, two main streams of work are involved – a pre-implementation (appraisal) stream and a post-implementation (evaluation) stream.
- The project has focused primarily (but not solely) on reviewing procedures and practices in the post-evaluation stream of work. This review provides feedback on potential improvements in methods relating to i) post-evaluation procedures and the associated data requirements; and ii) pre-appraisal methods, so that they better forecast observed scheme impacts. These two feedback loops are shown in the diagram.
- The diagram also indicates the report chapters/topics that contribute to each activity box and hence to the overall assessment process. Some of the report chapters focus on specific assessment impacts (eg travel behaviour impacts in chapter 2), while others are more concerned with process aspects and cover the full range of significant impacts (eg post-evaluation methods generally in chapters 5 and 6).

It will be recognised that the scope of the research topic is potentially very broad and difficult to cover in sufficient depth within a single research project such as this. The research has therefore involved synthesising a lot of information into a relatively concise form. However, each investment project also has to do this in one way or another in order to undertake a full assessment, so the difficulties arising from the broad scope of the research mirror the difficulties of being able to make balanced and informed project investment decisions.

At an early stage in the research, discussions were held with the Project Steering Group (PSG) to provide guidance to the consultants on the most appropriate focus and coverage for the project. The topics agreed for coverage are reflected in the report's structure and content, as outlined in section 1.6.

**Figure 1.2 Road scheme pre- and post-implementation assessment framework**



**Note:** Numbers in brackets in each box denote the report chapter(s) in which the relevant aspect is addressed.

## 1.4 Potential impacts of road schemes

The research is intended to describe the range of impacts resulting from major road projects, principally in larger urban/metropolitan areas, drawing on international evidence and with specific application to the New Zealand situation. Currently in New Zealand, the impacts of only smaller road projects, in the cost range \$0.5m to \$30m, are subject to post-implementation review. This is starting to change with larger projects (\$30m to \$400m) now potentially subject to post-implementation review. A pre- and post-monitoring framework is also under development for the very large roads of national significance (RoNS) projects.

The approach taken in this report is designed to encompass broader impacts (to the extent information is available), including those impacts that are often not examined in relation to individual road projects. Such broader impacts focus primarily on the medium- and longer-term timescale, and potentially include the following topic areas:

- increased car-based accessibility and its impacts on trip lengths, speeds, reliability and the total amount of road based travel
- induced travel (new trips) and use of alternative modes
- accessibility for those with limited or no car availability
- road crashes and associated social costs
- fuel use (particularly non-renewable fuels) and total energy consumption
- overall transport costs to households and businesses
- global environmental effects (carbon emissions)
- local environmental, social and health effects
- land use development patterns, urban density and urban form effects.

For appraising the evidence on the impacts of major road schemes, whether internationally or in New Zealand, it is helpful to classify these impacts against a common set of factors. Table 1.1 sets out our (idealised) set of factor headings and sub-headings for this purpose.

We note that:

- In practice, information on many of these (sub)-headings on any given project is unlikely to be comprehensively available for many schemes to be appraised, either because the relevant impact has been judged to be minor or zero, or because the study in question did not address these particular impacts.
- Quantification of impacts for any particular road scheme or programme essentially requires comparison of the situation 'with the road' and the situation 'if the road in question had not been provided'. This raises the issue of the estimation of the 'counter-factual' case, which needs to be addressed in all such impact appraisals.
- In terms of the pre-appraisal requirements, there are legislative and funding requirements (in New Zealand) which stipulate topics for examination, plus other potentially significant effects that need to be evaluated. However, the depth of any particular assessment, for example, the need or otherwise for sophisticated modelling, needs to be determined on a project-by-project basis.

## 1.5 Other considerations

A number of considerations need to be taken into account when organising and synthesising information on impacts: the way in which information is gathered and analysed can potentially have a significant effect on the specification of relevant data and on the interpretation of results.

Table 1.1 indicates the factors commonly quantified for typical mid-sized New Zealand projects at the pre-implementation (scheme assessment report) stage and those commonly considered at the post-implementation review stage.

The following considerations are relevant to this research:

- An understanding/definition of project context and likely area of influence is needed. The area of influence may vary by project scale, type and factor involved. For example, in terms of traffic demand, for small rural improvement schemes in low-growth regions and where no route choice is involved, traffic flow data from the link itself may be sufficient. For larger and more complex schemes in major urban areas, where growth is more significant, a wider spatial assessment of the impacts on traffic demand is likely to be required.
- In terms of the choice of factors to be reviewed post-implementation, in all cases it is likely that a review of changes in traffic demand (volume and composition), travel time and the numbers of fatalities and casualties would be worthwhile, given the potential importance of these factors in scheme appraisals. However, not all of the issues and factors listed in table 1.1 will represent significant effects for any particular project. The pre-implementation appraisal will provide an understanding of the most likely relevant issues and factors that need to be considered in the post-implementation evaluation of particular projects. It is important to realise that road investments cannot 'automatically' be assumed to lead to universal improvements in each of the topic areas listed in table 1.1.
- A consideration of contributory and causal relationships is required in order to inform the analysis of project impacts, for example, the project is one possible influence on traffic demand, but economic growth and land use changes are other potential influences.
- The choice of detailed assessment methodology needs to make the distinction between relatively straight-forward projects and more complex projects. Often this difference reflects the project scale but sometimes it is more related to whether or not the project is in a rural or urban setting, or for other reasons.
- For more strategic assessment purposes, a further distinction needs to be made between individual project and overall programme impacts. For example the effects of a single project over a relatively short time period may point to certain conclusions, but the collective effects of a large number of projects over a longer time period could be quite different, especially on land use, urban form, mode use and travel behaviour patterns.
- In all cases, information for schemes is likely to be incomplete, in terms of extent of coverage (ie the number and range of factors) and in terms of timeframe (ie short-, medium- and long-term impacts). This will introduce uncertainties to a greater or lesser degree in each case and will need to be reflected in the strength of conclusions drawn in particular cases.
- Information gathered may be used to represent performance in some way, in conjunction with project objectives and/or wider objectives. The use of the information in this way may involve higher level interpretation and organisation of individual project factors into their contribution towards objectives.



This may be achieved by using project-specific objectives for individual schemes, and wider strategic objectives for collective scheme impacts.

- There would be merits in developing the above considerations further, with the intention of identifying a project typology (potentially involving the scale, type and circumstances of projects) to be used to identify/classify the type of information and analysis most likely to be required for each project type.

**Table 1.1 Potential impact factors**

Impact heading	Impact factor	Inclusion in typical New Zealand practices:	
		Pre-implementation	Post-implementation
A Transport demand	<ul style="list-style-type: none"> <li>• Route changes</li> <li>• Time of day changes</li> <li>• Trip end changes/trip length effects</li> <li>• Traffic demand volumes / composition</li> <li>• Mode switching</li> <li>• Induced (new) trips</li> </ul>	✓ ✓ ✓ ✓	✓
B Road network operations	<ul style="list-style-type: none"> <li>• Road vehicle levels of service, congestion, travel time and reliability</li> <li>• Road network utilisation measures</li> <li>• Levels of service for other modes.</li> </ul>	✓	
C User impacts	<ul style="list-style-type: none"> <li>• Accessibility (to services/activities)</li> <li>• User financial and non-financial costs</li> </ul>	✓	
D Safety and personal security	<ul style="list-style-type: none"> <li>• Crash numbers and social cost by severity</li> <li>• Crash rates by road type, user type, key factors</li> <li>• Personal safety /security perceptions and incidents</li> </ul>	✓ ✓	✓ ✓
E Choice	<ul style="list-style-type: none"> <li>• Impacts on demand for non-road freight modes</li> <li>• Impacts on demand for non-car travel modes</li> <li>• PT level of service</li> </ul>		
F Transport system costs, resource and energy use	<ul style="list-style-type: none"> <li>• Construction resources</li> <li>• Transport costs by households (% of household incomes)</li> <li>• Transport costs by businesses (% of total business costs)</li> <li>• Transport system energy/ fuel use – renewables, non-renewables</li> </ul>		
G Transport economic efficiency	<ul style="list-style-type: none"> <li>• Scheme costs to road provider – capital, O&amp;M costs</li> <li>• Scheme benefits and costs to users</li> <li>• Economic performance measures (NPV, BCR, FYRR, etc)</li> </ul>	✓ ✓ ✓	✓
H Economic development impacts	<ul style="list-style-type: none"> <li>• Impacts on business/industry development</li> <li>• Impacts on employment (net, gross, distribution between regions/ sectors)</li> <li>• Impacts on GDP/capita</li> </ul>		
I Global environment	<ul style="list-style-type: none"> <li>• Carbon (CO<sub>2</sub> equivalent) emissions from transport system use</li> <li>• Carbon (CO<sub>2</sub> equivalent) emissions from other transport system inputs (manufacture etc.)</li> </ul>	✓	

Impact heading	Impact factor	Inclusion in typical New Zealand practices:	
		Pre-implementation	Post-implementation
J Local environment	<ul style="list-style-type: none"> <li>Noise / vibration</li> <li>Air pollution (including NO equivalent)</li> <li>Water run-off (quality, quantity)</li> <li>Flora and fauna impacts/special areas</li> <li>Archaeology</li> <li>Visual impact (landscape/urban design/lighting)</li> </ul>	√ √ √ √ √ √	√ √
K Social	<ul style="list-style-type: none"> <li>Community severance/connectedness impacts</li> <li>Distributional effects</li> <li>Cultural aspects, impacts on particular areas/activities</li> <li>Iwi impacts</li> <li>Historic impacts</li> </ul>	√  √ √	
L Health	<ul style="list-style-type: none"> <li>Disturbance (linked to noise/vibration)</li> <li>Respiratory (linked to air pollution)</li> <li>Active mode use</li> </ul>		
M Land use and urban form	<ul style="list-style-type: none"> <li>Urban form and development patterns</li> <li>Urban densities and 'sprawl' impacts</li> <li>Urban 'liveability'.</li> </ul>	√	

## 1.6 Report content and structure

Based on the project scope and focus outlined earlier, and as agreed with the Project Steering Group, this report covers six main topic areas, which are addressed in the following chapters:

Chapter 2 Travel behaviour, covering:

- a review of empirical evidence (New Zealand/international) on traveller behaviour changes in response to new roads or road improvements
- implications of this evidence for New Zealand (prior) transport modelling and economic appraisal procedures and practices.

Chapter 3 Economic appraisal, covering:

- review of state-of-the-art (in New Zealand and internationally) on pre-appraisal of the economic effects of major road/transport projects
- issues relating to the pre-appraisal of wider economic benefits, induced land use changes and impacts on national economic outputs.

Chapter 4 Social, environmental, health and safety aspects, covering:

- New Zealand impacts, practices and procedures for both pre-appraisal and post-evaluation of these aspects having regard to New Zealand and international practice.

- Chapter 5 International post-evaluation procedures and practices, covering:
- review of post-evaluation procedures/practices for road projects in four leading countries internationally, resulting in conclusions on international good practice in the field.
- Chapter 6 Review of New Zealand post-evaluation procedures, covering:
- assessment of the 'post-implementation review' (PIR) procedures and practices used in New Zealand (by the NZTA) to compare actual scheme impacts with the prior economic appraisal forecasts
  - results in a set of recommendations to the NZTA regarding improvements and enhancements to current procedures.
- Chapter 7 New Zealand post-evaluation case studies, covering:
- post-evaluation case studies for five major New Zealand urban transport/roading schemes implemented over the last 10 years, to examine the actual scheme impacts (relative to a 'Do nothing' or 'Do minimum' situation)
  - results in conclusions on the validity of the pre-implementation forecasts and on the availability of appropriate data to undertake such post-evaluation studies.

## 2 Travel behaviour impacts

### 2.1 Introduction

This chapter addresses the impacts of changes in transport conditions (travel time, level of congestion, etc) on travel behaviour, including traffic volumes, modal shifts and new trip generation. Its primary focus is on the impacts of road system improvements (including new links) in urban/metropolitan areas. It particularly examines the empirical evidence on 'induced' travel, given its importance in any assessments of the overall traffic, environmental and economic impacts of urban road system improvements. The work has covered both (ex ante) modelling and project appraisal procedures in New Zealand and internationally, and the (ex post) empirical evidence on the range of behavioural effects from road system improvements.

The research findings are summarised in the following sections (with further detail given in appendix A):

Section 2.2 – a review and summary of international empirical post-implementation evidence on the various travel behaviour impacts resulting from the provision of additional road capacity.

Section 2.3 – in the light of this summary and our review of transport modelling and economic appraisal methods adopted in leading countries internationally (appendix A4), provides commentary on New Zealand modelling and economic appraisal practices and potential for their improvement.

### 2.2 Behavioural responses to transport system improvements – empirical evidence

Our review of the international empirical evidence on the impacts of urban transport system improvements (capacity expansion) on travel behaviour is summarised in the following sub-sections:

- 1 Traffic volume impacts (corridor level)
- 2 Travel behaviour impacts (including modal shift, trip retiming and induced travel)
- 3 Travel time impacts (corridor level)
- 4 Traffic volume changes relative to travel times
- 5 Impacts on traffic volumes and congestion levels (regional level)
- 6 Impacts on land use development.

#### 2.2.1 Traffic volume impacts (corridor level)

For 11 major urban road schemes (in New Zealand, Australia, the UK and European countries) implemented over the last 30–40 years, detailed analyses were undertaken of the effects on average daily traffic volumes across screenlines covering the scheme corridor. The analyses primarily took a shorter-run focus (within 12 months of scheme opening), but data for up to seven years after opening was available for some of the schemes: the observed traffic volumes were adjusted where possible to allow for background traffic trends over the analysis period.

The key findings were as follows:

- In the short run, in all 11 cases the increases in total screenline traffic volumes resulting from the road scheme were in the range 3% to 12% (unweighted average 7%) of the prior screenline volume.

- The short-run impacts occurred predominantly in the first three months following scheme opening, and further traffic growth then tailed off rapidly. However, in at least one case, strong growth appeared to continue for at least the first five years after scheme opening.
- The increase in screenline traffic volumes should not be taken as all representing 'induced travel', in the sense of entirely new person trips. A substantial proportion of the additional traffic in the corridor is likely to result from trip redistribution (from other corridors), modal shift (principally from PT) and possibly reductions in car occupancy. These aspects are discussed further below.

## 2.2.2 Travel behavioural impacts

Under this heading, we summarise the evidence on how increases in road capacity affect travel behaviour, under three sub-headings – modal shift; trip retiming; and new trip generation and trip redistribution ('induced travel'). The evidence appraised is taken from the same 11 urban road schemes appraised above, plus interview surveys of users of new/improved road schemes about changes in their specific trips as a result of the improvements.

### 2.2.2.1 Modal shifts

The evidence shows that the main modal shift is generally from PT to car use. Shifts from other modes (car passenger, walk, cycle) appear to be of lesser magnitude and less information is available to quantify them.

In regard to mode switching from public transport, for main radial corridors in large cities, where rail-based PT services account for a substantial proportion of overall modal share, the evidence indicates that new/improved road schemes may induce modal shifts from PT (primarily rail) to car that account for:

- up to half or more of the total corridor additional ('induced') traffic
- an overall increase in corridor traffic of up to 2% to 3% (with somewhat higher proportions likely in peak periods).

We would further comment that:

- This conclusion relates principally to short-term effects (within a few months of road scheme opening): in the longer term, the extent of mode switching may be somewhat greater.
- The limited evidence, but supported by wider market research, is that such PT mode shifts are primarily from rail services rather than bus services: this reflects generally that rail was usually the dominant PT mode in the corridors examined, and that usually a larger proportion of rail users have cars available.
- While direct evidence is not available, we would expect that most of the modal shifting effect relates to peak periods (when 'choice' travellers may have previously chosen train to avoid the car congestion) rather than off-peak periods (when congestion is much less of an issue).

### 2.2.2.2 Trip retiming

An important behavioural response to increased road capacity in congested situations, arguably second only to the reassignment response, is 'reversion to the peak'; this is the converse of 'active' peak spreading – it involves people changing their time of travel to take advantage of decongestion resulting from the increased road capacity. This response can have major impacts on peak period congestion levels (ie they do not reduce as much as expected, particularly in the 'peak of the peak') and on scheme economic benefits ('decongestion' benefits may be less than expected, but economic evaluation should also take account of 'time shifting' benefits).

For the three schemes for which good evidence was available, between 10% and 30% of motorists responded to the schemes by ‘reversion to the peak’: these relatively large proportions highlight the importance of this response.

#### **2.2.2.3 Trip generation and redistribution**

The extent of empirical evidence available on trip redistribution (‘trip end shifting’) and generation of entirely new trips is limited to user ‘after’ surveys for three major road schemes and relates to short-term responses only. Our conclusions on these aspects are as follows:

- From the empirical evidence, we would conclude only that both effects appear to be very small in the short term.
- For new generated trips, we would in any event expect minimal impacts from such schemes, which would primarily affect travel times in peak periods. For other schemes which affect off-peak travel, greater impacts might be expected.
- For redistributed trips, we would expect any impacts to gradually increase over time, and would relate primarily to peak periods for these schemes, but also potentially to off-peak periods for schemes that affect off-peak travel times.

#### **2.2.3 Travel time impacts**

We examined the evidence on the impacts of major new road/improvement schemes on motorists’ travel times on the new/improved route and the wider corridor affected. This assessment aimed to address the issue of whether any new road capacity would ‘fill up’ with additional traffic within the short/medium term, and thus travel times would not significantly reduce from their previous levels.

The suitable evidence (in New Zealand, Australia and internationally) on this topic was surprisingly limited. Despite the very large expenditures on schemes to increase urban road capacity, there is very limited systematic before/after monitoring of the effects of such schemes on travel times<sup>3</sup>. We were unable to identify any cases where both before and after travel time changes and the extent of induced traffic were available, so that the two effects might be compared.

Our main conclusion from the available evidence was that, in the short term (within a few months of opening), all the schemes examined resulted in significant travel time savings (and probably a reduction in the variability of travel times). No suitable longer-term monitoring data was available. However, if induced traffic responses are substantially greater in the longer term (see below), then it would be expected that some proportion of the short-term time savings would be eroded over the longer term (even in the absence of underlying traffic growth).

#### **2.2.4 Traffic volume impacts relative to travel time changes**

Road improvements that reduce travel times would be expected to result in increased traffic volumes, based on the slope of the demand curve. This section summarises the evidence on the demand elasticity for car travel (VKT) with respect to car travel time, which reflects the extent of demand responses to travel time changes. Such elasticities provide a useful body of evidence, as they are reasonably stable and hence transferable (for a given market segment) between countries and situations. However, it should be noted that these elasticities are normally derived from data at the aggregate (network-wide) level, and therefore may not be directly applied to estimate traffic volume changes at a corridor level.

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<sup>3</sup> Some New Zealand evidence was assembled as part of the New Zealand post-evaluation case studies undertaken in this research project – refer chapter 7.

Our main findings on car travel (VKT) elasticities with respect to total travel times were as follows:

- Typical overall elasticities are around -0.3 in the short run, -0.6 in the long run. This means that a 10% car travel time saving (between a trip's origin and destination) would induce an additional 3% car traffic in the short run, 6% in the long run. These elasticities cover all behavioural influences on traffic volumes, on an all-day basis.
- Elasticities for travel in a given time period (eg peak) may be significantly greater than these all-day estimates, on account of peak spreading/reversion-to-the-peak effects.
- Disaggregate elasticities will vary substantially with:
  - trip purpose (and hence period of day)
  - extent of modal (PT) competition
  - extent of other constraints on car use (eg parking restraint at trip end).

## 2.2.5 Impacts of additional road capacity on traffic volumes and congestion

A number of USA studies have investigated relationships at the regional level over extended periods (c20 years) between the amount of road traffic (VKT), levels of congestion and the additional road capacity provided (eg lane miles of freeway and arterial routes).

Most of the studies report their findings in terms of the VKT elasticity with respect to lane km (or similar capacity measure). While the results from the various studies are not all consistent, the weight of evidence points towards the following findings:

- 'Short-run' elasticity estimates (within one to two years of capacity increase) are typically in the range 0.15 to 0.3.
- 'Long-run' elasticity estimates are typically in the range 0.6 to 0.9. Different studies indicate that the long-run equilibrium position may be reached within four years, or not for 10+ years.

These findings indicate that, in the short-run, the induced traffic effect is relatively small: most of the 'theoretical' time savings and other benefits expected from road capacity enhancements in the absence of induced traffic will in fact be realised. However, in the longer run, they indicate that the induced traffic effect is quite substantial, resulting in a significant proportion of the initial time savings being lost.

## 2.2.6 Impacts of road schemes on land use development

### 2.2.6.1 Evidence on land use/economic development impacts

In the short run, the provision of additional road capacity will improve the relative accessibility of certain trip destinations (attractions) and hence tend to result in trip redistribution, eg a shopping trip from a given origin may switch to a shopping destination that has now become more accessible. Such a redistribution will result in additional (induced) travel in the new corridor used, offset by reduced travel in the corridor previously used: there is likely to be some net increase in VKT (in response to the improved network accessibility levels overall).

Similarly, in the long run, the addition of road capacity is likely to result in a redistribution of land development. Improved accessibility associated with the new (or improved) road will make it more attractive for businesses and residents to relocate in the vicinity of the new road (in particular its interchanges). The increased attractiveness of these sites will tend to result in increased land values (rents), until a new equilibrium between land supply and demand is reached. The new developments will generate/attract additional traffic to the new road, most of which will be redistributed from other origins

and destinations. This is the phenomenon of additional road capacity inducing land use changes, and generally increasing 'sprawling' of the city; these changes in turn will lead to increased demand on the new/improved road facility.

Our research examined the evidence available from international case studies (mostly from the UK and Europe) on the impacts of new road schemes on land use and economic development. Its main focus was on empirical (before/after) evidence relating to situations where new roads had been built, but some of the evidence examined was from theoretical/modelling studies rather than direct observations. The evidence examined covered the impacts of new road schemes on land values, development pressures and actual development (including impacts on employment). Market research into the importance of transport factors in commercial/industrial location decisions was also examined.

The main findings drawn from this evidence and other sources are as follows:

- New or improved roads that enhance the accessibility of particular areas result in increased land values in these areas, whether the land is zoned for commercial, residential or other developments.
- The types of new developments which are particularly attracted to highly-accessible locations associated with new roads in peripheral urban areas (eg land adjacent to motorway junctions) tend to be:
  - distribution/warehousing activities, serving national and regional markets
  - large mall (hypermarket) and superstore developments, that depend on large catchment areas
  - high-technology growth industries
  - offices requiring good access for employees and visitors, but not requiring central area locations.
- The evidence on factors influencing the location of commercial/industrial businesses is somewhat conflicting on the importance of transport factors. However there is evidence that good road access is a major factor influencing such decisions.
- Improving access to under-developed areas with previous poor access does not necessarily increase the development of such areas relative to other areas. There may be employment gains in some sectors, losses in others (eg distribution sector).
- Some theoretical studies suggest that enhanced access may result in substantial increases in employment in areas with poor access previously, eg the UK Severn Bridge/M4 study suggested an increase in employment in South Wales of some 4%. However such theoretical study results are often not substantiated by the empirical evidence, which tends to indicate much smaller impacts (even in gross terms).
- It is generally considered that improvements in accessibility to under-developed areas will not be a sufficient condition, and may not be a necessary condition, to stimulate economic growth in such areas. It has been argued that road investment will only make a significant difference where it is the only missing feature of a strong economy. New road infrastructure is likely to be more effective in stimulating development, in the context of a strong economy, where it removes a constraint to the spread of development pressures in the area/region concerned.
- There is very limited evidence, from either theoretical or empirical studies, on the net development/employment effects of enhanced access (as distinct from the gross effects in the area directly affected). In general, it is likely that most of the gross effects represent transfers from other areas.
- Major new road schemes would generally 'induce' different patterns of land use development than would occur in the absence of the scheme. In particular, they may lead to re-zoning of parcels of land



in the vicinity of the scheme (eg motorway intersections), which will be attractive to particular types of commercial development (as noted above). Such differential land use impacts should be taken into account when assessing the traffic, economic and environmental impacts of major road schemes.

#### 2.2.6.2 Evidence on traffic volume impacts

It is self-evident that increased land use developments in the vicinity of and as a result of new road schemes will result in increased traffic volumes using the new road. This is perhaps particularly the case because many of the 'induced' developments will be of the type for which access is important and which will tend to attract relatively large traffic volumes (eg large shopping malls).

However, very little 'hard' evidence is available on the extent of induced traffic resulting from land use developments associated with new road schemes, or on the proportion of total traffic or of all induced traffic that is accounted for by this 'induced land use' category:

- In a study of traffic growth on UK motorways and trunk roads, Marcial Echenique & Partners concluded that land use effects made as important a contribution to traffic growth as transport effects (SACTRA 1994, p238).
- Modelling work by Rodier et al (2001) showed that 'the long term land use development effects can be a large additional source of increased vehicle miles travelled (VMT) associated with highway expansion' (Noland and Lem 2001, p18).

Given the paucity of 'hard' evidence, all that can be concluded is the following:

- Induced traffic associated with land use development is primarily a medium/longer term phenomenon; however, it may start when the new road is at the planning stage and gradually increase prior to and subsequent to the scheme opening.
- In the short-term, this land use induced traffic is likely to represent a small component of all induced traffic and of total traffic in the corridor/area most affected. In the longer term, this induced traffic component may well exceed the total of all other induced traffic components, in some situations.
- It seems likely that induced land use will result in an overall net increase in traffic volumes in the region as a whole: the improved travel conditions resulting from a new road scheme will tend to increase overall traffic volumes. However, the net traffic effect from induced land use, over the whole region, is likely to be very much less than the gross effect in the corridor/area in question.

## 2.3 Conclusions and implications for New Zealand modelling and evaluation practice

### 2.3.1 Overview

The following sub-sections summarise our research conclusions on the various travel behavioural responses to urban road improvement schemes, including the importance of the induced travel phenomenon (2.3.2). We then outline (2.3.3) the implications of these conclusions for transport project evaluation and for transport/land use policy coordination. In the light of these implications, we finally (2.3.4) suggest enhancements to New Zealand transport modelling and evaluation procedures so as to provide decision makers with better information on travel behavioural effects and their implications.

The material in these sections draws particularly on the empirical evidence presented in section 2.2 (and appendix A2) and on our review of developments in UK, Australia and New Zealand modelling and evaluation practices relating to travel behaviour/induced travel (appendix A4).

## 2.3.2 The significance of behavioural responses (including 'induced' travel)

### 2.3.2.1 Traffic volumes – the empirical evidence

This chapter's review of the empirical evidence indicates that the extent of additional traffic 'induced' by new or improved road schemes is generally rather modest, certainly in the shorter term. In the shorter term, in a number of road schemes examined, the extent of 'induced' traffic (across an appropriate screenline) in the corridor concerned was estimated at an average 7% additional to the previous corridor traffic volumes. In the longer term, the traffic volume increase in the corridor may be significantly greater, due to ongoing trip redistribution and induced land use effects, although the evidence on these impacts is rather weak. In the short term and more so in the longer term, much of this 'induced' traffic in the corridor is likely to be redistributed from other origins-destinations, indicating that the 'total' induced traffic on a network-wide basis will be significantly smaller than in the corridor directly affected.

### 2.3.2.2 Economic impacts

In economic terms, the additional (induced) traffic resulting from a road network improvement will perceive a benefit through now being able to travel, taking advantage of the improved conditions; but this additional traffic will reduce the benefits for all other traffic if the road is at all congested. The balance between these two aspects, ie the net benefit associated with the induced traffic, will depend on the specific circumstances: in typically congested urban situations, there will be an overall net disbenefit associated with the induced traffic.

Further, in congested urban situations, relatively small (%) increases in traffic volumes will typically result in much larger (%) reductions in the economic benefits associated with schemes to increase road network capacity. The weight of evidence indicates that, for road schemes in moderately congested urban areas, the estimates of net user benefits are 20% to 50% lower when induced traffic effects are taken into account than if these are ignored (ie a fixed trip matrix is assumed). This highlights the importance of allowing for induced travel effects in scheme modelling and evaluation.

Induced road traffic effects are of greatest importance for scheme economic evaluation in situations with:

- a high degree of congestion (typically in urban areas, especially at peak periods), and/or
- high elasticity of demand (typically in urban areas, especially where alternative modes offer strong competition), and/or
- relatively large changes in travel costs (typically for larger schemes providing substantially enhanced capacity).

For PT, induced travel effects are also most significant when similar conditions apply – that is, when demand is relatively elastic and increases in response to improved service, and when the service is already congested or crowded.

### 2.3.2.3 Environmental and social impacts

In regard to the other components (environmental, health, safety, etc) which should be included in the evaluation process, in the absence of induced travel urban road capacity-enhancing schemes would generally result in freer-flowing traffic and hence in reduced global (CO<sub>2</sub>) and local emissions and generally in reduced accidents. There may of course be some disbenefits (negative effects), such as severance, disruption during construction and possibly noise. However, the existence of induced travel will tend to reduce the overall net benefits, through the additional traffic-generating additional emissions and probably crashes.

The overall balance between these benefits and disbenefits will be situation-specific, but this is an aspect in which the extent of high-quality research is surprisingly limited (both in New Zealand and internationally). The five New Zealand case studies undertaken for this research (refer chapter 7) were generally unable to reach firm conclusions on this balance, largely because of data limitations (regarding changes in traffic volumes and on aspects such as fuel consumption/CO<sub>2</sub> emissions, noise and pollution levels). Internationally, very few post-evaluation studies were identified that provided comprehensive before and after information of the nature required.

Some more detailed case studies, in New Zealand or elsewhere, would appear desirable, in order to provide better evidence on the balance of benefits and disbenefits for selected major schemes. Such studies would apply enhanced modelling and evaluation methods where appropriate, as well as before and after data collection. In the New Zealand context, it is hoped that some of the proposed RoNS schemes, for which extensive before and after data collection is being proposed, will provide suitable case studies, for both shorter and longer-term post-evaluation purposes.

### 2.3.3 Implications for transport and land use development

#### 2.3.3.1 Implications for transport policy development and project evaluation

It will be clear from the above and from earlier sections that the induced travel (traffic) effect associated with urban road capacity enhancement schemes:

- is real
- can significantly affect traffic volumes on the route or corridor affected
- will bring economic benefits to new road users (who would not otherwise make the trip), but disbenefits to existing users in situations where there is any significant degree of congestion
- will tend in most situations to reduce overall user benefits over time, as traffic volumes increase and congestion worsens
- in such circumstances will significantly reduce net user benefits and hence scheme economic performance
- will generally reduce the environmental and social benefits that might otherwise result.

These adverse economic effects resulting from induced travel essentially arise because road users are not recognising the full marginal social costs (MSC) associated with their trips: these costs include the congestion-related costs and other externality costs (emissions etc) that additional trips impose on other road users and society at large. These adverse economic effects could be 'neutralised' if road users were charged for the MSC they impose: this is the theory under-pinning urban road pricing (congestion charging).

The existence of the induced travel phenomenon does not invalidate the case for increases in road capacity in urban areas. Rather, it strengthens the need for:

- careful evaluation of the full range of impacts (including induced travel) of any such scheme, from the economic, environmental and social perspectives
- comparison of the merits of such schemes with options involving alternative modes and demand management policies, including road pricing policies
- consideration of the scheme as a component of an optimised 'package' of investment and management measures, which in particular would avoid or mitigate undesirable induced traffic volumes and would 'lock in' the potential benefits of the scheme package as travel demand increases over time.

This more holistic approach to examining the case for increases in urban road capacity should be reflected in evaluation procedures and practices. Under the current road project evaluation practices (in New Zealand as in many other countries) there is a danger of over-investment in expanding road capacity as a result of the present sub-optimal pricing arrangements. Some capacity expansion schemes which now appear warranted (in terms of their economic benefit–cost ratios) would not be warranted if the road system was priced on an optimal (MSC) basis or some proxy for this (Eddington 2006).

The UK Eddington (2006) report demonstrated that this was a very significant issue, certainly in the UK context. It commented as follows:

*If widespread road pricing were introduced, the nature and location of challenges on the roads would be altered. Analysis undertaken to understand what this means for the case for additional infrastructure in the UK in the longer-term suggests that road pricing would significantly reduce, but not completely eliminate, the amount of additional road build for which there would be an economic case.*

*By looking at the returns from additional fixed infrastructure, it is estimated that instead of 2,900 to 3,350 lane kilometres, if national road pricing were introduced, this would fall substantially to just an additional 500 to 850 lane kilometres on the strategic road network between 2015 and 2025. This is a reduction of some 80%.*

*Such a package might cost around £5-8 billion and would generate annual welfare benefits in 2025 of some £30 billion. The vast majority of the benefits of this package of road build and pricing derive from the pricing element with only around £600 million of benefits generated by the road build.*

*This section has highlighted that, owing to the interaction of road pricing with the case for additional road build, robust long-term decisions on strategic road capacity can be better made if the case for capacity enhancements has been tested in an environment where pricing – localised or widespread – is approaching. Given the long lead times of such transport interventions, this will be particularly important when considering interventions to tackle challenges beyond 2015.*

The previous New Zealand (Labour) Government took up this point in its update of the New Zealand Transport Strategy (MoT 2008), which stated that:

*Meanwhile (while research on alternative charging systems is still proceeding), the evaluation of major infrastructure projects should consider the possible effects that different methods of generating revenue may have on managing future demand and therefore whether the need for that project remains.*

While the current New Zealand government has not come to any decision regarding the introduction of point-of-use charges on existing roads, there seems to be a significant possibility of some such charging arrangements being introduced well within the effective lifetime of major road capacity enhancement schemes currently under investigation. We therefore see merit in the NZTA modifying its current practices for the economic evaluation of major capacity-enhancing projects, to require their evaluation to be undertaken based on both existing pricing arrangements and assuming more economically efficient pricing arrangements.

### **2.3.3.2 Implications for transport/land use policy coordination**

The transport ‘system’ and the land use ‘system’ are intimately interrelated: land use disposition ‘drives’ the pattern of demand for transport, while the accessibility provided by the transport system is a major

factor that 'drives' land use development. Despite this intimate dependency, land use planners and transport planners often do not recognise the strength of the second of these driving linkages, ie the impact of accessibility on patterns of land use development.

The strength of this relationship has been exemplified in numerous cases internationally. One well known example of transport-induced land use development is that of London's M25 Orbital route: this had major impacts on the pattern of commercial development throughout outer London over the medium term. An older example in New Zealand was the rapid development of Auckland's North Shore following the opening of the Harbour Bridge.

'Traditional' four-stage transport models used in New Zealand, as in other countries, do not include any interactive linkages ('feedback loops') between transport accessibility and land use development. We consider such linkages would be highly desirable in models for the New Zealand metropolitan areas, while recognising the difficulties in establishing and modelling the appropriate transport/land use linkages. The current exception in New Zealand is the Auckland (ART3/ASP2) models.

In the absence of such models, it would be highly desirable for evaluation procedures for major transport proposals to address in a qualitative manner whether these proposals are consistent with and supportive of current and proposed land use plans. To the extent they are not, there may be a good case for either modifying the transport proposals and/or modifying the land use plans to respond to both the pressures and opportunities likely to result from the improved accessibility associated with the road scheme.

Importantly, it is essential that the land use assumptions used for the do-minimum network scenario are compatible with such a network. The standard approach in New Zealand is to use a fixed set of land use assumptions for both the do-minimum and the do-something scenarios. Although unrealistic, the changes in networks on the basis of fixed land use are applied to derive changes in travel demand due to trip re-distribution, trip re-timing and changes in mode split. The results from four-stage models are used to derive factored inputs to project traffic models – effectively representing 'implied elasticities'. A common New Zealand approach is to use the difference in traffic demand between the do-something and do-minimum scenarios in a four-stage model as representing the traffic induced by a road project – to create a do-minimum demand level on a project traffic model – thus acting as a proxy for a lower level of traffic for a given road network pattern. However, none of this represents 'truly additional' induced traffic, as all approaches assume the overall total trip matrix is fixed.

## 2.3.4 Implications for New Zealand modelling and evaluation procedures and practices

### 2.3.4.1 Transport model development aspects

The range of behavioural responses typically resulting from changes in the transport system (infrastructure schemes, pricing, demand management etc) is set out in appendix A (table 5.1). Current multi-modal (four-stage) models used in the New Zealand metropolitan areas to estimate the effects of transport system changes are relatively good at modelling some of these responses (eg assignment), relatively poor at modelling other responses (eg trip generation or 'induction').

Table 2.1 provides a provisional 'generic' summary, relating to multi-modal (four-stage) models in New Zealand, of those model aspects on which further development work would be desirable, so as to better reflect travel behaviour responses in general and 'induced' travel responses in particular, and hence provide the basis for improved (ex ante) economic appraisals of urban transport schemes.

This summary of development requirements is intended to provide an initial basis for discussions between the relevant parties, noting that not all the suggestions will apply in all the current New Zealand multi-

modal models. We also recognise that some of the suggested model enhancements would be much harder to implement than others, in particular because of the paucity of data on some of the relationships involved (eg between transport accessibility, trip generation and land use development).

**Table 2.1 New Zealand multi-modal model enhancements – potential development tasks**

Modelling stage	Development requirements/recommendations
Trip generation ('induced travel')	Development of a dynamic accessibility – trip generation interaction module, with trip generation rates sensitive to accessibility changes: <ul style="list-style-type: none"> <li>• short term – apply elasticity techniques</li> <li>• medium/long term – research and development to implement variable demand relationships</li> </ul> Also investigate/apply relationships between economic conditions (eg real disposable incomes, petrol prices) and trip generation.
Trip generation/distribution – 'induced' land use effects	For major models, the development of a dynamic transport-land use interaction module, with land use and demographic data sensitive to accessibility changes. For all models where development patterns are affected (ie most other models), the application of different land use inputs for the do-minimum and do-something scenarios.
Trip distribution	Assess need for re-specification of trip distribution impedance functions, including for effects of economic conditions (also refer to 'Trip generation' above).
Vehicle occupancy	Investigate development of a module incorporating changes in vehicle occupancy in response to changes in travel costs.
Trip retiming	Incorporation of trip retiming module to reflect that motorists may change their time of travel in response to both travel time differences (congestion) and cost differences (road pricing). Also needs to address peak spreading/contraction within the modelled peak period (important in economic terms).
Mode choice	Mode choice formulation to recognise captive nature of many trips (either to car or to PT).
Assignment (routing)	Generally satisfactory (subject to incorporating appropriate time and cost parameters).

### 2.3.4.2 Economic evaluation aspects

For the (ex ante) economic appraisal (evaluation) of urban/metropolitan transport projects, the main weaknesses in capturing the range of behavioural responses are in the modelling process (as addressed above) rather than in the subsequent translation of model outputs into economic outputs.

The NZTA (2010) *Economic evaluation manual volume 1* (EEM), section A11 now specifies:

- the circumstances in which variable trip matrix methods (incorporating estimates of induced travel and other behavioural responses) are to be applied
- the methods which may be used in deriving estimates of variable trip matrices for the 'do minimum' and 'option' cases
- the methods for deriving economic benefits from these variable trip matrices.

This research has not identified any need for enhancement of these sections of the EEM at this stage. However, if some of the modelling improvements suggested in table 2.1 are implemented, then further consideration may need to be given to the associated economic evaluation methods. This comment would apply particularly if transport and land use interactions are to be incorporated into modelling and economic appraisal practices: this aspect is discussed further in the next chapter.

## 3 Economic appraisal

### 3.1 Introduction

This chapter reviews three issues:

- 1 The cost-benefit (pre-)appraisal of transport strategies that induce 'land use' change (following on from the relevant findings and recommendations of chapter 2)
- 2 Some issues with the pre-appraisal of wider economic benefits
- 3 Methods for the pre-appraisal of project/programme impacts on national economic output.

### 3.2 Appraising projects that induce land use change

#### 3.2.1 Introduction

Section 2.2.6 describes evidence that major new road schemes generally induce land use change (ie changes in neighbouring population, economic activity and locations of firms and households), which in the long term can be a leading cause of traffic growth in an area/corridor. Inducing such changes is likely to result in additional benefits and costs, the scale of which will be unique to each scheme.

A complication with accounting for induced land use change is that even if it could be predicted with reasonable accuracy, current best practice CBA methodologies do not allow these effects to be explicitly and fully taken into account in the analysis.

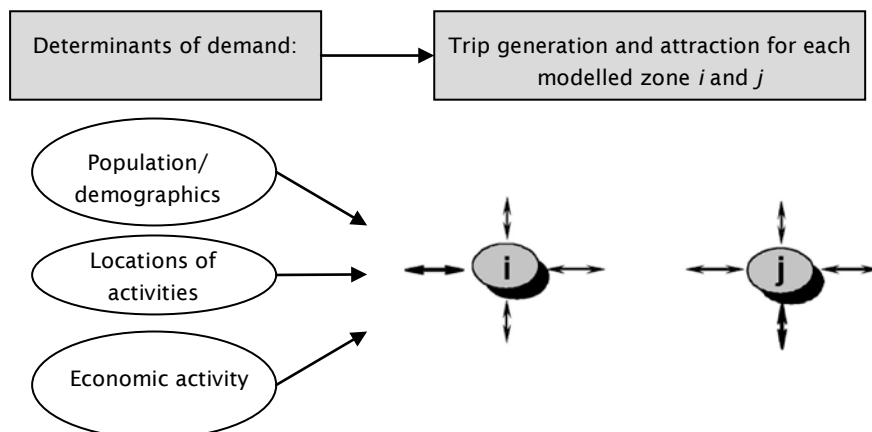
Compounding this issue is that land use effects are in large part a long-term phenomenon, and the long term does not count for much under New Zealand policy settings. Thus even if CBA methodologies could account for forecasted land use effects, the 8% (real) social discount rate used means effects after about 20 years are relatively immaterial (with each \$1 equivalent to about \$0.21 now). This issue is touched on in section 3.4.2 below.

#### 3.2.2 Transport CBA as it relates to land use

This section clarifies how prevailing transport CBA methodologies relate to land use, and outlines some methodological attempts made to account for it.

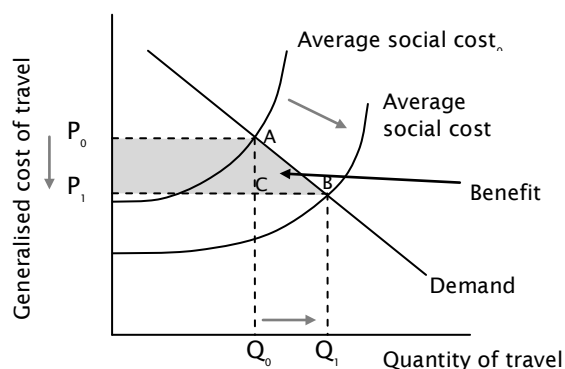
##### 3.2.2.1 Land use assumptions determine transport demand

The demand for travel is primarily determined by population/demographics, economic activity and the location of households and firms (plus other institutions such as schools and hospitals) (ATC 2006b, p100). For brevity these determinants are described here as 'land use'. Figure 3.1 provides a stylised representation of this.

**Figure 3.1 Determinants of travel demand**


Source: NZIER and ATC (2006b, pp99-100)

The land use assumptions are the principal determinants of the generation and attraction of trips between each modelled zone, which leads to the derivation of a demand schedule for travel across the transport network. A scheme that reduces transport costs leads to consumer surplus benefits (for the single market case) equal to the shaded area  $P_0ABP_1$  in figure 3.2 below.

**Figure 3.2 Measuring benefits in a single market**


Source: NZIER

The approach to measuring benefits generalises across the network straightforwardly (Bates 2004 and Hotelling 1938).<sup>4</sup> BTRE (1999), Rouwendal (2001) and Boardman et al (2006) describe the measurement of these direct transport (or 'primary market') benefits as representing total social benefits if other related markets are priced efficiently (ie price equals marginal social cost). Wider economic benefits (WEBs) discussed further in section 3.3 below seek to account for situations when related markets have characteristics that cause additional costs and benefits.

### 3.2.2.2 Land use assumptions are exogenous

Best practice transport CBA assumes land use (specifically, the number of employees, households etc for each modelled zone) to be unchanged by a transport scheme. Although land use can evolve over time (eg with population growth), and although land use transport interaction (LUTI) modelling (as discussed

<sup>4</sup> A technical condition is that the 'integrability condition' holds (ATC 2006a p75, or Boardman et al 2006, p130).



further below) can account for induced land use changes, the CBA methodology requires the land use configuration to be the same in the do-minimum and all project scenarios.

A major reason why international best practice transport CBAs ignore induced land use changes is that models for the forecasting of these effects, and the flow-on travel demand effects, are not sufficiently advanced and consistent with economic theory so as to enable reliable estimates of the associated economic benefits. As noted in the UK Department for Transport (DfT) (2010d) WebTAG 3.1.3, section 2.6:

*...it is currently not possible to conduct a CBA in which land use changes feed through into travel demand changes. The reason is that, at present, the way in which land use responses and transport responses are represented mathematically in land use/transport interaction models are not sufficiently consistent to allow the calculations to be undertaken in a manner which accords with the theory on which transport cost/benefit is currently based.*

David Simmonds Consultancy and John Bates Services (Simmonds and Bates) (2001, p5) make similar comments, explaining that CBA ignores land use change because the existing appraisal procedures in isolation are insufficient to account for the full welfare impact. They say that ‘as soon as we introduce changes that are not represented in generalised [transport] cost, the conventional approach becomes less reliable, and may give wholly misleading results’. Simmonds and Bates (2001, piii) state that:

*the methods conventionally used to estimate user benefits arising from transport strategies are inapplicable if those strategies are expected to have impacts upon the distribution of land uses. This is an increasingly serious problem in transport appraisal practice.*

This ‘fixed’ land use assumption required for transport CBA is often ignored or not explicitly acknowledged in the transport economic literature. For instance, the EEM does not actually make reference to the assumption, and nor do the ATC (2006a) national guidelines.

### 3.2.2.3 The effects of major transport strategies on regional population and economic activity

Major<sup>5</sup> transport strategies have the potential to materially affect the determinants of transport demand in the long term, shifting future demand schedules for travel.

Coleman (2010) finds that highway investment can reduce urban density and increase private transport use:

*If private transport infrastructure – a highway – is built, people move out from high density central city locations to low density suburban locations, and population density declines: or to be more succinct, highways induce sprawl (p24).*

*...United States evidence, and Auckland’s own history suggest that new roads cause population dispersal and employment decentralisation, as firms and citizens flee the central city in search of desirable locations with easy city access located slightly further out of town (p27).*

Grimes (forthcoming) in a paper for the *Handbook of regional science* describes the conceptual framework that population and employment increase (in the neighbourhood of the scheme) following major net-beneficial improvements to transport networks. The work is underpinned by the theory of ‘spatial equilibrium’ in the urban economics literature, which is that people will keep adjusting their locations in response to a new development until the net benefits of locating in one place are equal to those from locating elsewhere.

<sup>5</sup> Isolated network improvements that do not make a material change in accessibility in the network are much less likely to have any land use effects.

Other evidence in the literature that transport schemes can cause long-term changes to land use, economic activity and regional population are as follows:

- Glaeser and Gottlieb (2009) show that a positive local shock (eg a major new transport investment) will impact on population, prices and wages of the affected area.
- Baum-Snow (2007) and Duranton and Turner (2007) find that if a highway makes a region more productive, then we will see an increase in population and employment as long as housing supply is at least somewhat elastic.
- In the USA, Blanchard and Katz (1992) find considerable regional geographic mobility of population and employment in response to local shocks (of all types).
- Maré et al (2009) find evidence of migration responses within New Zealand that are similar to those found by Blanchard and Katz.
- Cochrane et al (2010) explicitly model the endogenous interactions of New Zealand local authority investments with outcomes for population, employment and incomes. They find that an exogenously sourced infrastructure investment increases population of a local area and of neighbouring areas.
- Grimes et al (2010) find that Australasian house prices tend to move together over the long run, implying that migration plays an equilibrating role across the regions of both countries. Thus, in economic terms, New Zealand needs to be considered as a 'subnational' component of the broader Australasian economy.

Duranton and Turner (2009) find empirical evidence in the USA that roads can fill back up again and negate any congestion reduction gains. This is described as the 'fundamental law of road congestion', which is largely driven changes to economic activity, population and land use:

*We investigate the relationship between interstate highways and highway vehicle kilometres travelled (VKT) in US cities. We find that VKT increases proportionately to highways and identify three important sources for this extra VKT:*

1. *an increase in driving by current residents*
2. *an increase in transportation intensive production activity; and*
3. *an inflow of new residents.*

*The provision of public transportation has no impact on VKT. We also estimate the aggregate city level demand for VKT and find it to be very elastic. We conclude that an increased provision of roads or public transit is unlikely to relieve congestion.*

Metz (2008) finds that historically in the UK travel time per capita is remarkably constant. Metz suggests that new infrastructure does not result in travel time being saved to allow other activities to be carried out. Rather, travel time is conserved, allowing more distant destinations to be reached within the time available for travel.

### 3.2.3 Land use/transport interaction (LUTI) modelling

LUTI models attempt to represent any possible two-way interactions between transport impacts and land use impacts. The reader can obtain a fuller introductory account of LUTI models from DfT (2010d) WebTAG unit 3.1.3, which outlines the general principles of LUTI modelling and the different kinds of models available.

The Auckland Council's ART3/ASP3 model is currently the only state of the art LUTI model in New Zealand. However, unlike some overseas LUTI models the ART3/ASP2 suite holds regional population and regional GDP fixed (with respect to a transport project).

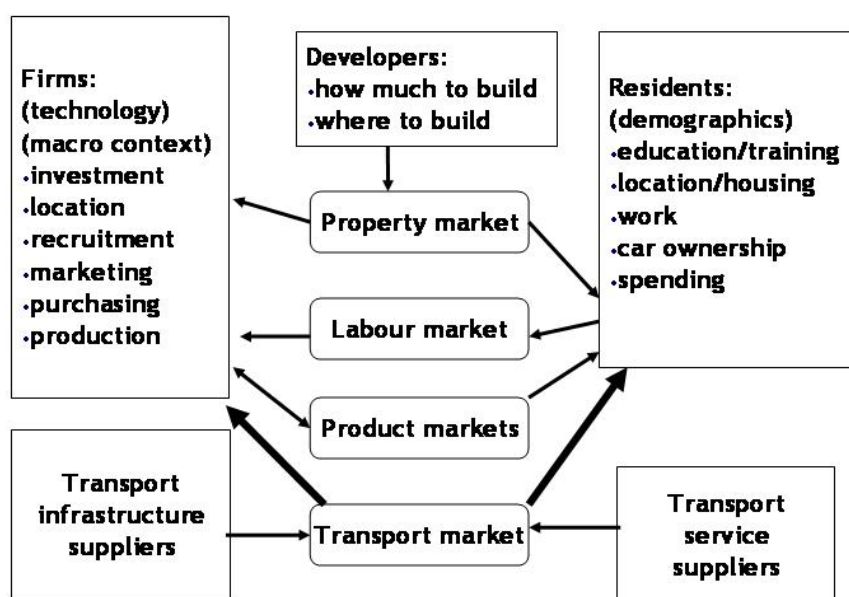
### 3.2.3.1 Principles of LUTI modelling

A normal transport model requires inputs of land use which have been forecast exogenously (ie taken as given). LUTI models generate their own forecasts of land use, which depend on assumed land use policies and the changes in accessibility (which result from changes to the transport system).

Vickerman (2008) describes how LUTI models vary in the precise way they operate but essentially comprise a series of linked detailed models covering travel/transport, production and GDP, labour markets and population and land use (but not necessarily all of these). The scope of LUTI modelling and the role of transport are illustrated below in figure 3.3. It identifies the population as individuals and as households and firms and other productive organisations. The latter are divided into firms in general plus three categories of firms of special interest: property developers, transport infrastructure providers and transport service providers (eg PT operators).

Transport influences the location decisions of residents and firms in a number of ways. These influences can be clarified by considering the key decisions made by different categories of land use actors, as shown in figure 3.3. All of the different kinds of decisions listed for firms and residents are likely to be influenced, directly or indirectly, by the transport system.

Figure 3.3 LUTI modelling: the markets generally modelled, and key decisions by land use actors



Source: Simmonds and Feldman (2011)

Vickerman (2008) says the main problem with LUTI models arises from the assumptions implicit in each of the constituent models. The production sector is typically modelled using an input-output framework (refer to section 3.3.6) that is often static in nature and depends on existing patterns of behaviour that do not change. Similarly the links between population, labour force and labour demand also depend on assuming that existing patterns of behaviour do not change, when the evidence from major changes in the transport network is that behaviour can actually change quite significantly.

Rather than suggest that LUTI models are problematic, this indicates that there is scope to continually improve this modelling technique. For instance, section 3.3.7 below describes a further research possibility to better represent the workings of the economy in LUTI models.

### 3.2.4 Attempts to account for transport induced land use change in CBA

The following are relatively recent attempts to account for induced land use changes in transport appraisals:

- Simmonds and Bates (2001) (followed up by ITE 2003) propose using various aspects of a land use/transport interaction model to measure the sum of conventional transport benefits and benefits related to land use improvements at trip destinations and at residences.
- The DfT's (2010b) WebTAG 3.16 proposes methodology to appraise transport projects that 'unlock' the potential for housing development when there is excess demand for housing.
- Parker (2012) proposes a refinement to existing methodologies to account more generally for total social net-benefits when schemes induce shifts in demand schedules.

Simmonds and Bates (2001) note some earlier attempts at developing transport CBA methodologies when land use changes are induced, such as Neuberger (1971) and others that are based on LUTI modelling.

Simmonds and Bates (2001, p4) note that although those earlier papers are interesting they:

*do not provide a full response to the issues. In particular:*

- *the studies which have added further calculations to conventional transport benefit measures do not sufficiently explain their reasoning, or demonstrate why their methods are sufficient to measure all benefits without double counting*
- *those which propose alternative methods require, at the very least, greater changes in appraisal practice, and they may be compatible only with particular land use/transport models.*

Simmonds and Bates (2001) propose a methodology to appraise the overall net benefits of such schemes. They partition welfare into three classes: transport, 'attraction' of land uses, and the 'production' of trips. The latter two rely on measuring changes in intrinsic utility, which currently is perceived to have problems. As such their proposed approach was not generally used or developed.

The DfT's (2010b) WebTAG 3.16 considers the land use value uplift as a benefit additional to the transport benefits, and subtracts the congestion deterrent the land use change causes. This is added to conventional transport benefits with a do-minimum land use scenario. The DfT approach is only used when neither the transport nor the development can be justified in the absence of the other scheme (given prevailing appraisal methods). The approach is not suitable for applying generally to transport projects that induce land use changes when those changes are permissible.

Parker (2012) proposes to measure not only the consumer surplus benefits under a given demand schedule but the total change in social welfare from inducing shifts of a multi-market demand schedule. The approach continues to use only the generalised costs (both resource costs and perceived prices) and quantities of travel that are produced from transport models, but for each of the do-minimum and option land use scenarios estimated using, say, LUTI modelling. Initial applications using the Auckland Transport (LUTI) Model suggest that in the continued absence of efficient pricing benefits are higher if the network can cope with the land use changes, and benefits are lower if it is congested. (This finding is similar to the more traditional appraisal of induced travel effects).

### 3.2.5 Summary

This section has highlighted methodological issues with accounting for transport induced land use changes in CBA. Thus accounting for induced land use changes is a two-pronged problem: overcoming the difficulties in appropriately forecasting the effects, and being able to account for any expected effects in a welfare appraisal.

Modelling technologies such as LUTI attempt to forecast transport induced land use change. However they are not widely available, and there still appears to be significant scope for further improvement in their forecasting capabilities.

However, even if transport induced land use change can be robustly forecasted, they are not permitted to play a role in the direct benefits estimation because there are no mainstream methods developed to do so. It would seem that insufficient effort has been made by the profession to develop appropriate transport appraisal methods to account for induced land use change.

It is not the case that induced land use changes ought to be excluded in principle; rather, they ought to be included.

## 3.3 Wider economic benefits (WEBs)

### 3.3.1 Introduction

The NZTA-funded research Kernohan and Rognlien (2011) outlines the concepts of WEBs and procedures to estimate them. This section does not aim to duplicate any of that work, but it aims to highlight some issues for further consideration and debate where applicable.<sup>6</sup>

### 3.3.2 Agglomeration

The NZTA now recognises additional benefits from transport projects that increase the effective density of certain types of industries for major transport schemes in large urban centres. The productivity gains that accrue are in excess of the transport user benefits.

This section outlines some issues relating to the current procedure, and some criticisms made.

Increased disaggregation of transport models may exaggerate agglomeration benefits, making appraisals unduly sensitive to arbitrary judgements

The results of the NZTA's agglomeration procedure (which is based upon the UK DfT's procedure) can be materially affected by arbitrary decisions on whether a transport model's zones are aggregated:

- NZIER's work for the northern busway extension tested how responsive the agglomeration procedure results were to aggregating the Auckland Regional Transport model's 512 area zones. This sensitivity analysis indicated that aggregating neighbouring zones did not affect the agglomeration results for the majority of the 512 zones, but may do when one particular origin-destination (OD) pair that has a substantial change in connectivity is aggregated with a neighbouring OD pair that does not.
- Thus aggregating a model of 512 zones (262,144 OD pairs) to 110 zones (12,100 pairs), as has been done on some Auckland appraisals, may arbitrarily dull the net result.

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<sup>6</sup> There is nothing to add to Kernohan and Rognlien (2011) regarding the 'increasing competition/mitigating existing market failures' WEB.

- This means that different analysts may obtain very different results depending on the extent to which they choose to aggregate the zones across a transport model. Parker (2012) suggests that some degree of aggregation is probably warranted. This would help to ensure that calculations do not use very small differences in prices and quantities that are within a model's margin of error and are then extrapolated beyond what is reasonable.
- More research and guidance is needed to help ensure that practitioners use consistent and appropriate conventions regarding the aggregation of zones so that estimated benefits are robust and comparable.

The procedure is centred on unchanged land use. It is designed to apply when a transport strategy does not change the amount of employment in each zone, and refinements are needed for it to apply to projects that materially induce changes to employment:

- The focus is on improving the 'effective density' to workers in their existing locations, rather than on the impacts of appraising changes in area densities.
- One could argue this is odd given that the concept of agglomeration principally relates to people clustering (ie agglomerating) in locations, and it is this behavioural phenomenon that is not fully accounted for in the procedure.
- The procedure seems to allow for changes in employment by zone between the do-minimum or option scenario, but it is insufficiently specified to account for the net benefits when employment changes. If the transport scheme induces changes to employment by zone then the procedure needs to be adjusted. The procedure should measure only the productivity spillovers (ie externalities) from the workers that relocate on those workers that are assumed to be already in each location.

There is scope for the NZTA to improve its guidance on:

- the treatment of aggregating a transport model's area zones so that different appraisers are likely to estimate benefits for the same project that are broadly consistent and appropriate
- the treatment of agglomeration benefits of transport schemes that induce changes to employment in each modelled area.

### 3.3.3 Imperfect competition

When industries price their goods and services at more than it costs them at the margin, then there is said to be a 'price-cost margin' (Kernohan and Rognlien 2011). There are benefits from cost reductions that accrue to the owners of firms that are not reflected in transport demand, and hence are additional to transport user benefits. Kernohan and Rognlien estimate that this wider benefit is equal to an additional 10% over and above benefits to businesses (ie relating to work-based travel purposes).<sup>7</sup>

The wider benefit is premised on there being more goods and services traded in the economy because of the transport scheme. However, in the first instance this should imply more travel (which is only applied to some appraisals) and more journeys in particular (which has not been applied to any New Zealand appraisals that we are aware of). Thus it immediately raises some internal consistency issues.

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<sup>7</sup> Specifically they estimate it to be 10.7%, but this appears spuriously accurate and should be rounded down to an approximate 10%. A key parameter they used was 20% for the 'price cost margin', but from the 'whole economy' line in their figure 8.2 the long-term average across business cycles appears closer to 15%.

### 3.3.4 Increased labour supply

This WEB corrects for a tax distortion arising from observing, or modelling, people's behaviour. It is not the increased GDP that results from an increased labour supply that is the missing benefit; rather it is that people respond to their net wages, and so the willingness to pay for the induced travel excludes the tax component that is a benefit to society overall. Thus as marginal social benefit exceeds marginal private benefit there are potentially additional benefits that are omitted from conventional appraisals.

The method of the DfT (2010a) WebTAG 2.8 and DfT (2005) and of Kernohan and Rognlien (2011) involves a) estimating the increased labour supply caused by the reduced commuting costs (as it increases the effective wage), b) multiplying by the increased gross wages, and c) estimating the taxable component of the wages.

This procedure may overstate the benefits of increased participation because the procedure makes a separate account for induced travel. The procedure fails to include the congestion costs, crash risk and environmental impacts imposed on others that will result from their travel to work (Simmonds and Feldman 2009). These increased costs need to be included and they may also suppress the labour supply effect.

The claim by Kernohan and Rognlien (2011) that the conventional benefits capture the direct effects of more employment is an optimistic view of prevailing transport appraisal techniques. Generally transport models do not allow for induced trip generation in the travel to work segment<sup>8</sup> (as that would imply an increase in jobs in one or more zones); most are constrained so that the number of trips to work is directly proportional to the input number of jobs (Simmonds and Feldman 2009). Assuming more jobs in a location constitutes a 'land use change', which is ruled out of conventional appraisal conventions.

### 3.3.5 Move to more/less productive jobs

The comments made directly above for the increased labour supply WEB applies here too, but we would add that DfT's (2009) WebTAG 3.5.14C guidance requires the use of a LUTI model to forecast the employment and residential relocation consequences of the scheme. These are land use changes that, contrary to what Kernohan and Rognlien (2011) say on page 67, are not captured in standard appraisal techniques.

#### Economic impact assessment

An issue typically of interest to policymakers is how infrastructure investment ultimately impacts on growth, jobs and household income. The approaches considered here to answering this question are 1) input-output (IO) analysis; 2) computable general equilibrium (CGE) analysis; 3) macroeconometric analysis; and 4) inferring effects from conventional appraisals.

### 3.3.6 IO analysis

Wallis (2009) describes the key features of IO analysis, which is sometimes also referred to as 'multiplier analysis'. The main problem with IO analysis is that it can substantially overestimate the economic impact of schemes because it ignores resource constraints and thus price changes in the economy. However, IO analysis may be useful for regional impact analysis when the effects are so minor as to not change prices in the wider economy.

CGE modelling is more credible as it accounts for scarce resources across the economy.

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<sup>8</sup> Notwithstanding the fact that induced trip generation is rare for trips of any purpose.

### 3.3.7 Computable general equilibrium (CGE) modelling

*CGE models markets across an entire economy, and can account for welfare*

CGE models are a class of economic models that use empirical data to estimate how an economy might react to changes in policy, technology or other external factors. They cover the overall economy and distinguish a number of sectors, commodities, primary factors, international trade and perhaps types of households. They build upon IO tables to account for price changes from resource constraints.

As well as reporting on macroeconomic variables such as GDP and employment etc, CGE models can produce a range of welfare measures such as equivalent and compensating variations (monetary measures of the impact a scheme has on people's utility). CGE is advantageous to CBA when it is important to describe the economic impacts and how they are distributed across industry sectors etc.

*CGE analysis will in principle differ from CBA (for the type of effects both seek to capture) only if there are complications in the wider economy that CBA is insufficient to account for*

Non-market impacts aside (such as leisure travel time savings), if all markets in the economy priced at marginal social cost, and if everyone had standing in the welfare appraisal, then CBA and CGE would not be expected to result in materially different *welfare* impacts<sup>9</sup> in each year of the appraisal. In cases where this is judged appropriate then CBA methodologies are a more cost-effective way to appraise the net-benefits of schemes. CBA is arguably more suitable for non-market effects.

However there is scope to consider CGE modelling for welfare appraisals when it may be inappropriate to assume such simplified and idealised conditions hold. As Layman (2004) discusses, CGE can complement rather than substitute for CBA. Some of the conditions where this can occur are described below.

*CGE models come in various forms*

CGE models can be either 'static' or 'dynamic' where the former represents long-run steady state effects of policies whereas the latter models the adjustment paths an economy takes between different states. Dynamic models have the advantage that the mechanisms that give rise to capital accumulation that subsequently affect GDP are made explicit and there is no implicit double-counting.<sup>10</sup>

They can be national models or spatial (SCGE, see Gunn 2004), where the latter can explicitly model at a regional level. (It is data availability, rather than modelling technology, that limits the ability to build SCGE models.)

*CGE models can represent economies of scale (both fixed and variable inputs to production)*

It is recognised (eg the EEM volume 1, p2-6) that economies of scale can lead to benefits additional to standard approaches. CGE modelling can offer a way to estimate these across the wider economy for various scenarios. Bröcker and Mercenier (2010) estimate that, using CGE, benefits and costs are some 40% higher. This would not affect benefit-cost ratios (BCRs) unless different multipliers applied in different situations, but it would affect net present values.

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<sup>9</sup> Welfare impacts can be measures of compensating (or equivalent) variation, or possibly consumption.

<sup>10</sup> For example, Dixon (2009) reviewed the Australian Productivity Commission's (2008) modelling of a seemingly small reduction in assistance to the Australian Automotive industry (a cut in tariffs from 10% to 5% and elimination of a support scheme), which was estimated to generate an annual welfare benefit of about A\$500 million. Dixon noted that most of the benefits the Commission identified rested on what he called an implicit 'manna-from-heaven' assumption, whereby how the extra capital that generated the extra income came into existence in the lead up to the year modelled was ignored. Dixon corrected this and found the annual benefits ranged between -A\$92 million and A\$66 million.



*CGE may be better than CBA when benefits cross a national boundary*

CBA ignores how effects ripple through perfectly competitive secondary markets on the basis that all wider gainers and losers have standing in the welfare appraisal. BTRE (1999, p107) notes that when only national interests count, and when infrastructure schemes substantially affect export-earning industries (such as seaports or airports), then CGE applications may provide superior insights to a standard CBA by restricting standing.

*CGE can model the effects of public interventions on wider private investment behaviour to support a more appropriate social discount rate policy*

One reason why New Zealand uses an 8% (real) discount rate is because of concern that public investment forgoes private sector investment, which is judged to return 8% (Treasury 2008). NZIER (2011a and 2011b) suggests that if this was a real and valid concern then under the 'shadow price of capital' framework CGE modelling could be used to assess the wider effects from displacing and augmenting private sector investment. Simulations could establish 'rules of thumb' for routine simple CBAs to account for these 'wider economic investment effects' and to remove obstacles preventing a 'social rate of time preference' discount rate to be used. NZIER (2011a) suggests this may be in the vicinity of 3% to 4% real.

*CGE modelling is limited by the availability of quality data, by the proficiency of the modeller and their communication skills, and by the scale of impact of schemes*

CGE modelling is 'database dependent'; the accuracy of CGE modelling results is highly dependent on the quality and suitability of the initial database. The better the data, the better the model.

Criticisms are sometimes made that CGE models are 'black boxes'. However there are well accepted methods to understand and communicate what is happening within the model.<sup>11</sup> As such, any allegations of a lack of transparency should usually be levelled at the modellers rather than at the models.

Another criticism is that CGE models only consider the market economy. CGE models can be generalised to account for non-market impacts, such as un-priced environmental externalities. This is common for application to climate change policy analysis. Transport-oriented CGEs can even take externalities like noise, accident risks and air pollution into account (Bröcker and Mercenier 2010).

CGE modelling is also better suited to schemes that would have a material impact on the national (or in the case of SCGE models regional) economic activity.

*CGE is, and can be, used to support transport appraisals in a variety of ways*

Spatial CGE models exist in Europe, and have been used to appraise the Trans-European Rail Networks (eg Vickerman 2008 and Bröcker et al 2004). The transport aspects are imbedded in the model in a rather aggregated fashion (the treatment of network congestion is particularly broad-brushed). The relevance to New Zealand is limited by scale.

SCGE modelling could play a major role in improving the ability for LUTI models to account for inducing changes in economic activity and in turn inducing more demand for transport. As described by Parker (2012) and NZIER and PwC (2010), the Auckland LUTI model regards economic activity as exogenous, and there is scope to have a LUTI interact with a SCGE model (were one developed) to improve this.

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<sup>11</sup> CGE results are ideally presented with the aid of 'back of the envelope' (BOTE) modelling (a set of equations and parameters that govern the macroeconomy). Giesecke and Schilling (2010) used a BOTE model as an effective way to explain the intuition and qualitative results and workings of a CGE modelling exercise on the effects of New Zealand's 2009 fiscal stimulus package.

CGE modelling is sometimes used to expand the standard transport CBA results (such as was done for the roads of national significance (RoNS), see SAHA 2010). NZIER (2011a) describes such an approach as risky, as it raises more questions than answers. It is better to incorporate CGE modelling into the primary transport modelling analysis.

### 3.3.8 Macroeconometric analysis

BTRE (1999) notes that macroeconometric analysis produces broad generalisations about economic relationships by applying the statistical tools of econometrics to highly aggregated data. One area of application is the estimation of a national 'production function', in which the quantity of output depends on quantities of inputs.

*Aschauer (1989) led the way with his striking findings for the US: for 1991, they imply that an additional \$1 billion of infrastructure in place would have boosted private sector output in that year by \$940 million or more. Such a large estimate of returns is remarkable, particularly as it relates only to private sector output... Aschauer suggested that 'this could conceivably be due to deficiencies in the cost-benefit methods which tend to understate the true return to public capital accumulation'. (BTRE 1999, p183)*

JTRC (2007) notes that while this (what it calls) macroscopic literature addresses the issue of whether public investment crowds out private initiatives (which was the purpose of Aschauer's work), 'it is not of direct relevance to project appraisal' (p13), a view echoed by Vickerman (2008). Lakshmanan (2010) notes that these macroeconometric models are of a 'black box' variety, whereby 'we have little inkling about the causal mechanisms and processes which translate infrastructure improvements into output and productivity enhancements'.

BTRE (1999, pp184–185) concludes that the macroeconometric findings vary too much to suggest anything about the adequacy of CBA, and that there is no role for macroeconometric approaches for project appraisal.

### 3.3.9 Inferring GDP impacts from a CBA methodology

Although some CBA theorists casually claim that work-based travel benefits in a CBA generally relate to an equal increase in GDP (eg DfT 2005, p4), CBA outputs have little to do with GDP. CBA methodologies generally do not need to, and indeed do not make any attempt to, estimate how indirect effects eventually manifest themselves throughout a largely distortion-free economy, such as increased private sector investment, and increased international trade among industry sectors. It is debatable whether it is even a reasonable first approximation to estimate work-based travel benefits, freight benefits and agglomeration benefits as GDP impacts.

If decision makers need to understand the impact on macroeconomic variables such as GDP, then modelling via CGE is advised, and CBA results are unlikely to suffice.

### Conclusions and recommendations

The conclusions and recommendations for the three areas considered in this chapter are:

- 1 Current best practice CBA of transport strategies does not allow for induced land use change (population, economic activity and locations), even though this can be a dominant effect of some schemes in the long term. This omission occurs not because it ought to in principle, but because insufficient effort has been made to establish methodologies to model and account for it.

*It is recommended that New Zealand authorities (led by the NZTA) appropriately resource and target effort towards research to develop and improve (pre-)appraisal methodologies. This shortcoming of standard methodologies (in the context of major transport strategies) should be more proactively publicised to wider stakeholders. Even in the continued absence of accepted CBA methodologies to appraise induced land use changes, it should be more routine for major projects to model what the consequences are (ie forecasting, as distinct from appraisal) of these induced effects by using, say, LUTI modelling (even if benefits cannot yet be determined).*

- 2 The developments in WEBs are grounded in CBA theory. Although much progress has been made in the last decade, there is still scope to refine and improve the procedures and the conventions used in practice. The assumptions implicit in the imperfect competition and labour supply WEBs regarding induced travel can be quite inconsistent with the traditional user benefits and transport modelling, and risk overestimating project benefits, all else being equal. For the agglomeration WEB procedure there is scope to improve the consistency of application to transport model outputs, and to develop more refined guidance on how to account for induced land use change.

*In the New Zealand context it is recommended that greater facilitation is made for project sponsors, CBA practitioners and theorists to pool together their experiences, thoughts and issues on the development and application of WEBs. An NZTA-endorsed internet-based community may be appropriate (or something of the sort). Where appropriate, the NZTA should issue supplementary guidance on how to estimate WEBs.*

- 3 CGE is the leading method to pre-appraise project/programme impacts on national economic output for schemes of significant scale to a region (or nationally). In summary, CGE modelling may be particularly well suited to the following areas and issues:
  - a forecasting changes to macroeconomic variables, such as GDP and employment
  - b assessing welfare measures such as consumption and compensating/equivalent variation
  - c complementing LUTI modelling to help estimate the induced demand caused by firms being more productive and dependent on transport for both inputs and outputs
  - d accounting for the 'wider economic investment effects' of project resourcing, and providing 'rules of thumb' for routine CBAs so that a more reasonable (ie lower) discount rate can be used
  - e disaggregating benefits regionally and socially, depending on the nature of the CGE model (particularly whether it is a SCGE model)
  - f assessing the additional impacts from economies of scale from fixed factors of production across the economy
  - g restricting standing to New Zealanders when the effects of initiatives may cross national boundaries.

*It is recommended that the case is carefully considered to develop a SCGE (regional CGE) model capable of interacting with LUTI models (such as Auckland's) to assess the impacts on transport demand in the short, medium and long term.*

## 4 Social, environmental, health and safety effects

### 4.1 Introduction

Social, environmental, health and safety effects are important and need to be considered alongside the economic and traffic benefits underpinning most road schemes.

Social, environmental, health and safety effects represent broad-ranging and inter-connected topic areas. The precise boundaries between these and other topics, for example induced traffic effects and their associated environmental consequences, are often hard to define.

This review is part of the overall research literature and practice review which includes travel behaviour (chapter 2) and economic (chapter 3) topics.

The purpose of this review is to:

- provide an outline review of transport-related social, environmental, health and safety issues
- underline the need to consider a balanced range of factors when assessing the implications of road investments
- highlight specific aspects from the review that are particularly relevant to current New Zealand practice.

This review considers recent approaches to assessing road scheme effects in terms of the following factors:

- social: distributional effects and severance
- environment: air pollution, greenhouse gas emissions and noise
- health: active modes and disturbance
- safety: road crashes and perceived safety.

The above factors have been selected in order to cover an illustrative cross-section of social, environmental, health and safety issues. This review does not therefore represent a complete and in-depth study of all potential effects.

The scope of this review covers a selection of published literature (international and New Zealand) and current New Zealand practice.

The review considers the localised effects of road schemes, together with associated wider network impacts. It is primarily focused on the on-going operational effects (ie rather than construction effects) of road schemes, ideally confirmed by quantified pre- and post-implementation monitoring.

The review describes the following:

- 1 New Zealand monitoring related to the social, environmental, health and safety effects of the overall road network or wider transport system
- 2 Monitoring work in New Zealand specifically to assess the social, environmental, health and safety effects of road projects
- 3 New Zealand monitoring/post-evaluation evidence (drawing on 1) and 2) above) regarding the social, environmental, health and safety effects of road projects
- 4 International evidence on the social, environmental, health and safety effects of road projects.

- 5 What needs to be done in New Zealand to provide better monitoring of the social, environmental, health and safety effects of road projects?

The NZTA Transport Investment Online ([www.nzta.govt.nz](http://www.nzta.govt.nz)) specifies the type of assessment required for current funding application purposes ([www.pikb.co.nz/assessment-framework](http://www.pikb.co.nz/assessment-framework)), which is based on the three factors of strategic fit, effectiveness and efficiency:

- The strategic fit assessment is undertaken on the basis of the priorities outlined in the GPS.
- The effectiveness factor considers the contribution that the proposed solution makes to achieve the potential outcomes identified in the strategic fit assessment. Higher ratings are provided for those proposals that provide long-term, integrated and enduring solutions. Effectiveness is weighted lower than strategic fit but higher than efficiency in the assessment profile.
- The efficiency factor is mainly based on CBA as defined in the EEM and specified ranges of BCR (low <2, medium 2 to 4, high >4).

More detailed assessment, forecasting and monitoring methodologies are emerging for very large New Zealand road investments through the RoNS process. This work is well resourced and represents best current New Zealand practice in terms of assessing, forecasting and monitoring the implications of road investments.

Although this research has not specifically addressed this scale of investment, the RoNS assessment and monitoring framework is termed an 'enhanced' post-implementation review (ePIR) and is likely to influence the way 'standard' PIRs are undertaken in the future for non-RoNS investments.

## 4.2 Findings by topic area

### 4.2.1 Overview

There is considerable scope for further research and the adoption of better analytical, forecasting and monitoring methodologies across a range of topics in order to more fully assess the effects of road projects.

The review recommends more comprehensive pre- and post-implementation analysis and monitoring on the basis of the significance of topics, based on the location, project type and circumstances involved in each particular case.

Findings for each of the topics reviewed are described below:

The effects of New Zealand road projects are currently monitored (post-opening) in terms of i) complying with Resource Management Act 1991 (RMA) conditions and ii) performance against forecast BCRs through the PIR process. Both of these are useful but to identify the full range of significant road project related effects a more comprehensive approach to assessment is needed.

There is a lack of quantified pre-implementation assessments for a number of possible effects, especially in social and health topic areas.

However, this is not an argument to introduce comprehensive and standardised pre- and post-implementation monitoring frameworks for all road projects, as this would be unnecessary and wasteful in resource terms.

Instead, it is suggested that 'core' pre and post-implementation monitoring and analysis is undertaken for all road projects (say to cover travel time, traffic volume, heavy commercial vehicle (HCV) composition and safety), with additional monitoring and analysis undertaken for larger projects on a bespoke basis, focusing on specific issues identified by stakeholders. In some cases, for example to estimate changes in greenhouse gas (GHG) levels, predictive modelling rather than actual measurement of conditions will be required.

It is also possible that in some cases a very wide range of potential effects should be considered, for example, in the case of a major new road project being constructed in the centre of an urban area. However, such cases are expected to be rare and it is more likely that additional monitoring would typically only be required for (say) two or three additional issues for any particular road project.

Table 4.1 presents a summary, for each of the nine factors reviewed, of our findings on the following aspects:

- nature and extent of any network-wide monitoring of the impacts of the (existing) New Zealand land transport system
- New Zealand monitoring procedures and practices at the project level, both prior to implementation (pre-construction) and subsequent to implementation (post-opening)
- summary of evidence on impacts of road projects/programmes in New Zealand
- overview of relevant international evidence on each topic area
- conclusions on improvements needed to monitoring/evaluation procedures and practices in the New Zealand roading sector.

The following sub-sections summarise our findings in relation to each of the sub-topic areas.

#### 4.2.2 Distributional effects

Distributional effects, including changes in mobility, accessibility, costs and environmental conditions, especially for identified sub-population groups, such as vulnerable users (including those with travel difficulties and those on low incomes), are often important factors in the assessment of road projects. Distributional effects include relative changes in access to employment or essential services, and are sometimes referred to as 'social exclusion' effects.

Where distributional effects are likely to be significant, for example for very large road projects such as major corridor improvements, quantified surveys and associated analysis are required. However, currently little or no quantification of post-implementation distributional effects is undertaken in New Zealand.

#### 4.2.3 Severance

The interaction within and between local communities often needs to be quantified in the assessment of road project impacts, particularly in terms of the potential severance (or the prevention or deterrence of local trip making) and the consequent changes to the strength of existing community connections.

Bypass type road projects often reduce severance effects in some areas and introduce them in others. On-line upgrades may increase the level of actual and perceived severance effects.

It is important to consider localised effects and also any wider community effects. Severance effects are particularly significant on vulnerable groups, such as the young, elderly and mobility impaired.

Severance can be estimated by analysing changes in local travel times, route availability, and convenience with special reference to identified groups. Such estimates are required when significant severance issues are anticipated, particularly in residential areas and also in situations where rural network connectivity is reduced.

Currently little or no quantification of pre- and post-implementation severance levels is undertaken in New Zealand.

#### 4.2.4 Air pollution

The literature reviewed indicates that the effect of road investment can result in short-term reductions in air pollution, although this improvement tends to be counteracted by 'induced traffic'. It is therefore important that the estimation of air pollution (generally at the local level) takes account of all types of induced traffic effects, including diverted, retimed, mode change, land use change and completely new trips, that may occur.

In the longer term, if higher capacity is introduced and continued traffic growth leads to a return to congested conditions, this may result in higher air pollution levels.

Air pollution levels can be derived either directly through measurement or indirectly by modelling and calculated estimation.

Currently, the quantification of pre and post-implementation air pollution levels in New Zealand is undertaken through estimation rather than measurement in most cases.

#### 4.2.5 GHG emissions

In general, road investments that induce additional traffic demand are likely to lead to increased GHG emissions. Often there is likely to be a reduction in localised congestion even if the amount of traffic increases.

In the longer term, despite forecast improvements in vehicle technology, overall GHG emissions are unlikely to be reduced as traffic levels rise, in part due to the provision of significant new road capacity. However, to put this in context, changes in GHG emissions due to the effect of road projects are likely to be relatively marginal compared with the overall changes in system-wide GHG emissions.

The control of transport-related GHGs is only likely to be possible if traffic growth is reduced or reversed, due to demand management measures (such as pricing or rationing) or changes in external circumstances (such as higher fuel costs) which might significantly reduce the fuel consumption of the transport sector.

Currently, the estimation of pre and post-implementation GHG levels in New Zealand is undertaken on the basis of calculated fuel use.

#### 4.2.6 Noise

Noise is a relatively well researched area and is commonly monitored and considered in detail as part of the planning and assessment of road projects. There are well established predictive models that estimate the noise impact of road projects and calculate the potential effects from alternative mitigation measures.

However, road project noise assessment in New Zealand focuses solely on the current standard (NZS 6806) and needs to be more comprehensively considered, particularly in terms of 'peak noise incidents' resulting in disturbance.

The effect of significant noise increases in important 'tranquil areas' is also not considered in current noise assessment practice.

Noise monitoring of post-implementation conditions through measurement is reasonably straightforward; however, more post-implementation monitoring of actual conditions to confirm the accuracy of forecasts is needed.

In addition to 24-hour average noise levels, night time and peak noise levels should also be monitored.

Currently, the quantification of pre and post-implementation noise levels in New Zealand is undertaken through estimation rather than measurement in most cases.

#### 4.2.7 Active mode use

Changes in active mode use, especially walking, cycling, and the effect of PT in encouraging increased walking and cycling activity to access PT services, are important when assessing the health effects of road projects.

Monitoring of post-implementation active mode use through counts and surveys is reasonably straightforward; however, little pre and post-implementation monitoring is currently undertaken in New Zealand.

#### 4.2.8 Disturbance

Disturbance has a variety of causes (including noise, vibration and fumes) and is an important health issue with links to a number of negative health outcomes.

The extent of disturbance associated with a road project is not sufficiently addressed through the consideration of compliance with current noise standards, and can only be determined by comparing pre- and post-implementation monitoring surveys.

It is important to consider localised disturbance effects and any associated effects on the wider community.

Currently, very little, if any, pre and post-implementation quantification of disturbance levels is undertaken in New Zealand.

#### 4.2.9 Road crashes

As might be expected, in most cases, new road investments have been found to improve safety. However, it cannot be assumed that all new roads will automatically lead to substantial improvements in safety or that all potential safety benefits will be captured. Both of these aspirations are frequently unrealised in practice.

Safety needs to be considered comprehensively, through considering past crashes and any forecast changes in speed, traffic composition and volumes.

It is important to avoid the use of over-simplified assumptions or the use of 'default rates' when forecasting future conditions.

Specific measures are likely to be needed in order to 'lock-in' potential safety benefits and 'bespoke' solutions are required.

Quantified pre and post-implementation safety information is comprehensively available in New Zealand.

#### 4.2.10 Perceived safety

Perceived safety is an important influence on travel behaviour and the actual road safety record associated with a particular network or travel mode is not necessarily a good indicator of whether or not they are perceived as being safe.

When assessing levels of perceived safety it is important to establish the context and to assess both the actual and the perceived degree of risk involved. Particular issues are likely to arise when planning for more vulnerable users.

It is important to consider perceived safety aspects of new designs together with any associated wider network perceptions associated with changes in conditions elsewhere.

The extent of perceived safety is not sufficiently addressed through the consideration of actual road crashes, and can only be determined by comparing pre- and post-implementation monitoring surveys.

No pre- and post-implementation quantification of perceived safety levels is currently undertaken in New Zealand.



**Table 4.1 Summary of findings on New Zealand monitoring procedures and project impacts**

Topic	Sub-topic	New Zealand monitoring – network-wide effects	New Zealand monitoring – project based a) pre-implementation	New Zealand monitoring – project based b) post-implementation	Summary of New Zealand impacts	Additional international evidence	Summary of monitoring improvements needed in New Zealand
<b>Social</b>	<b>Distribut- ional effects</b>	None identified.	Requirement to consider transport disadvantaged but no quantified assessment identified.	No post-implementation monitoring identified.	No reliable quantified information identified.	Distributional effects (eg impacts on particular areas, identified groups and vulnerable users) are considered in some countries when assessing the differential impacts of projects.	Pre- and post-implementation monitoring is needed in locations, circumstances and project types where distributional effects are likely to be significant. The incorporation of suitable techniques into social impact assessment (SIA) and PIR methodologies and monitoring requirements is also required.
	<b>Severance</b>	None identified.	Requirement to consider but unquantified and superficially addressed.	No post-implementation monitoring identified.	No reliable quantified information identified.	Quantifying actual and perceived changes to interactions within and between local communities is important in assessing the severance impacts of road project impacts, and is undertaken in several countries, (eg UK, Denmark and Sweden).	Pre- and post-implementation monitoring is needed in locations, circumstances and project types where severance is a significant issue. Information from the literature would allow standardised and relatively simple techniques to be adopted. This need not embrace all aspects of severance but would provide useful quantification. Incorporation of severance into SIA and PIR methodologies is also required.
<b>Environ- ment</b>	<b>Air pollution</b>	Monitoring is undertaken regionally and collated for national reporting purposes.	Pre-implementation monitoring or measurement rarely undertaken.	Post-implementation monitoring rarely undertaken.	Little reliable quantified information identified.	Road projects may reduce air pollution in the short term, but this is often counteracted due to the effects of induced traffic growth.	Air pollution measurement and monitoring techniques are well established, but these are not usually undertaken for individual road projects. More specific monitoring of major projects when air quality is expected to be significant is needed. Environmental assessments, health impact assessments and PIRs could all make use of project specific pre- and post-implementation monitoring data.

Topic	Sub-topic	New Zealand monitoring – network-wide effects	New Zealand monitoring – project based a) pre-implementation	New Zealand monitoring – project based b) post-implementation	Summary of New Zealand impacts	Additional international evidence	Summary of monitoring improvements needed in New Zealand
	<b>Green-house gases (GHG)</b>	Fuel use monitoring is undertaken at a national/ regional level.	Pre-implementation calculated estimates based on fuel use.	No post-implementation monitoring identified.	No reliable quantified information identified.	Transport-related GHGs are forecast to increase in the absence of demand management measures. Road projects have relatively small impacts on overall GHG trends.	Calculated GHG pre-implementation estimates are often produced based on estimated fuel consumption. Post-implementation estimates of fuel use and GHG emissions are required where GHGs are expected to be significant issue. These estimates need to be incorporated into EA monitoring and PIR methodologies.
	<b>Noise</b>	No systematic noise monitoring is undertaken.	Pre-implementation measurements and estimates are undertaken for very large projects.	Post-implementation measurements or estimates are rarely undertaken.	Little quantified information identified.	Studies indicate the effect of road projects on noise are mixed, with noise relief on the relieved parts of the network and increased noise where traffic increases occur.	Specific pre- and post-implementation monitoring and associated surveys are needed in locations, circumstances and project types where noise is likely to be a significant issue. In addition to 24hr average noise levels, night time and peak noise levels need to be monitored for EAs and PIR purposes.
<b>Health</b>	<b>Active modes</b>	National trend data is collected, indicating increases in PT and decline in walking and cycling.	Pre-implementation measurements or estimates are rarely undertaken	No post-implementation monitoring identified.	No reliable quantified information identified.	It is important to consider the effect of road projects on active mode use in quantified terms.	Pre- and post-implementation monitoring of active mode use is needed in selected cases. The effect of road projects on active modes, especially walking, cycling, and PT, is potentially significant for health impact assessments.
	<b>Disturbance</b>	None identified.	No pre-implementation monitoring identified.	No post-implementation monitoring identified.	No reliable quantified information identified.	More rigorous international research into transport related health impacts is underway, lead by the health sector, developing techniques with potential for use in HIAs and PIRs.	Pre- and post-implementation monitoring of disturbance effects is needed in selected cases. This would provide a quantified basis for EAs, SIAs and PIRs in locations, circumstances and project types where the potential for significant disturbance exists.

Topic	Sub-topic	New Zealand monitoring – network-wide effects	New Zealand monitoring – project based a) pre-implementation	New Zealand monitoring – project based b) post-implementation	Summary of New Zealand impacts	Additional international evidence	Summary of monitoring improvements needed in New Zealand
Safety	Road crashes	Comprehensive safety monitoring and reporting is undertaken (using the crash analysis system)	Pre-implementation analysis is usually undertaken.	Post-implementation reviews are undertaken only for a sample of smaller projects.	Overall safety benefits but potential not being fully captured.	Comprehensive assessments of safety are required taking account of future speed and volume changes. Importance of avoiding simplistic assumptions when considering network effects.	Post-implementation monitoring and analysis of new road projects is needed. Consistent, rigorous and standardised methodological approaches to multiple project and theme based analyses are also required (Appendix C5.2). More comprehensive network wide pre- and post-safety analysis is needed to supplement project related safety audits and to improve safety assessment and forecasting techniques.
	Perceived safety	Perception surveys are undertaken nationally and in some regions.	None identified.	None identified.	Sustainable modes are perceived as dangerous in New Zealand.	Injury rates (alone) are not sufficient to confirm system safety. Sustainable modes are perceived as dangerous in New Zealand but not in other countries, (eg Holland, Denmark, Germany).	Pre- and post-implementation monitoring of perceived safety effects is needed in selected cases. This would provide a quantified basis for consideration within SIAs and PIRs in locations, circumstances or project types where perceived safety is likely to be a significant issue.

## 4.3 Conclusions and recommendations

New Zealand has undertaken research into a number of topic areas, and has been able to apply some of this into current practice. However, there remain a number of research gaps and no comprehensive framework has been developed to analyse, forecast, assess and monitor the social, environmental, health and safety effects of road projects.

Some topics are currently analysed solely or primarily in qualitative terms, such as severance and health effects, and in these areas more supportive quantification and analysis is needed. Other aspects are currently not subject to any project-related analysis, forecasting or monitoring, for example distributional effects or perceived safety, despite the potential importance of these topics in particular circumstances.

A number of topic areas are currently subject to detailed pre-implementation assessment in New Zealand, including air quality, noise and safety, but these are rarely supported and verified by appropriate and quantified post-implementation monitoring and analysis.

The effects of road schemes in New Zealand are occasionally monitored in terms of the achievement of forecast BCR and compliance with the RMA. This approach is very limited and a more comprehensive approach is required in order to identify the full range of significant road scheme related effects.

There is considerable scope for the adoption of better analytical, forecasting and monitoring methodologies across a range of topics in order to more fully assess the effects of road schemes.

However, it is not recommended that fully comprehensive and standardised monitoring procedures be introduced across all road schemes: this is unnecessary and would also be wasteful in resource terms. Rather, it is suggested that pre- and post-implementation monitoring and analysis is undertaken of 'core topics' (say to cover travel time, traffic volume, HCV composition and safety) for all road schemes.

Additional monitoring and analysis is recommended to be undertaken for larger schemes on a bespoke basis, to address specific issues identified by stakeholders.

In some cases, for example to estimate post-implementation changes in GHG levels, predictive modelling rather than actual measurement of conditions will be required.

It is possible that in some cases a very wide range of potential effects should be considered, for example, in the case of a major new road scheme being constructed in a large urban centre. However, such cases are expected to be rare and it is more likely that additional monitoring would typically only be required for (say) two or three additional issues for any particular road scheme. An exception to this is represented by monitoring for larger projects such as the RoNS monitoring (see discussion in section 6.5).

A (selective) expansion of post-monitoring/evaluation effects should not be regarded as an end in itself (in the 'nice to know' category). It needs to be accompanied by a greater focus on systematic feedback from the monitoring findings to improve New Zealand practices in the planning, design and pre-appraisal of candidate road schemes.

One of the limitations in current post-implementation monitoring practice is the fact that often only short-term changes in conditions are analysed, typically one to five years after opening. Only rarely are longer-term changes monitored. More long-term monitoring would be desirable, for a sample of major projects, although we recognise the inherent difficulties with identifying longer-term effects.

The primary reason for recommending further research and increased post-implementation monitoring is to improve feedback to improve the planning and design of road projects in New Zealand.

There remain a number of research gaps, and no comprehensive framework has been developed to analyse, forecast and monitor the social, environmental, health and safety effects of road projects.

The conclusions and recommendations from this review of international and New Zealand literature and practice are summarised in table 4.2.

**Table 4.2 Social, environmental, health and safety effects: conclusions and recommendations**

Issue	Conclusions	Recommendations
<b>Quantification of effects</b>	This review found that New Zealand has undertaken research into a number of environmental topic areas, including air quality, noise and safety and these are now applied in current practice. However, these are rarely supported and verified by quantified pre- and post-implementation monitoring.	Specific and quantified pre- and post-implementation monitoring and analysis is recommended in all locations, project types and circumstances where project effects are expected to be significant.
<b>Core monitoring requirements</b>	The effects of a sample of smaller road schemes in New Zealand are currently monitored in limited terms	'Core' pre- and post-implementation monitoring and analysis is recommended to be undertaken for all road projects, to cover: travel time, traffic volume, HCV composition and safety.
<b>Additional monitoring requirements</b>	A comprehensive approach to appraisal and review is required in order to identify the full range of significant road scheme related effects. Current approaches in New Zealand are often limited to BCR or RMA consent conditions. Some potentially significant effects are either omitted or unquantified in current practice	Additional monitoring and analysis is recommended to be undertaken for larger projects on a bespoke basis focussing on all potentially significant impacts, including specific issues identified by stakeholders. Additional issues considered should be determined by particular circumstances, but could include: severance, air pollution, GHG emissions, noise, active modes, disturbance and perceived safety.
<b>Multi-project and longer-term effects</b>	Consideration of individual project effects in current New Zealand practice is not sufficient to identify wider effects.	In addition to individual project monitoring, multi-project and longer term monitoring and associated analysis is also recommended to establish trends, patterns and overall performance of road project investment.

## 5 International post-implementation procedures and practices

### 5.1 Introduction

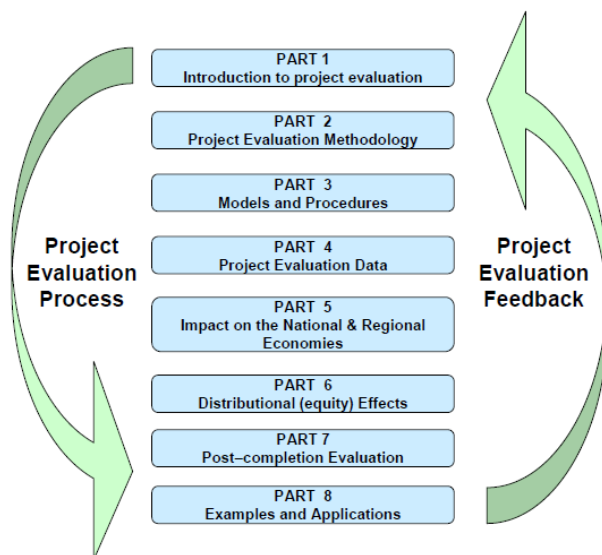
This chapter provides a summary of post-implementation review procedures for road projects in four countries, namely: Australia, England, Norway and France.

### 5.2 Australia

A process is recommended at the federal level (Austroads), but this is optional for authorities who are encouraged to develop their own policies for the 'post completion review' (PCR) of projects.

The Austroads guidelines (Tsolakis et al 2005) describe the PCR as the final step in a project evaluation process, acting as a feedback mechanism by 'closing the loop' of the process, as illustrated in figure 5.1.

**Figure 5.1** Austroads project evaluation process



**Source:** Tsolakis et al 2005

PCRs are intended to provide information on:

- how effectively the stated objectives (purpose) of the project were met
- how effective the project evaluation methods were in selecting a particular project option to meet the stated objectives
- how efficient the project implementation process was, including comparison between planned and actual actions, costs and resource use.

The guidelines suggest that an overall stratified random sample is selected for PCRs, to represent around 10% of total investment value. Large projects over (approximately) NZ\$10m and other particular cases, such as exceptionally good, poor, strategic or long-term projects, are also recommended for consideration for a PCR.

However, the general and advisory nature of the PCR guidelines may be one reason why few examples are available of how this process has been applied.

## 5.3 England

'Post opening project evaluations' (POPEs) are mandatory at one and five years after opening for all Highways Agency 'major' trunk road projects with a value of over NZ\$20m (Highways Agency 2009; Highways Agency website<sup>12</sup>).

POPEs are also undertaken down to a project value of (approximately) NZ\$50,000 when sufficient information is available, although individual written reports are only undertaken for 'large' local network management schemes with a value of between NZ\$2m and NZ\$20m.

The scope of POPEs for major projects is limited to traffic volumes, travel times, accidents and emissions (for economic evaluation purposes). The written reporting for each project contains the original appraisal summary table and the post-implementation, more restricted post-opening evaluation summary table (see table 5.1).

The overall results from the POPE process are summarised in terms of the five objectives for transport and are comprehensively reported, for example: 'Forecasting of economic benefits (of major projects) is generally not accurate (only 38% of schemes have predicted time benefits and 29% of schemes have predicted accident benefits within 15% of the outturn' (Highways Agency 2009). 'For 24% of small local network management schemes (LNMS), outturn benefits were within 50% of the predicted benefits. The appraisal of benefits is more accurate for the larger schemes with 61% of large LNMS within 50% of the predicted benefits' (Highways Agency 2009).

A review (Oxera 2005) of the POPE system made seven recommendations:

- 1 Retain and enhance the POPE system.
- 2 Widen the scope of issues considered.
- 3 Oversee by national board (including Highways Agency and DfT).
- 4 Tailor individual evaluation plans in discussion with stakeholders.
- 5 Build the costs of post-evaluation into core project costs.
- 6 Make a toolkit of techniques available to evaluators.
- 7 Take a more active and tailored approach to information and findings dissemination.

The response by the Highways Agency to the recommendations was outlined as follows, based on advice from the agency (pers comm, August 2011):

*You specifically asked what changed as a result of the Oxera report ... I think the simplest thing is to set out how we have addressed each of the recommendations in the report:*

- 1 *The POPE framework should be retained, but enhanced. This particularly refers to capturing pre-implementation data. The Highways Agency has retained the POPE framework and particularly the involvement of the POPE team at the 'before' construction stage to record baseline data. We have introduced a 'Scheme Evaluation Plan' which is drafted at this stage. This defines the scope of the evaluation and helps to*

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<sup>12</sup> [www.highways.gov.uk/roads/18348.aspx](http://www.highways.gov.uk/roads/18348.aspx) (Accessed April 2012)

Table 5.1 Example of post-opening evaluation summary table: English POPE methodology

Evaluation Summary Table (EST)		A46/A607 Junction Improvement Scheme					
Objective	Sub-Objective	Qualitative Impacts	Quantitative Measures				Assessment
ENVIRONMENT	Noise	Traffic has not increased by more than 10%					No impact
	Local Air Quality		AADT has increased by more than 700vpd				Slight Adverse
	Greenhouse Gases	Traffic has increased by more than 10% on some arms	Increase in traffic				Slight Adverse
	Landscape	Implementation of signals and gantries	N/A				Slight Adverse
	Townscape	Traffic decreased through Syston	N/A				Slight Beneficial
	Heritage of Historic Resources	No significant archaeological sites found	N/A				Neutral
	Biodiversity	Little impact on surrounding area	N/A				Minor Adverse to Neutral
	Water Environment	Any impact has been appropriately mitigated	N/A				Neutral
	Physical Fitness		Not assessed				No change
	Journey Ambience	Journey times improved, but accidents increased	N/A				Slight beneficial
SAFETY	Accidents		Accidents 12	Deaths 0	Serious 1	Slight 11	PVB £3,051,588
	Security		N/A				Neutral
ECONOMY	Public Accounts		Central Govnt PVC				PVC £3,125,990
	Business Users and Providers		Users:				PVB £9,891,844
	Consumer Users		NA				
	Reliability						
	Wider Economic Impacts						No
ACCESSIBILITY	Option Values		N/A				N/A
	Severance	No impact on non motorised users					Slight Beneficial
	Access to Trans System	No impact	N/A				N/A
INTEGRATION	Transport Interchange	No impact	N/A				N/A
	Land Use Policy	Development not dependant on scheme, and has been included in local plan					Slight Beneficial
	Other Government Policies	No impact on government policies					Neutral



*ensure that sufficient before information is captured to allow evaluation of the issues identified. At this stage we also inform the project team what information we will require (such as environmental statement documentation), so that it can be provided at this stage and reduce the risk of any documentation getting lost.*

- 2 *POPE should cover a wider range of issues, while allowing individual evaluations to be tailored to address key information needs. POPE now covers all of the NATA sub-objectives which are considered in the appraisal of a scheme. As you will see in the attached methodology (Highways Agency 2010), although every sub-objective is covered for every scheme, the level of detail varies by scheme. In the Scheme Evaluation Plan the amount of detail required on each sub-objective is decided having considered the objectives of the scheme in question and also any relevant issues raised at Public Inquiry (eg impact on landscape might be a key issue/concern for a particular scheme, but less of a concern on another scheme where the works are within the current highway boundary). This recommendation also noted areas where appraisal is less complete, in particular social impacts. POPE is mindful of this, and where appropriate (ie schemes with a quality of life, social exclusion objective or significant impact) a residents survey is carried out. This includes questions specifically on whether the settlement concerned is now a better place to live, if it has changed how they use and access local amenities etc. For schemes predicted to have significant impacts on local businesses, it is possible for a short survey of businesses to be undertaken and for schemes predicted to have significant impacts on pedestrians, equestrians and cyclists, it is possible for a non-motorised user survey to be undertaken.*
- 3 *POPE should be directed by a national programme board, with champions in the DfT and Highways Agency. Whilst a formal project board was not set up, the way POPE is managed has changed considerably. The Project Sponsor remains in our Traffic Appraisal Modelling and Economics Group to provide technical oversight and feedback into the appraisal guidance. There are focal points in Environment Group and Major Projects directorate to ensure that the needs of these internal customers are represented and I work closely with these colleagues on a day-to-day basis on POPE. The role of the Scheme Project Manager has been formalised, with their sign-off being required for the Scheme Evaluation Plan and the evaluation report. POPE is now part of the 'Project Control Framework (PCF)' for major projects, which sets out all the required processes over a scheme's lifecycle.....*
- 4 *Tailored evaluation plans for each scheme should be agreed through consultation with local stakeholders. As mentioned above, each scheme does now have a scheme evaluation plan. At this 'before' stage, the POPE consultant meets with the local authority. Other people are consulted at a later stage, in particular Statutory Environmental Bodies and Local and Parish Councils. Where appropriate other environmental stakeholders are included, eg National Trust, River Trusts, Wildlife Trusts where they are responsible for land impacted by the scheme. As noted above, consultation is sometimes extended to residents and businesses.*
- 5 *The DfT/HA should move from an annual evaluation budget-setting round to a situation where evaluation costs are built into scheme costs. POPE is now paid for by the Major Projects Directorate. This has been a very effective way of ensuring buy in from the scheme teams to POPE processes and results. For practical reasons, the costs are not allocated to individual scheme budgets. However, evaluation costs per scheme are*

*monitored. We have tried to avoid annual budget-setting, but have to also be mindful of the best procurement method. The current task is for 2 years; I hope that the next one will be for 4 years.*

- 6 *Guidelines are required on choosing from the menu of options in the toolkit and the options need to be tested on the ground. You will see in the attached methodology (Highways Agency, 2010) what options are available and when they are appropriate. The toolkit has been altered several times since it was first introduced as a result of it being tried out and refined.*
- 7 *The programme board should develop a more active and tailored approach to dissemination. Reports are routinely sent to: Scheme Project Managers; Area Teams (responsible for day to day running of the network); DfT ITEA; DfT Strategic Roads; English Heritage (other Statutory Environmental Bodies prefer just to receive meta reports); Environment Group; and Local Authorities. POPE feeds into the Major Project Directorate's 'Lessons Learnt' process and findings/recommendations are fed to specific teams as necessary.*

The recent change in English appraisal methodology, from the New Approach to Appraisal (NATA) to a more business case oriented approach has not affected the POPE process to date. The Highways Agency (pers comm, January 2012) has provided the following explanation:

*Our approach for POPE is to compare the outturn impacts against those predicted during scheme appraisal. As the NATA methodology was only updated in April 2011, it is too early for any open schemes to have been appraised using that methodology. Therefore, we haven't yet altered the POPE methodology to reflect the changes. In time, we will need to. However, it is worth bearing in mind that many of the changes to the AST (appraisal summary table) are in terms of how things are categorised rather than the underlying methods, so the impact on our methodologies might not be as large as it first appears.*

In further correspondence (pers comm, April 2012) the Highways Agency also confirmed:

*The Highways Agency spent approximately £1.1million on POPE activities last year (2011). All our major schemes are evaluated at both one and five years after opening. There is also a before study to collect/collate data needed for the evaluation. ... In general for LNMS (small schemes) we evaluate at one year after all the schemes with sufficient baseline information to do so. This year there was a budget restriction affecting the number of POPE LNMS studies we could do, therefore we made sure that the sample covered the range of scheme types. A LNMS (local network management scheme) can be put forward as a safety, economy, accessibility, environment or integration scheme. We haven't evaluated any multi-modal projects as the Highways Agency is only responsible for the trunk road network.*

## 5.4 Norway

In Norway (Kjerkreit and Odeck 2009) all large projects over (approximately) NZ\$45m in value are potential candidates for a detailed 'post evaluation of economic benefits and costs' (five years after opening). However, only (approximately) five in-depth studies are undertaken each year.

Projects develop over time. Typically, it takes about 5 to 10 years from the time the municipal master plans are made to the time the decision to build is made. Thus, 20 years may elapse from the start of the planning process to the time of post-opening evaluations (see figure 5.2).

Over this period, both the project definition and also the appraisal techniques used may change considerably. However, it is the calculations and forecast impacts presented to the decision makers before the go-ahead decision that are the focus of post-opening evaluations.

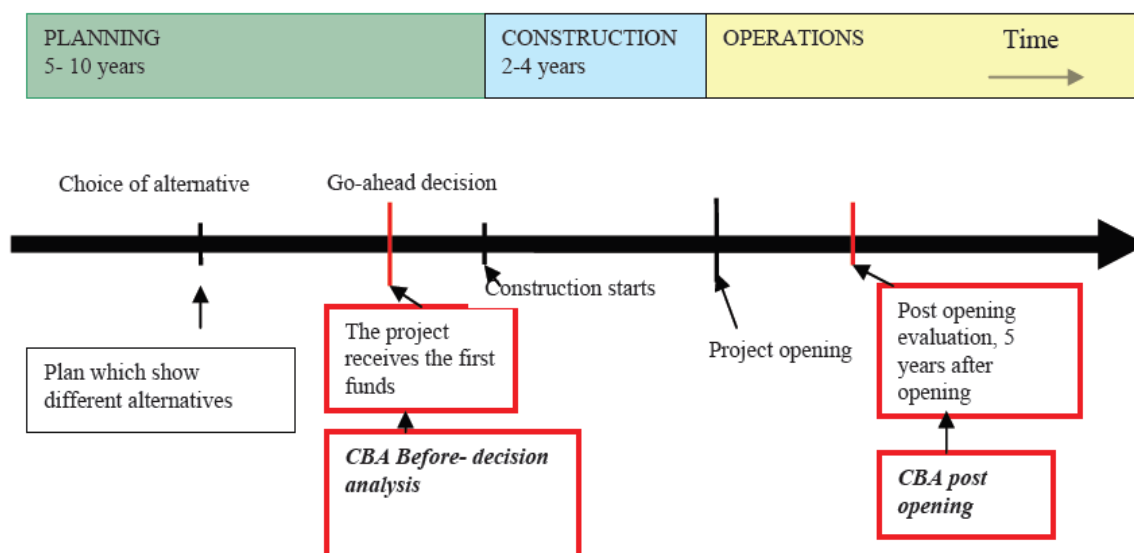
The factors taken into account in Norwegian evaluation are as follows:

- monetised impacts: travel time savings, community life effects, vehicle operating costs, natural environment, accident costs, visual landscape, induced traffic, outdoor recreation, inconvenience cost (ferry projects)
- non-monetised impacts (including): accessibility for cyclists, noise nuisance, local air pollution, road maintenance costs, residual value of capital, cost of public funds, road investment costs.

Kjerkreit found that 6 out of 11 projects examined (in a study of the effectiveness of the process) were forecast to have a negative NPV (meaning the value of benefits was expected to be less than costs). This indicates that monetised benefits were unlikely to be the main reason for building the projects.

In 9 out of 11 projects the outturn benefits were greater than that forecast and in 7 out of 11 outturn projects costs were greater than forecast. Only three projects had an outturn BCR greater than 1.0.

**Figure 5.2 Norwegian road project timeline**



Source: Kjerkreit 2009

## 5.5 France

All projects with a value of over NZ\$150m are subject to 'post evaluation' (PE). This is a process originally required by 1982 legislation, but partly because of difficulty in establishing a comprehensive evaluation framework and partly because of the long timescale required to gather adequate before and after monitoring data, the PE system was enacted in practice 20 years later (Chapulut et al 2005).

The PE methodology consists of:

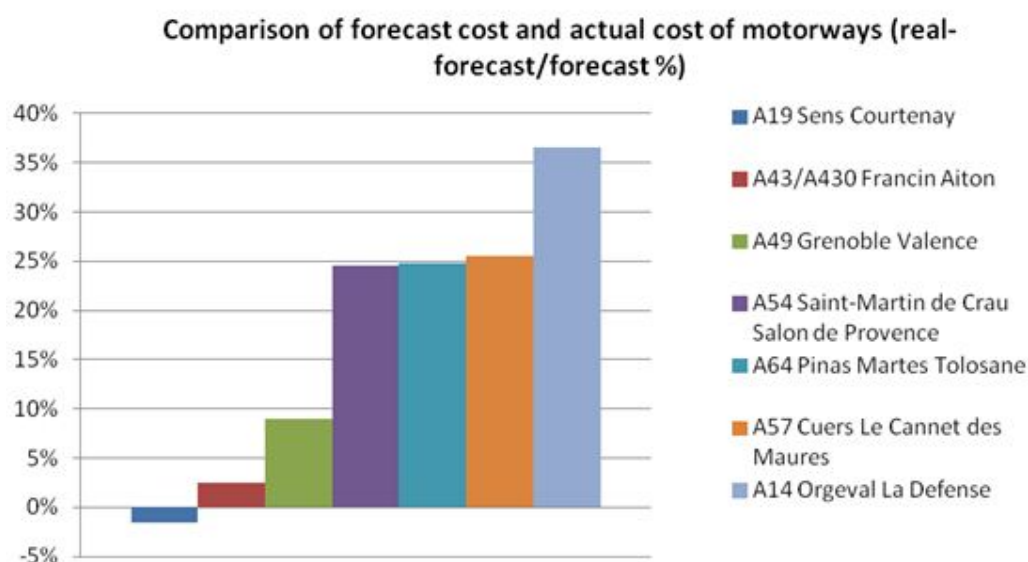
- 1 Comparing forecasts made during the public inquiry with the real effects according to six essential criteria: costs; traffic flows; road safety; quality of service; economic returns; main environmental measures; followed by
- 2 Explanation of differences between the real effects and the prior forecasts.

Currently almost 60 post evaluation reports have been completed or are in progress. These are seen as a way to improve French assessment practices through:

- more accurate definition of the base cases and project scenarios, including infrastructure as well as service descriptions
- better risk identification, enabling well-argued risk analysis
- in-depth analysis enhancing expertise about traffic induction, diversion and infrastructure impacts on environment and economic development (Chapulut et al 2006).

An example of results from the PE process, in terms of cost comparisons, is illustrated in figure 5.3. This indicates very substantial (c.25% or greater) cost over-runs on four out of the seven projects, with only one of the project outturns being less than forecast.

**Figure 5.3 Comparison between public inquiry cost forecast and real cost for motorways**



## 5.6 Summary

This review of post-evaluation road project procedures in Australia, England, Norway and France identified the following issues, conclusions and recommendations, as set out in table 5.2. This represents a profile of good international practice and could usefully be considered in the context of enhancing New Zealand PIR procedures. Some comparisons between international practice and current New Zealand practice are provided in the next chapter.

**Table 5.2 International post-evaluation procedures – conclusions and recommendations**

Issue	Conclusions	International recommendations for New Zealand
<b>Formalisation of review processes</b>	Post-implementation monitoring and analysis is more likely to be available and of higher quality when required as a formal process (France, UK, Norway) rather than where post-implementation evaluation is a discretionary process (Australia).	Require post-implementation monitoring and analysis as a formal process, ideally via legislation.

Issue	Conclusions	International recommendations for New Zealand
<b>Sampling</b>	All new projects are eligible for sampling, including large projects, for post-implementation reviews.	Treat all new projects as eligible for post-implementation review sampling purposes.
<b>Timing of reviews</b>	Post-implementation reviews are typically undertaken 5 years after scheme opening (in England, both 1 year and 5 years after opening).	Undertake post-implementation reviews 5 years after scheme opening.
<b>Scope of reviews</b>	A wide range of potentially significant effects, are subject to review, relative to pre-implementation forecasts.	Include all potentially significant effects in post-implementation reviews.
<b>Integration of processes</b>	Post-evaluation procedures in the countries examined are integrated with scheme development and implementation processes. This integration improves the quality and usefulness of post-implementation reviews.	Integrate post-implementation procedures with scheme development and implementation processes.
<b>Feedback</b>	Feedback is required between post-evaluation results and the development of future forecasting and evaluation procedures.	Provide feedback between post-evaluation results to assist the improvement and development of forecasting and evaluation procedures.

## 6 Review of New Zealand post-evaluation procedures

### 6.1 Introduction

This chapter provides details of our research findings relating to current New Zealand post-evaluation procedures, which are known as post-implementation review (PIR) procedures.

The NZTA PIR programme involves the audit of a sample of smaller completed road projects, with costs in the range \$0.5m to \$30m (average cost \$4m), against the initial project objectives, costs and economic justification as described in the NZTA (2008b) *Planning, programming and funding manual* (PPFM, 5.19).

The PIR process focuses on the extent to which the post-implementation project effects are consistent with the pre-implementation forecasts. PIRs do not examine any wider scheme impacts that were not covered in the pre-implementation forecasts/appraisal.

The original brief for this research project did not include any specific review of PIR procedures and practices. The main component of the post-evaluation work was 'case studies' to assess the impacts of selected major New Zealand roading projects (these are reported in chapter 7). However, once the research was underway, it became apparent that review of current New Zealand PIR procedures and practices would be a desirable additional component of the project.

As an outcome of discussions early in the project, NZTA's Performance Monitoring Unit (through its Technical Audit Manager) agreed to provide supplementary funding to enable the research to be extended 'to review the current NZTA PIR process in terms of its stated objectives as defined in the PPFM'. This chapter and the associated appendix C focus on the work undertaken to meet this objective, while also covering how the PIR process relates to a more holistic approach to 'impact assessment' for major roading projects and examining evidence from the PIR evaluations on the effects of New Zealand roading projects and programmes.

PIRs make an important contribution to funding accountability, especially in view of the scale of investment currently being made annually in new and improved roads (approximately \$1.2 billion pa, forecast average for the NZTA and territorial authorities over the three-year National Land Transport Programme period 2009–12).

The current PIR process contributes to NZTA funding process accountability for small and mid-sized new road projects, by providing a 'reality check' on the value for money being obtained.

PIRs are not specifically named as a legislative requirement, but are undertaken by the NZTA in part fulfilment of legislative provisions in the Land Transport Management Amendment Act 2008.

It should also be noted that, in response to the PIR study findings, the NZTA is making adjustments to the PIR process, as discussed in section 6.5 below.

### 6.2 Method

This research reviewed the methods used for PIR project selection, project investigation, and the interpretation and application of results.

The PIR process is primarily applied to road capital projects: PIRs have been undertaken for a decade (2001/02 to date) and the cumulative results now represent a valuable information source.

Australia, England, Norway and France currently undertake post-implementation reviews for large projects (refer chapter 5); in contrast, New Zealand currently reviews only smaller projects.

The average total annual value of projects reviewed during the period 2001/02 to 2009/10 was \$62m per annum, which represents approximately 5% of current new capital expenditure on state highways and local roads.

An important component in the development of study findings and recommendations was discussions with a range of New Zealand practitioners in the sector in order to:

- understand how PIRs are currently viewed by the sector
- identify issues raised by the current approach to PIRs
- identify potential improvements to the PIR process.

The responses from practitioners have been taken into account in the development of the following findings on the current PIR process.

## 6.3 Review findings

The main findings from the PIR review can be described as follows:

**Sampling.** Various problems are experienced with sampling procedures at present, including difficulties with using NZTA's Transport Investments Online to establish reliable project status lists. Even so, it would be possible to make significant improvements to current sampling methods to make them more representative and to allow better comparisons between different project types. In particular, the sampling methodology should be representative of the overall programme in terms of project type (especially the need to review larger and more complex projects) and there is a need to sample a higher percentage of the value of the overall programme.

**Information.** In practice, the pre- and post-implementation information needed to undertake PIRs is often incomplete, reducing the quality and usefulness of PIR results. Currently, there is a NZTA requirement (section E5-1 of the PPFM 'Supply of Information between approved organisations and the NZTA') but this pre-supposes that the submitter has the information readily to hand, which is often not the case. The NZTA does not currently require specified information to be systematically collected and recorded. In other words, the PPFM does not currently require approved organisations (for NZTA funding) or the NZTA's Highway Network Operations unit to collect and maintain relevant data or documents, at each stage of the project life cycle.

**PIR methodology.** The current methodology is broadly consistent with similar procedures in other countries. However, more detailed advice on when and how to apply more appropriate techniques is needed to improve the quality and consistency of PIR outputs. In particular PIRs have tended to simply 'assume' that a number of benefits have been achieved which calls into question the value of the process and analyses as currently carried out. Additional methodologies for multi-project procedures and for large complex projects (in association with the emerging RoNS monitoring procedures) also need to be developed.

**Results analysis.** Analysis of PIR results has been undertaken over a number of years and this enables useful aggregated summaries and descriptions of associated trends to be produced when required. Improved stratification of the results (especially by scale and type of project) would allow further value to be derived from the existing database.

**Feedback.** Feedback could be improved at three levels:

- Individual reporting and advice back to submitters could be extended to provide final review findings and to arrange follow-up meetings, advice and support to remedy identified problems.
- Improve feedback from PIR findings/lessons into enhancements to forecasting/appraisal methods (in the EEM) and training/re-education of evaluators.
- Key information and recommendations from the PIR process could be released (in a suitable and agreed form) to others, both internally within the NZTA and also to the wider transport sector, to increase awareness of PIR findings.

**Indicators and targets.** The NZTA's (2009) *Statement of intent 2009–12* (SOI) target required 90% of PIR sampled projects to achieve their stated benefits. For working purposes, the (former) NZTA Performance Monitoring Unit (responsible for PIRs) adopted informal BCR targets as follows: 90% of projects are expected to achieve the better of:

- at least 90% of their forecast BCR, or
- a BCR of 4.0.

However, for various reasons these targets have not proved effective in practice. With hindsight it would have been better if the performance indicator had been 'overall cumulative benefits', rather than based on a percentage of projects. The addition of an equivalent 'overall cumulative cost' performance indicator is therefore needed to enable overall 'value for money' to be calculated. Furthermore, a 'matrix' of indicators and targets is really required to adequately monitor and improve performance.

Analysis of PIRs undertaken to date indicates that the proportions of projects with estimates within a  $\pm 20\%$  accuracy range are as follows: benefits 56%, costs 75%, BCRs 66%. (However, there may be some bias in the post-estimates of the benefits in particular given the tendency, noted above, to assume forecast benefits have been achieved in some areas.)

More recent SOIs have not included specific requirements to monitor BCR targets. However, in order to demonstrate consistency with the more general SOI value for money requirements, project performance against economic evaluation forecasts continues to be monitored.

**Processes.** At present, the PIR process is effectively a free-standing process, and is not sufficiently integrated with or supported by other important NZTA processes, such as Transport Investments Online, EEM and the NZTA assessment framework.

**Overall.** The review confirmed the need for PIRs to investigate project performance and obtain better value for money from investments through the application of lessons learned. PIRs also have the potential to perform a more comprehensive check on a wider range of factors and project types.

## 6.4 Conclusions and recommendations

The PIR review recommendations are to some extent dependent on the future scope and purpose of the post-implementation review (PIR) process. This may change for a variety of reasons, for example:

- The current purpose and scope of PIRs, described in the *Guidance notes* (NZTA 2008, currently limit considerations to an examination of significant differences between actual and forecast conditions on the basis of the original evaluation methodology and project objectives. Thus their current focus is on the quality of the original pre-implementation evaluation, rather than on the absolute impacts and merits of the scheme itself.



- The effects of NZTA 'streamlining' and 'block funding' initiatives are likely to increase the usefulness of PIRs, especially in terms of maintaining accountability and confirming the returns being delivered on investments.
- Recent changes in 'post approval reviews' mean that these now represent audits of evidence, effectively reducing the level of pre-funding and pre-implementation technical scrutiny.

The review of post-evaluation road project procedures in Australia, England, Norway and France identified the following issues, conclusions and recommendations set out in table 6.1. It should be noted that recommendations for changes to New Zealand PIR procedures are made in the context of good practice identified in the international review and the comparison with current New Zealand PIR practice.

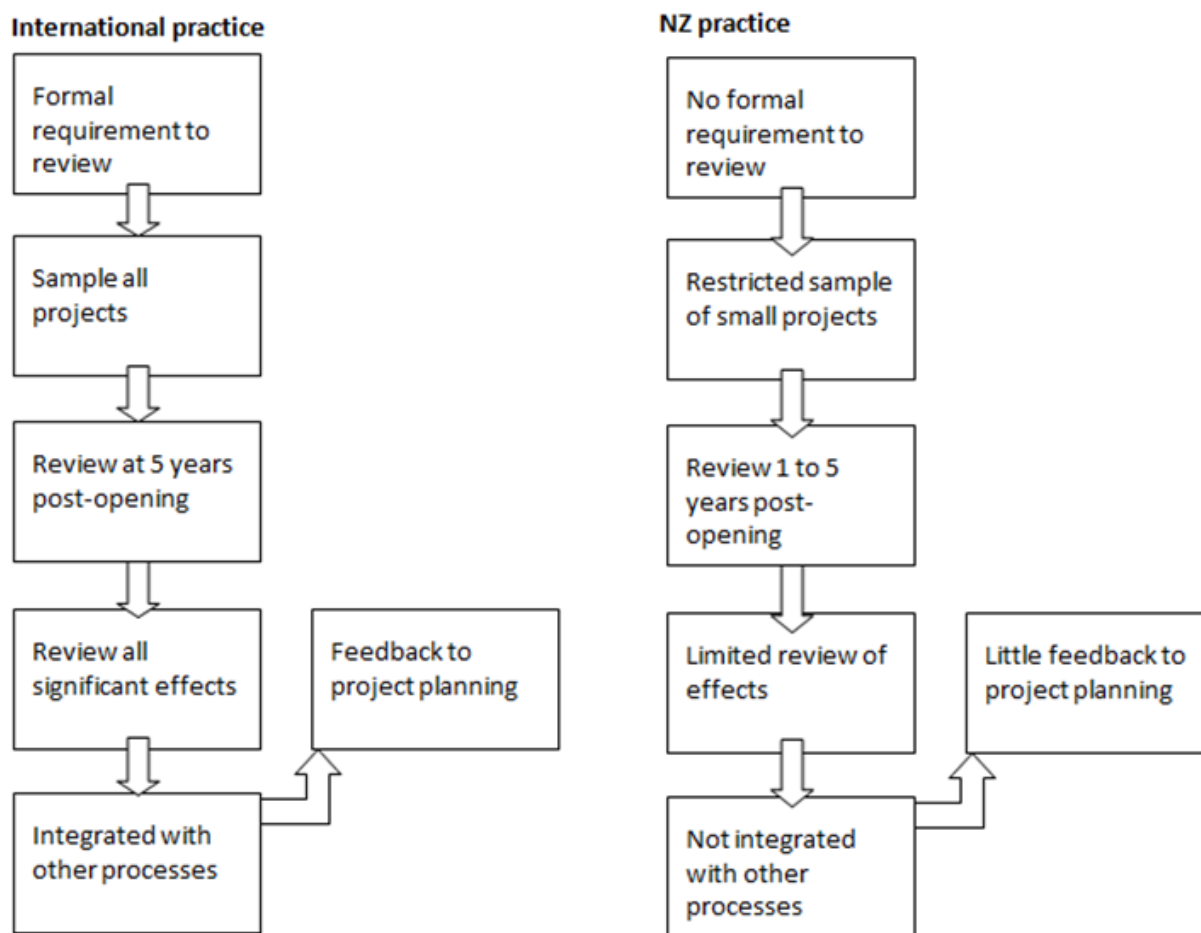
A profile of international good practice was identified earlier (section 5.6) and this could usefully be considered for application to New Zealand post-implementation review procedures.

**Table 6.1 New Zealand PIR practice: conclusions and recommendations**

<b>Issue</b>	<b>Conclusions re New Zealand practice</b>	<b>Detailed PIR study recommendations</b>
<b>Formalisation of review processes</b>	Post-implementation monitoring and analysis in New Zealand is a discretionary informal process.	Define and formalise the role and scope of the PIR process.
<b>Sampling</b>	Only a minority of project types and smaller projects are currently eligible for New Zealand post-implementation review sampling purposes.	Improve, widen, stratify and record sampling methodology. Increase the number of PIRs undertaken.
<b>Timing of reviews</b>	Post-implementation reviews in New Zealand are undertaken between 1 and 5 years after scheme opening.	Undertake all PIRs, including a sample of large complex projects, 5 years post-opening.
<b>Scope of reviews</b>	Only a limited number of economic costs and benefits are included in the current post-implementation review process.	Consider all significant effects in consultation with stakeholders. Review all economic benefit categories rather than only those benefits over a certain threshold (currently 20% of total benefits). Improve techniques and advice, including for the assessment of non-monetised benefits. Develop procedures for larger and more complex projects. Undertake multi-project theme type analyses.
<b>Integration of processes</b>	Post-implementation procedures are not currently integrated with New Zealand scheme development and implementation processes.	Adjust PPFM and Transport Investments Online to introduce project requirements to assist PIR investigations. Increase the resources available for PIRs and integrate them into project requirements.
<b>Feedback</b>	No feedback to the wider New Zealand transport sector is provided from the post-implementation review process to assist the improvement and development of forecasting and evaluation procedures.	Adjust indicators and associated targets to provide an appropriate assessment of performance. Apply additional methods to investigate identified problems (and to investigate 'why' identified effects have happened) and disseminate results to the sector.

A comparison between prevailing international practice and current New Zealand practice is provided in figure 6.1.

**Figure 6.1 Comparison of New Zealand and international post-evaluation practice**



The lessons learned from PIRs could potentially be applied throughout the project lifecycle, which would allow PIR findings to be used to improve project development, planning and evaluation practice.

A phased approach to implementing the study recommendations was considered as desirable, involving a programme of incremental improvements. A phased approach<sup>13</sup> was therefore recommended by the PIR review to maintain accountability and to assess value for money:

## 6.5 Response to findings and recommendations

Following completion of this PIR review, the NZTA has been pursuing a number of the review recommendations, and has commented as follows (NZTA Investment Monitoring, pers comm, March 2012):

*We have no official response to the recommendations of the PIR. However, we have been working on:*

<sup>13</sup> Effectively representing short, medium and longer-term initiatives.

- *Modifications to Transport Investment Online, so that we can capture targets and feedback on all projects/packages going forward.*
- *Bringing delivery of PIRs in-house, both to save money and as an aid to up-skilling NZTA staff in their assessments of projects.*
- *More of a focus on what the findings of PIRs mean to NZTA and how we can learn from these.*

*We have yet to revisit our sampling methodology. This was attempted this year, but we had no budget to complete PIRs for large projects. There will be a greater focus on our sampling for the 2012/13 year, as well as a review of the methodology being applied to the PIRs."*

## 6.6 Roads of national significance (RoNS)

The review of PIRs (particularly) and the case studies considered in this research focus on small-medium scale projects, and all these studies pre-date work now being undertaken relating to post-evaluation of the RoNS. As a result the research is generally silent on RoNS-related issues.

The RoNS projects are currently subject to separate considerations to establish an enhanced (ePIR) process and monitoring framework. In this respect there has been liaison between this research project and the RoNS ePIR advisor, which has identified some relevant points as follows:

- The PIR review and the case studies undertaken have been highly dependent on the availability of comparative pre- and post-information. In practice, required data is often partial or incomplete and this means that confidence in the findings emerging from the current research is often limited.
- With one exception, the RoNS do not have major constraints on historic data availability and a more comprehensive pre and post-implementation assessment framework and associated data monitoring process can be and needs to be developed for the RoNS.

The RoNS ePIR process can also usefully take some lessons from the findings of this research, especially the following:

- Good project record-keeping is essential and there is a need for a formal (probably contractual) requirement to be introduced to ensure that appropriate data are collected for the 'before' situation and accessible records are maintained into the future.
- Post-implementation surveys and associated analysis are needed and the costs of these should be included within project cost approvals.

In the medium-term, we see a strong case for greater integration/consistency between NZTA's 'standard' PIR procedures and the RoNS ePIR procedures.

## 7 New Zealand post-evaluation case studies

### 7.1 Introduction

The impacts of a selection of recent road projects in New Zealand have been reviewed through a series of five case studies.

These case studies were chosen to reflect a range of larger project types than would normally be reviewed in the current New Zealand PIR process, within the cost range \$30M to \$360M (total approximately \$900M), as follows:

- Auckland northern motorway extension (Alpurt B2)
- Auckland southern motorway ramp signalling (ASMRS)
- Auckland northern busway (NB)
- Tauranga Harbour link
- Wellington inner city bypass (WICB).

Two principal themes were explored in the case studies:

- 1 Assessment of the impacts of the schemes, through comparisons between actual post-implementation conditions, and the do-minimum (or do nothing) scenario which represents the conditions that would have been expected in the absence of the project.
- 2 The accuracy or otherwise of the prior forecasts of conditions following implementation of the scheme.

For each case study, these themes were addressed through obtaining and comparing information for:

- actual base year (pre-implementation) conditions
- actual post-implementation conditions.
- forecast do-minimum conditions (ie in the absence of implementation).
- forecast post-implementation conditions.

Providing the relevant information concerning base year conditions, actual and forecast future conditions is fully available, then the impact of projects can be comprehensively determined.

### 7.2 Description of case studies

#### 7.2.1 Auckland northern motorway extension: Alpurt B2

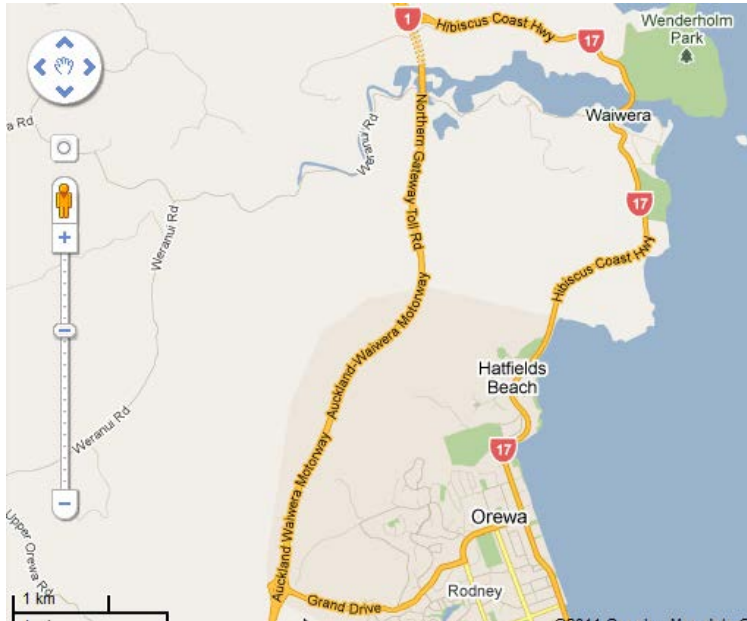
The Alpurt B2 project is the most recently completed element in a longstanding intention to upgrade SH1 between Auckland and Northland to motorway standards.

The aims of the project were to:

- develop an alternative route to the existing state highway that bypasses Orewa and reduces congestion in Orewa and Silverdale at peak periods and holiday weekends
- improve the strategic route between Auckland and Northland

- improve the traffic safety characteristics of the present route and reduce the current high accident rate.

**Figure 7.1 Alpur B2 (SH1) toll road location**



The project was developed as a 7.5km dual carriageway toll road with automated toll collection. The alignment of the project was through rolling and environmentally sensitive countryside between Silverdale and Puhoi.

The new route is shorter (by 5km) than the former state highway route via Orewa and has been designed to a much higher standard (dual two-lane carriageways).

### 7.2.2 Auckland southern motorway ramp signalling (ASMRS)

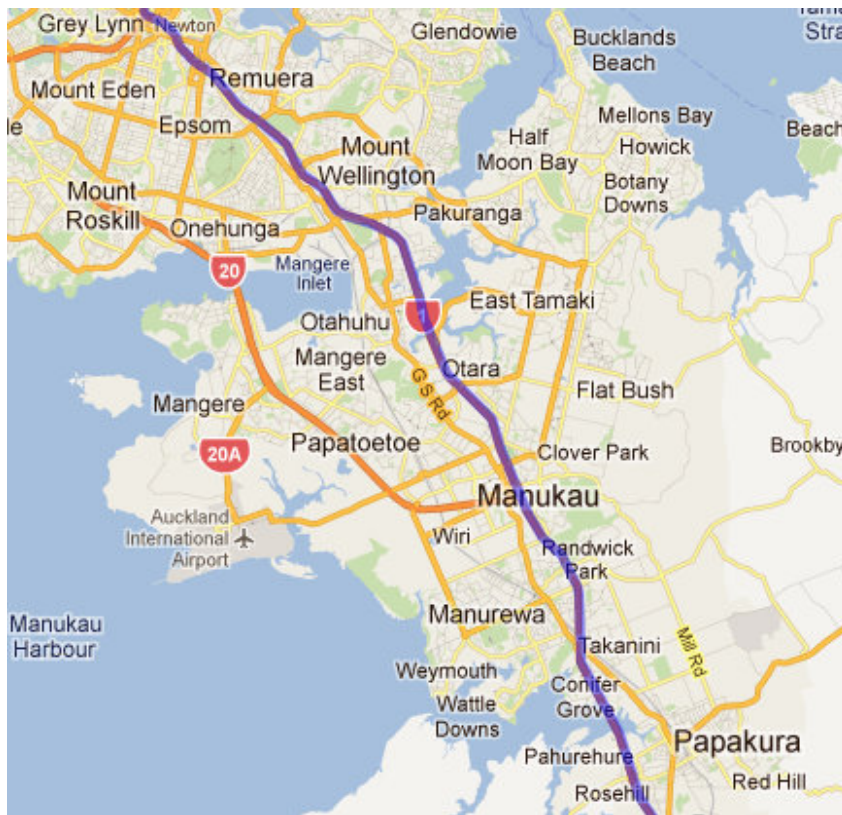
The aim of the project was to actively influence traffic patterns and manage corridor traffic conditions, using flow monitoring and control systems together with the delivery of traveller information, to optimise the operation of the motorway and its supporting arterials.

The project involved:

- installing ramp signalling at all northbound and southbound on-ramps (32 in total) between central Auckland and Drury
- providing priority access for freight and/or high occupancy vehicles (HOVs) at four of the ramps (Grafton St southbound trucks only, Takanini northbound buses only, south-eastern arterial northbound and Mount Wellington northbound 2+HOVs, trucks, taxis and motor-cycles).

This ramp signalling project on the southern motorway was the largest element of a wider initiative, which also introduced ramp signals on the northern and north western motorways.

**Figure 7.2 Auckland southern motorway (SH1) location**



### 7.2.3 Auckland northern busway

The project aims were to:

- increase accessibility to PT
- provide an alternative mode of transport between the North Shore and Auckland city
- reduce travel times of HOVs and bus users along SH1
- increase person carrying capacity of the harbour bridge
- minimise adverse environmental effects of private motor vehicle use
- enhance activity in city centres by improving accessibility and capacity.

**Figure 7.3 Northern busway (SH1) location**

The original project concept was developed by the Auckland Regional Council in the early 1980s in response to the level of congestion and difficulties experienced by bus services in peak periods.

As defined in the latest evaluation, the project comprises:

- a dedicated busway from Constellation Drive to Onewa Road, potentially available to HOV traffic. This operates as a two-way, two-lane facility between Constellation and Akoranga stations (6.2km) and one-way, one-lane facility (2.5km) between Akoranga and south of the Onewa Road interchange
- improvements at Onewa interchange to permit dedicated busway operation
- associated basic stations, park/kiss and ride facilities at Akoranga, Westlake, Sunnynook, Constellation and Albany
- extension of the existing HOV lane along Onewa Road
- provision of bus-only ramps from SH1 to the Albany station.

The busway and associated works and service changes were implemented over the period between July 2005 and February 2008. Subsequent park and ride extensions were added in 2009.

#### 7.2.4 Tauranga Harbour link

The original Tauranga Harbour Bridge was opened in 1988 and included a \$1 toll for its use. Over the next 13 years, the daily traffic flow on the bridge increased from 10,000 vehicles per day (vpd) to 27,500 vpd, largely as a result of the continued strong residential development across the harbour from the city centre.

The toll on the original harbour crossing was removed in 2001; this resulted in a substantial increase in demand (largely through traffic switching from the alternative cross-harbour route) and an increase in travel times. The proposal to duplicate the crossing emerged from the pressure placed on the route following toll removal.



The duplication project's aims were to provide more efficient and a quicker access between Tauranga and Mount Maunganui, reduce congestion on the existing harbour bridge and Hewlett's Rd and the traffic bottleneck at Chapel Street for through traffic.

The duplication of the harbour bridge was preceded by the Hewlett's Road flyover and the improved Hewlett's link, and was accompanied by the grade separation of Chapel Street. The duplication resulted in a doubling of the capacity of the original crossing by providing a new two-lane road over Tauranga Harbour and associated connections. The scheme was originally planned as a tolled crossing but was implemented in non-tolled form.

**Figure 7.4 Tauranga Harbour link location**



The duplication project was constructed in two stages, namely: the four-laning of Hewlett's Rd on the Mount Maunganui side of the harbour, completed in September 2007, and the bridge duplication, which took place between July 2007 and January 2010.

### 7.2.5 Wellington inner city bypass

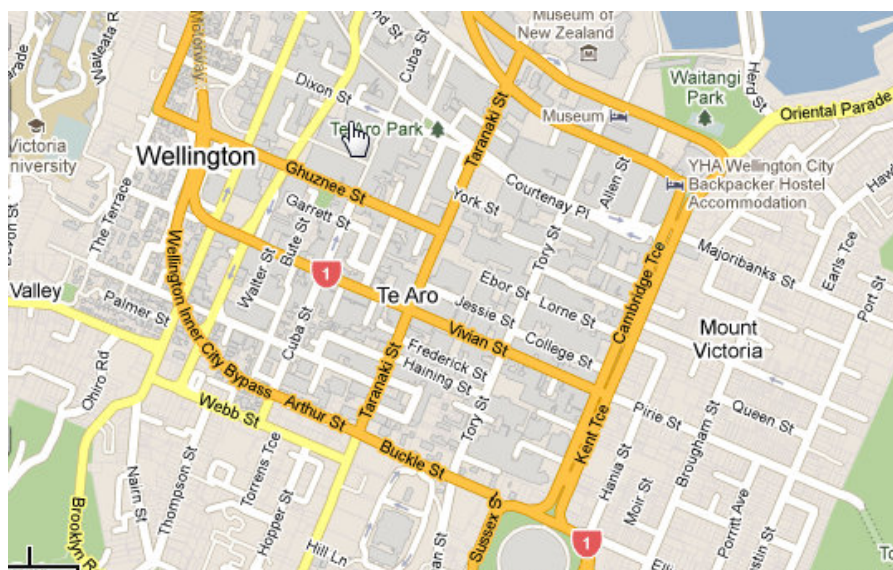
The project aims were to provide a less congested, safer, and more efficient route between the Terrace Tunnel and the Basin Reserve. The bypass is a one-way, two-lane road, at ground level, with dedicated turning lanes and a 50km/h speed limit. It separates cross-city and central business district traffic and provides a safe route for pedestrians and cyclists.

This project involved the rationalisation of SH1 traffic in central Wellington, including revised traffic management arrangements to straighten the south-bound movement and a short section of new two-lane northbound highway connecting the Basin Reserve with the Terrace Tunnel.

The effect of the project was to shorten the distances travelled by SH1 traffic through the city between the Terrace Tunnel and Basin Reserve. Averaged over both directions, the state highway was shortened by 205m from 1660m to 1410m.

The project was implemented between August 2005 and Feb 2007.



**Figure 7.5** Wellington inner city bypass (SH1) location

## 7.3 Key findings – costs

Table 7.1 shows the approximate changes in scheme capital costs between pre-construction cost estimates and actual outturn costs.

**Table 7.1** Capital cost comparisons – pre- and post-implementation

Project	Prior	Actual	% Change	Comment
Auckland northern motorway extension: Alpur B2	\$358.0m	\$341.0m	-5%	Due to the complex nature of the funding arrangements for this project it has been difficult to establish true outturn capital costs or on-going subsidy costs. However, from the information available, it appears actual costs were similar to those forecast.
Auckland southern motorway ramp signalling	\$30.8m	\$27.5m	-11%	This was part of a wider AMRS project and was tendered on an overall fixed price basis, and this cost saving applied only to one contract element.
Auckland northern busway	\$210.0m	\$220.5m	+5%	Outturn costs for the busway and associated property were similar to those anticipated. Other costs associated with the stations and services were funded separately and not included here.
Tauranga Harbour link	\$254.7m	\$168.9m	-34%	Outturn costs were far lower than anticipated. This implies that the pre-implementation estimates were inaccurate and/or the successful tender price was very competitive.
Wellington inner city bypass	\$38.9m	\$42.8m	+10%	Outturn costs were higher than those predicted, but it is not clear whether this was associated with mitigation measures or for some other reason.

In four of the projects, there appears to have been little substantial change between the approved pre-construction cost estimates and the actual outturn costs. The exception to this is the Tauranga Harbour link where outturn costs were significantly lower than the pre-construction estimate.

It should be noted that more significant cost estimate changes are likely to have occurred throughout the project development lifecycle, from initial pre-feasibility report, project assessment report and pre construction estimates.

Changes in project scope and variable 'cost conventions'<sup>14</sup> are complicating factors in comparing changes in cost estimates.

## 7.4 Key findings – traffic volumes and travel times

Table 7.2 summarises for each scheme the average daily traffic volumes immediately pre and post-implementation.

**Table 7.2 Traffic volume comparisons – pre- and post-implementation**

Project		Prior AADT	Actual AADT	% change	Comment
Auckland northern motorway extension: Alpur B2	SH17	17,700	7000	-60.5%	The bypassed community of Orewa experienced substantial traffic relief immediately post-implementation in 2009. However, this relief was less than the forecast 75% reduction.
	SH1	-	13,100	-	Immediate post-implementation traffic flow was 7% lower than forecast for the immediate post-implementation period (2009).
	Total	17,700	20,100	+13.6%	This difference was due to a combination of continued traffic growth, transfer traffic from SH16 and some induced local trip making.
Auckland southern motorway ramp signalling		111,586	115,787	+3.8%	Low growth in daily traffic over a four-year period (2006 to 2010).
Auckland northern busway		166,130	158,102	-4.8%	Decline in daily traffic over a five-year period (2005 to 2010).
Tauranga Harbour link		36,508	38,716	+6%	Low growth in daily traffic over a four-year period (2006 to 2010).
Wellington inner city bypass		42,960	45,364	+5.6%	Represents an increase in traffic over a three year period (2005 to 2007) 2.6% greater than forecast.

Post-implementation traffic volumes were higher than pre-implementation levels in four out of the five case studies, broadly in keeping with background trends. The exception was the Auckland northern busway, for which road traffic volumes post-implementation were found to have reduced, to an extent broadly consistent with the increase in bus passengers on the route.

Little clear evidence of short-term induced traffic effects emerged from the case studies, although it should be emphasised that more detailed study would be required to reach definitive conclusions on induced traffic effects.

<sup>14</sup> For example, quoted costs may be 50th%, 95th %, based on different years or discounted back to different years. Often it is not clear on what basis the costs were prepared.

Alternative routes/local roads associated with the case studies were found to have either longer post-implementation travel times (relative to the changes in travel time on the project route) or travel times were little altered, as a result of project implementation.

Table 7.3 summarises travel times immediately pre- and post-implementation.

**Table 7.3 Travel time comparisons – pre- and post-implementation**

Project		Prior min/sec	Actual min/sec	% change	Comment
Auckland northern motorway extension: Alpur B2	SH17	16m 30s	16m	-3%	Slight improvement in journey times under normal conditions, more substantial improvements in seasonal conditions.
	SH1	16m 30s	7m 15s	-56%	Large improvement in travel times in most conditions, although at seasonal peaks the new road is substantially slower than travel via the alternative route.
Auckland southern motorway ramp signalling		-	-	-	No summary information available.
Auckland northern busway		34m 30s	36m 24s	+6%	An apparent worsening of journey times – possibly due to temporary road works.
Tauranga Harbour link		12m 11s	9m 22s	-23%	Average of peak and inter-peak conditions.
Wellington inner city bypass	SH1	8m 52s	6m 31s	-27%	Improved travel times especially in peak periods (AM peak shown).
	Local roads	18m 48s	19m 29s	+4%	Worsening of peak period travel times (AM peak shown)

Post-implementation overall travel times for general traffic have been improved compared with pre-implementation levels in four case studies. In the case of the Auckland northern busway, bus travel times (not shown here) have been substantially reduced, although general traffic times appear to have increased (for non-project related reasons).

For the case study schemes, there is minimal evidence on changes in travel time reliability. This partly reflects that reliability monitoring is not currently a project evaluation requirement and is rarely undertaken.

## 7.5 Key findings – safety

Table 7.4 summarises annual road crash costs before and after scheme implementation, and compares these cost changes with regional and sub-regional trends in crash costs over the same period. The scheme-related costs reduced in absolute terms in four out of five projects, but the benefits forecast in pre-implementation evaluations were achieved or exceeded in only three of the projects.

**Table 7.4 Road crash costs – pre- and post-implementation**

Project	Prior	Actual	Project change in social cost	Sub-regional change in social cost	Regional change in social cost	Comment
Auckland northern motorway extension: Alpur B2	\$15.5m	\$14.3m	-8%	-9%	-15%	The reduction in social cost is in line with project forecasts, similar to sub-regional trends and lower than regional trends (for a short post-implementation period).
Auckland southern motorway ramp signalling	\$70.0m	\$56.7m	-19%	-21%	-24%	The reduction in social cost is much higher than project forecasts but is similar to sub-regional trends and lower than regional trends.
Auckland northern busway	\$18.0m	\$17.4m	-3%	-12%	-9%	The reduction in social cost is similar to project forecasts but lower than sub-regional or regional trends.
Tauranga Harbour link	\$3.96m	\$2.1m	-46%	-25%	-16%	Changes in social cost were not included in project forecasts. The actual change is higher than sub-regional and regional trends (for a short post-implementation period).
Wellington inner city bypass	\$4.8m	\$6.4m	+33%	-19%	-25%	The increase in social cost is counter to project forecasts of a reduction in social cost and also counter to reductions in sub-regional and regional social costs.

Having regard to the percentage changes in regional and sub-regional crash costs over the assessment period, our interpretation of the results for each scheme is as follows:

- For the first three schemes listed, the average changes in crash costs appear not to be significantly different from the regional/sub-regional trends, ie any changes in crash costs as a result of the schemes themselves appear to be small and probably not significant.
- For the Tauranga Harbour link scheme, a significant reduction in crash costs, relative to the regional/sub-regional trend, appears to have occurred; however, the harbour link data relate to only a very short post-implementation period.
- For the Wellington inner city bypass, the change in crash costs (+33%) appears to be substantially worse than the background regional/sub-regional trends (-19% and -25%). This is a strong indication that the forecast safety benefits of the project are not being achieved, and that it has actually resulted in a significant increase in crash costs.

From these five case studies, we draw the following indicative findings in relation to forecast and actual impacts on crash costs:

- In undertaking any post-evaluation of scheme impacts on crash costs, it is important to allow for background (regional/sub-regional) trends in crash costs.

- The crash cost benefits achieved by the case study schemes appear to differ quite substantially from the pre-implementation forecasts for several of the case studies. (Other analyses carried out for this research project indicate actual crash benefits more generally are substantially lower than the forecast benefits.) More detailed analyses of the incidence and types of crashes would be needed to understand the reasons for the incorrect (usually optimistic) forecasts.

In interpreting these findings, two qualifications are necessary:

- The above findings are indicative, being based on only five case studies and in some cases a short post-implementation period for crash data.
- Safety represents a relatively small proportion of forecast benefits in four of the case studies, and in the case of the harbour link, no safety benefits at all were forecast. As such it is likely that relatively little attention (for example, compared with travel time savings) has been paid to analysing and forecasting safety issues in the case studies reviewed.

## 7.6 Key findings – economic evaluation

Table 7.5 presents a summary of the percentage changes in capital costs, net benefits and BCR resulting from comparing our post-implementation assessment of costs and benefits with the corresponding pre-implementation forecasts.

**Table 7.5 Benefit: cost comparisons – % change (pre- and post-implementation)<sup>(a)</sup>**

Project	Cost change	Benefit change	BCR change	Comment
Auckland northern motorway extension: Alpurā B2	5% (\$269m to \$282m)	-4% (\$477m/\$457m)	-9% (1.8 to 1.6)	Small changes in costs and benefits have a proportionately greater impact on the BCR. This is good in terms of predictive accuracy, when comparing immediate pre- and post-implementation conditions.
Auckland southern motorway ramp signalling	-11% (\$33m to \$30m)	- (\$174m to \$174m)	+12% (5.3 to 5.9)	The reduction in costs has a similar impact on the BCR. This is good in terms of predictive accuracy, when comparing immediate pre- and post-implementation conditions.
Auckland northern busway	+6% (\$172m to \$182m)	+18% (\$199m to \$235m)	+12% (1.2 to 1.3)	This is good in terms of predictive accuracy, when comparing immediate pre- and post-implementation conditions.
Tauranga Harbour link	-27% (\$185m to \$134m)	+3% (\$542m to \$559m)	+42% (2.9 to 4.2)	The substantial reduction in costs has an even greater proportional impact on the BCR. This is poor in terms of predictive accuracy, when comparing immediate pre- and post-implementation conditions.
Wellington inner city bypass	+10% (\$25m to \$28m)	-12% (\$98m to \$86m)	-20% (3.9 to 3.1)	Small changes in costs and benefits have a similar impact on the BCR. This is reasonable in terms of predictive accuracy.

Note: <sup>(a)</sup> Costs and benefits have been discounted on the basis of the criteria applying at the time of each evaluation and so are not directly comparable across all five schemes.

The findings of the review of economic evaluation are therefore that four of the projects slightly over-estimated the BCR although all were within 20% of forecast which represents good predictive accuracy. For the Harbour Link predictive accuracy was poor, but this was as a result of substantially over-estimating the costs.

However, some qualifications need to be made in relation to these findings:

- All the post-implementation estimates of benefits have been based entirely on our re-estimates of benefits for the early years of the project life, and have assumed (in the absence of detailed re-forecasting) that the benefit growth profile over future years will be similar to that in the original forecasts. This assumption may be subject to substantial error. (More realistic comparisons may be between the pre-implementation forecast and the post-implementation estimates of the first year rate of return, thus eliminating the need to make assumptions about future benefit growth profiles.)
- Even for the first year (or other early period) following scheme implementation, our re-estimates of benefits can be no more than indicative, as comprehensive data were not available for all the required aspects of all the projects.

## 7.7 Key findings – other modes

The Auckland northern busway is the only one of the case studies in which modal switching effects have been examined in any detail (as is appropriate, given the nature of the project). Table 7.6 provides summary statistics (based on surveys) of car traffic levels, car user numbers and bus user numbers shortly before the scheme implementation (2005) and following completion of its full implementation (2010).

**Table 7.6 Auckland northern busway modal impacts – pre- and post-implementation**

	Prior (2005)	Actual (2010)	% Change	Comment
Cars (AM peak) south-bound (S/B)	14,749	14,482	-2%	The reduction in peak volumes is considerably smaller than daily volumes (approximately 4.8%)
Car passengers (AM peak S/B)	3093	4055	+31%	The substantial increase in car passengers may be due to a range of factors, including one way ride sharing and the limited availability and cost of CBD parking.
<i>Total car users</i>	<i>17,822</i>	<i>18,537</i>	<i>+4%</i>	Overall a modest increase in total travel by car has occurred.
PT users (AM peak S/B)	5096	7444	+46%	The substantial increase in patronage occurred following the introduction of the northern express service and the opening of the northern busway.
PT mode share	22.2%	28.7%	+6.5%	PT mode share increased despite the increase in car travel described above. Note: The mode share of total PT over the Harbour Bridge is higher than the busway only mode share % quoted.

The main findings from table 7.6 (relating to AM peak, inbound travel) are:

- Over the period 2005–10, total car users increased by 4% while bus users increased by 46%.
- As a result, the bus mode share increased from 22.2% to 28.7%, ie by 29%.

- For the car mode, the car user increase of 4% was made up of a 2% reduction in car drivers (ie cars) and a 31% increase in car passengers (based on information supplied by Auckland Transport).

For the other four case studies, no multi-modal modelling has been undertaken and no post-implementation monitoring modal information is available. It is likely, however, that these projects will have either been neutral in mode share terms or will have further increased car-based mode shares due to increases in the relative attractiveness of road travel.

## 7.8 Key findings – environmental effects

### 7.8.1 Vehicle operating costs and global environmental impacts

No monitoring or post-implementation estimation of vehicle operating cost (VOC) changes, associated fuel consumption or greenhouse gases (GHGs) was undertaken for any of the case studies.

VOC, fuel consumption and GHG production are unlikely to have reduced significantly, because of the small changes in traffic volumes in the immediate post-implementation period.

There may have been some reduction in the rate of increase of these factors due to reduced congestion in each of the case studies, but in the case of the harbour link and Alpur B this may to some extent have been countered by the presence of significantly higher post-implementation speeds.

### 7.8.2 Local environmental impacts

Local environmental impacts were monitored (noise and groundwater only) in only one of the five case studies (WICB). This found that noise effects consisted of a mixture of small scale increases and decreases (producing an overall neutral impact), and that construction effects on groundwater were relatively minor.

In addition to project-related factors, changes in local environmental effects (such as air quality, noise and severance) are influenced by a range of background factors, including changes in traffic volumes, congestion levels, fuel types and engine quality.

It is probable that short-term local environmental effects (comparing pre- and post-implementation conditions) have varied primarily in relation to changes in traffic flow on particular links. This is likely to have been particularly significant in bypass (Alpur B2 – Orewa) or urban traffic management (WICB – Ghuznee Street) projects.

## 7.9 Summary of case study findings

Table 7.7 provides a summary of the case study findings.

**Table 7.7 Case study findings**

Aspect	Conclusions
<b>Costs</b>	In four of the case studies, there was little substantial change between pre-construction cost estimates and actual outturn costs. The exception to this is the Tauranga Harbour link where outturn costs were significantly lower than the pre-construction estimate.
<b>Traffic volumes</b>	Post-implementation traffic volumes were higher than pre-implementation levels in four of the five case studies, broadly in keeping with expected background trends. The exception was the Auckland northern busway, for which general road traffic volumes post-implementation were found to have reduced. There was little clear evidence of short-term induced traffic effects from any of the case studies.

Aspect	Conclusions
<b>Travel time</b>	<p>Post-implementation travel times for general traffic improved compared with pre-implementation levels in four of the case studies.</p> <p>The smaller projects (ASMRS and WICB) have affected conditions within localised areas; however, their effects have been marginal in terms of changing overall levels of accessibility or in achieving overall reductions of negative environmental and other externalities. The case of ASMRS illustrates the need to record aggregate summary information, allowing performance measurement against agreed indicators, rather than relying on data from isolated sites.</p> <p>The larger Alport B2 and-Tauranga Harbour link projects resulted in more substantial increases in network traffic capacity and major changes in operational conditions. This meant that the new links provided by the projects substantially improved travel conditions in the immediate post-implementation period. Post-implementation monitoring needs to be comprehensive if the full range of potential impacts is to be understood. Very little post-implementation information was available from the harbour link project, apart from travel time surveys. Post-implementation network management needs to ensure seasonal delay problems are not simply transferred to the new link and that potential safety benefits are fully realised (Alport B2).</p> <p>In the case of the Auckland northern busway, bus travel times were very substantially reduced (general traffic times increased slightly for non-project reasons). This resulted in substantial changes in operational conditions in a heavily used corridor, with the following effects:</p> <ul style="list-style-type: none"> <li>• significant reduction in peak period car traffic volumes in the corridor</li> <li>• greater numbers of people using a corridor to access the CBD</li> <li>• improvements to PT accessibility without worsening travel conditions for private vehicles.</li> </ul> <p>Better pre-implementation and post-opening monitoring is needed to accurately describe changes in travel times and reliability.</p> <p>Alternative routes/local roads were found to have either longer or little altered post-implementation travel times (relative to the changes in travel time on the project route).</p> <p>For the case study projects, minimal evidence is available on travel time reliability.</p>
<b>Safety</b>	<p>For the three Auckland case studies, project-related changes in crash costs are not significantly different from regional/sub-regional trends.</p> <p>For the Tauranga Harbour link scheme, a significant reduction in crash costs, relative to the regional/sub-regional trend, appears to have occurred:</p> <p>For the Wellington inner city bypass, the change in crash costs (+33%) appears to be substantially worse than the background regional/sub-regional trends (-19%, and -25%). This is an indication that forecast safety benefits of the project were not achieved and also points to the need for particular care in forecasting forecast safety benefits when speeds are increased on existing urban streets.</p>
<b>Economics</b>	<p>The findings of the review of economic evaluation are therefore that four of the projects slightly over-estimated the BCR although all were within 20% of forecast, which represents good predictive accuracy. For the Tauranga Harbour link predictive accuracy was poor,</p>
<b>Other modes</b>	<p>The Auckland northern busway resulted in the total number of bus users increasing by 46%. As a result, the bus mode share increased from 22.2% to 28.7% over a five-year period, The impact on walking and cycling is not known.</p> <p>For the other four case studies, no multi-modal modelling or monitoring was undertaken.</p>
<b>Environmental effects</b>	<p>No monitoring or post-implementation estimation of VOC changes, associated fuel consumption or GHGs was undertaken for any of the case studies.</p> <p>Local environmental impacts were monitored (noise and groundwater only) in only one of the five case studies (WICB).</p>

This table indicates that there is considerable scope for improvement in the post-implementation monitoring and evaluation of project impacts.



## 7.10 Discussion of research issues

### 7.10.1 General

The confidence in case study findings is dependent on the quality and availability of the pre-and post-implementation monitoring, analysis, forecasting and assessment information held by the implementation and operational agencies.

However, the only universally available data for all road projects, for both pre and post-implementation conditions are: traffic counts, crash statistics and cost information. All other information may or may not be available, depending on the particular project concerned.

In two cases (NB and WICB) post-implementation model tests have helped inform the assessment of post-implementation conditions.

The factors examined for each case study were mainly selected on the basis of data availability and relevance of particular factors to the project. An alternative to this approach would have been to produce a comprehensive assessment table common to all projects examined, but this was not possible, as quantified data is not available to fully populate such tables.

The case studies reviewed project performance in the early post-implementation period. It was generally been assumed in the case studies that later impacts would be pro-rata, although in reality a reassessment of the longer-term forecasts or further reviews at (say) five and 10 years following implementation would be needed to confirm the short-term findings from the case studies undertaken. In the absence of such reassessment, it would be more realistic to compare outturn and forecast impacts on the basis of first year results (eg FYRR) rather than on the basis of projected benefits over the full evaluation period (eg BCR).

Furthermore, while it is often possible to say that measureable changes in prevailing conditions have occurred following the implementation of a project, it is much more difficult to attribute the actual cause of such changes. For virtually all effects, a range of background factors could have influenced any observed changes in pre and post-implementation conditions. For example, depending on the time that elapsed between pre and post-implementation review periods, a number of non-project related influences could be relevant, including:

- traffic volumes could have varied from forecasts due to unanticipated changes in fuel prices
- PT patronage could have varied due to changes in fares or service frequency
- safety and environmental effects could have varied due to by changes in vehicle technology or regulation
- travel time could have varied due to unexpected land use or network changes.

To determine causation, a series of detailed checks would be necessary, including a comprehensive look at changes in background conditions and other (non-project) interventions over the period involved. Whether or not this is possible in any particular case, is largely dependent on the scope and quality of post-implementation monitoring and analysis undertaken by the project owners. Detailed examination of the potential impact of background factors was not been undertaken in this research – although in some situations it was possible to compare impacts in the scheme area with background impacts away from this area, and to estimate the net impacts of the scheme accordingly (eg through examining the regional/sub-regional trends in crash costs).

### 7.10.2 Information

The amount of information available is partly dependent on the scale and nature of the project concerned: in general the larger or more complex the project, the better the information available. However, the data and documentary material held on base year conditions and forecast effects of projects is often limited in terms of scope, detail or availability. This is typically due to the partial nature of information produced and partly due to the absence of any project requirement to undertake post-implementation monitoring or to maintain accessible documentation in the post-implementation period.

Project information is often difficult to obtain post-implementation, partly due to an unnecessary culture of secrecy and partly due to a lack of motivation to retrieve and supply information. This is a task that is low on the priority lists of most professionals with access to the requested information, especially if there are no resources to pay for the time involved.

More often than not, those closely associated with planning a particular project have ‘moved on’ and the institutional knowledge has been lost. In the post-implementation period, responsibility for projects is typically passed on to operational staff who may have little expertise in planning and evaluation, resulting in difficulty in responding to information requests.

The absence of organised, structured and consistent project information makes case studies (and post-implementation reviews) extremely and unnecessarily difficult to undertake.

Even when information is available, further difficulties arise in using available material for structured comparisons between before and after conditions, as a result of the different timing and referencing of estimates, forecasting and monitoring information. For example:

- it may not be clear on what basis cost estimates have been prepared and what year they apply to
- projects may rely on earlier evaluations that have not been updated to reflect later changes in costs, benefits and project scope prior to funding approval
- modelled forecasts or economic evaluations may not state what scenarios or input assumptions have been applied
- project reports cannot be located in public records and may have been returned to external consultants.

### 7.10.3 Costs

Cost estimates tend to change markedly throughout any given project and, even though many of these changes are formally approved, for PIR purposes it is important to standardise on the cost estimates at a specific stage in the scheme development – ideally those costs (and associated benefits and BCR estimates) which were used as the basis on which the decision to proceed with the scheme was taken. However, we found that the construction approval cost was only identical to the pre-implementation economic evaluation cost used in one of our case studies (Alpur B2).

It is also important to note that the basis on which cost estimates have been prepared is often unclear as to what has been included or excluded. This relates to the issue of defining project scope, which was particularly difficult in the case of the Auckland northern busway.

For true comparison purposes, costs need to be in equivalent year terms and also to have been prepared on the same basis (eg the 50th and 95th percentiles). Often the available project documentation is not specific about the cost year referred to, ie whether costs have been discounted back or escalated forward to a common year, or whether figures are simply in nominal cash terms in a given year.

The categorisation of costs and associated funding arrangements also mean that post-implementation evaluation can be difficult, for example the mix of capital grant and capital funding from borrowing for Alpur B2, and the on-going operational subsidy in the case of Alpur B2 and the northern busway.

#### 7.10.4 Safety

Safety data was obtained from the NZTA CAS system. Where social costs have been quoted it should be noted that these reflect the cost of road crashes and injuries. Different values have been estimated for each region for each time period. The values are influenced by the number of fatalities and injuries per crash (some regions have higher numbers of casualties per crash) and by reporting rates.

Additionally an unpublished estimate is used when calculating non-injury/property damage only costs. The total number of open road non-injury crashes and the total number of urban non-injury crashes are estimated from the actual numbers reported.

Future trends in the social cost of crashes are influenced by changes (probably increases) in VKT, the proportion of 'two wheelers', better vehicle safety and other improvements (including education, enforcement, regulation, road engineering improvements). At the national level, this is expected to result over time in a downward trend in social cost and in the number and severity of casualties,

The assessment and forecasting method for estimating safety impacts is (typically) based on links directly affected by the project scope, in other words the pre-implementation safety record of the old road is compared with the forecast post-implementation record of the new road. For economic evaluation purposes the safety methods in the EEM volume 1 (section A6) are generally used for link and intersection analysis.

These forecasts are based on a restricted definition of project influence and the application of assumptions that do not fully account for site-specific factors or influences of localised speed changes on affected parts of the network.

In contrast, the use of CAS polygons (covering the project area of influence), as applied in the case studies to describe actual before and after safety records, is a more accurate technique.

In some cases, such as the northern busway, a wider network-wide default crash rate per vehicle km unit method has been used; however, this is a very coarse technique.

The use of approximate forecasting methods may be one reason why the case studies exhibited wide discrepancies between forecast and actual social costs of crashes.

For example, increased speeds on existing roads could be a contributory factor in the non-achievement of forecast safety benefits on the Alpur B2 and WICB. Speed-related changes do not appear to have been factored into the safety forecasting procedures for these projects.

Given what appears to be generally poor performance in forecasting the social crash cost impacts of road schemes, it may be appropriate for the NZTA to undertake a detailed reappraisal of current forecasting methods, making use of the considerable before and after data that has now accumulated from the PIR system and from case studies such as those represented here. In particular, there is potential to improve the scope of safety assessments by considering all affected parts of the network, especially where traffic volumes, speeds or composition are expected to change significantly. In doing this it is important to avoid the simplistic application of safety models based on pro-rata demand/social cost reduction or to assume that uncommitted safety treatments will be applied to future networks.

### 7.10.5 Traffic modelling

The reliance on transport modelling for significant elements of economic evaluation raises the question of how best to utilise modelling methods in the evaluation of post-implementation conditions.

In each of the case studies, modelled outputs have been examined and the merits and limitations of the various modelling approaches used have been reviewed, for example:

- in one case (WICB), the consultants undertaking a post-implementation review of traffic changes, re-ran the model retrospectively to review the accuracy of pre-implementation forecasts
- in another case (NB), as part of a post-implementation review being undertaken concurrently with this research, the ART3 model was run to estimate current effects with and without the project.

No detailed assessments of induced traffic effects were undertaken in the development of the case study projects, although in the case of the WICB an independent review of the potential significance of induced traffic was undertaken during the evaluation process. Some post-implementation estimation of re-routed traffic was also undertaken for Alpur B2.

The EEM volume 1, A11 contains advisory procedures for the modelling of potential induced traffic effects for major projects. However, the techniques generally used in current New Zealand practice to estimate induced traffic effects remain relatively simplistic, when compared with good international practice.

The appropriate interpretation and operation of models is increasingly required for the review of large scale and complex projects. In the case of networks with substantial route or mode choice, particularly in major urban areas, modelled overall estimates of traffic volumes, travel times and other key variables are required to supplement measurable monitoring information gathered at specific locations.

However, even if all forecasting was to be re-run retrospectively, there are limitations in the ability of models or any other analytical techniques to accurately predict future conditions. It is also possible that forecasts could be flawed because of incorrect assumptions relating to planning, economic growth forecasts or population projections.

For interpretation purposes, therefore, it is important to understand: the nature of the modelling undertaken, all assumptions used, and the basis on which forecasts have been prepared; and to systematically record these for later review. This will facilitate understanding of why estimates of user benefits may have been either under or over predicted.

### 7.10.6 Economic evaluation

The type of case studies reviewed in this research have not (historically) been subject to systematic comprehensive and detailed post-implementation review. This is partly due to the scale and complexity of the projects concerned.

For all the case study projects examined, the main focus of our evaluation was to compare observed conditions shortly after project implementation with observed conditions in the few years prior to implementation.

Depending on the project concerned, these pre and post situations are generally between two and six years apart. However, this varies depending on the type of project and data set being used, for example, in terms of safety, five years pre-implementation and five years post-implementation data were analysed when possible.

Ideally, our assessments would allow for any 'underlying' changes (ie not related to the project itself) in this two to six year (or longer) period. For example, sub-regional, regional and national casualty trends

and associated social costs were used to allow background comparisons to be made with equivalent localised pre- and post-implementation changes within the probable area of influence of projects.

When considering economic evaluation aspects, our primary focus was on shorter-term project impacts, and comparing these with the prior situation and/or the shorter-term 'do minimum' forecast scenario.

We did not attempt to calculate updated estimates of project BCR performance in any detail, as this would have involved re-forecasting exercises in the light of changes since the pre-evaluation. However, we did assess in outline the probability or otherwise of the pre-forecast BCR being achieved.

We suggest it would be appropriate to include the first-year rate of return (FYRR) performance (compared with its pre-implementation forecast) in all post-implementation reviews. .

## 7.11 Future research and monitoring needs and recommendations

The appraisal of New Zealand case studies in this section has identified the lack of an overall comprehensive framework to adequately guide pre-implementation appraisal and post-implementation review. New Zealand currently relies on a diverse mixture of individual guidelines, resulting in gaps and inconsistencies in the approach to appraisal and review. This in turn means that a comprehensive understanding of project effects is lacking in many cases.

A summary of research needs and associated recommendations is provided in table 7.8. This table indicates that current practice is fragmented and partial and that more comprehensive monitoring is required within an overall pre-implementation appraisal and post-implementation evaluation framework.

**Table 7.8 Research needs and recommendations**

Research need	Research recommendations
<b>Appraisal and review framework</b> There is no comprehensive framework to guide pre-implementation appraisal or post-implementation review procedures.	There is a need for 'core' and 'occasional' performance indicators to be developed within an overall appraisal and review framework. Guidelines and indicators need to be developed within an overall framework for application in pre-implementation appraisals and post-implementation reviews. This should be supported by the development of a project typology for scope and information requirements.
<b>Techniques/methodologies</b> For some factors there is an absence of New Zealand techniques (eg for severance and disturbance). As a result, a number of potential factors tend to be omitted or treated subjectively in project appraisals.	Quantified analytical techniques should be developed for appraisal purposes. Methodologies for post-implementation reviews also need to be developed incorporating analysis, modelling and forecasting techniques as required.

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## Appendix A: Travel behaviour impacts

### A1 Introduction

This appendix examines the methods commonly adopted for assessing (ex ante) the impacts of road improvements and new road schemes on travel behaviour, and also the empirical (ex post) evidence on the effects of road schemes, in both shorter and longer terms, on travel behaviour. Particular attention is paid to the assessment of and evidence on 'induced travel' – which can be a major determinant of the economic benefits (or disbenefits) of road schemes but is often a controversial topic.

The appendix is arranged in the following sections:

- Section A2 outlines the types of behavioural responses that typically result from road schemes, and discusses how these responses and induced travel in particular should be appraised (ex ante) in modelling and economic evaluation procedures.
- Section A3 summarises findings from an international review of the empirical evidence on the range of behavioural responses, including the nature, magnitude, circumstances and importance of induced demand.
- Section A4 presents a summary of international practices in regard to the modelling and economic evaluation of induced travel and other behavioural responses.
- Section A5 draws conclusions from the previous sections relating to transport modelling and evaluation procedures, and outlines the implications for project and programme evaluation and selection.

### A2 Travel behaviour responses and induced travel – theoretical issues and concepts

#### A2.1 Behavioural responses to improvements in travel conditions

Travel behaviour is a complex phenomenon, with individuals adjusting their behaviour in a variety of ways to changes in travel conditions. Table A.1 presents a typology of motorists' behavioural changes in response to changes in road travel conditions, typically as a result of transport infrastructure improvements. All behavioural responses except item C 'Trip re-timing' are likely to result in increased road traffic – vehicle kilometres travelled (VKT). Item C is likely to result in increased traffic in peak periods as a result of motorists switching their time of travel from the off peak.

'Induced travel' is an often-used term in the transport literature, but is a somewhat elusive and often loosely defined concept. Essentially, in this report and appendices, the term refers to any increases in travel that result from improvements in the transport system, usually involving the provision of new infrastructure.

The induced travel phenomenon potentially applies across all types and modes of travel:

- It applies similarly to both person travel and freight and commercial travel. While the following commentary generally focuses on person travel, it is largely also applicable to freight and commercial travel.
- It may be applied to (person) travel in total, often referred to as 'induced travel'; and to road/car traffic as a subset of person travel, often referred to as 'induced traffic'. While this appendix focuses

primarily on induced road/car traffic, it also addresses induced traffic on alternative modes, principally public transport (PT).

- The induced travel phenomenon is potentially relevant to both metropolitan/urban and non-urban situations. However, it is of greatest magnitude and consequence in congested metropolitan/urban situations, where the provision of new road capacity may have major effects on travel times, with the potential for substantial induced traffic. This appendix therefore focuses primarily on metropolitan/urban situations, although its commentary is generally also applicable to other situations.

**Table A.1 Behavioural responses to changes in road travel conditions**

Type of behavioural change	Transport modelling terminology	Comments <sup>(a)</sup>
A Route	Assignment	Infrastructure improvements in a corridor usually result in faster travel, thus attracting some trips from broadly parallel corridors. These trips will reduce their travel time but typically increase their travel distance. Hence road traffic VKT increases. This phenomenon is sometimes known as 'spatial convergence'.
B Mode	Mode choice	Improvements in car travel conditions typically result in some people switching from PT (or walking or cycling) to travel by car. Hence road traffic VKT increases. This is sometimes known as 'modal convergence'.
C Timing	Trip re-timing	In the event of high levels of congestion in peak periods, some motorists will choose to travel outside these periods (peak spreading). If this congestion is relieved, they may then revert to travelling in peak periods. Overall road traffic VKT may be unaffected, but peak period VKT may increase. This is sometimes known as 'temporal convergence'.
D Car sharing	Vehicle occupancy	An increase in road travel costs (eg through higher petrol prices or direct road-use charging) may result in more car sharing and hence reductions in overall VKT (although there may be no change in person travel by car). The converse effect may result from reductions in travel costs.
E Trip origin and/or destination	Trip distribution	Improved travel conditions may result in people making longer trips, through a change in either trip destination (eg shopping further from home) or trip origin (eg moving house further from the place of employment). In the medium/long term development patterns may change to take advantage of the improved accessibility, and this may also result in additional VKT (transport-induced land use changes, sometimes resulting in 'urban sprawl').
F New trips/ trip frequency	Trip generation	Improved travel conditions may lead to people making additional trips, taking advantage of the improved accessibility, but maybe without spending any more time on travel in total. This may particularly be the case with recreational and other 'discretionary' types of trip.

**Note:** <sup>(a)</sup> 'VKT' = vehicle kilometres of (car) travel.

The UK SACTRA (1994) report provides the most comprehensive examination to date internationally of induced travel/traffic issues and how they should be addressed in travel (usually road traffic) modelling and evaluation. The report categorises the range of behavioural responses to changes in road travel conditions (consistent with table A.1), and defines several measures of induced travel:

- Induced travel in total (all modes) would usually be taken to cover any (net) changes in overall person travel (person km) resulting from transport system improvements. With reference to table A.1, this

would include the effects of responses A, E and F. For a particular (eg peak) time period, it would also cover response C.

- Induced trips in total refers to response F only: this is often referred to as ‘generated’ trips.
- Induced (road) traffic would usually be measured in road traffic VKT. It would cover all the above responses plus any impacts on VKT from responses B and D.
- Induced (road) trips refers to additional vehicle trips on the road network: this would cover responses B, D and F.

The above concepts (sub-sets) of induced travel essentially refer to impacts over the whole of the area/region being considered. However, for some purposes, the primary interest is in the impacts on a specific corridor, eg the corridor in which a new road scheme is being proposed. In such a case, the induced traffic impacts in the specified corridor are likely to be greater than those for the road network as a whole: some of the additional corridor traffic is likely to be attracted from other parts of the network (response E)<sup>15</sup>.

## A2.2 Transport modelling practices regarding induced travel – overview

The (net) benefits of road improvements or new road schemes typically involve a trade-off between the benefits to some road users (or other groups) affected and the disbenefits to others. The extent of any induced traffic is often a major factor affecting the balance between the benefits and disbenefits, and hence the overall economic merits of the scheme. Given this, it is clearly important that the transport modelling and economic evaluation methods used in scheme appraisal adequately reflect the induced traffic effects likely to occur in practice.

Section A4 of this appendix provides a summary of how the modelling and economic evaluation procedures commonly adopted in New Zealand, Australia and the UK deal with induced travel and traffic. In terms of the capability of current transport modelling procedures to reflect the real-world range of behavioural responses to transport system changes, our summary findings are as follows:

- Many simpler road traffic models (‘fixed trip matrix’ models) allow only for response A ‘Assignment’ in table A.1. They thus cover only one component (often not the most important one) of the full range of induced travel responses.
- More complex urban (road) traffic models (‘variable trip matrix’ models) may also allow at least in part for response E ‘Trip distribution’, and in some cases for response C ‘Trip re-timing’.
- Multi-modal transport models, as used for the main metropolitan areas, generally also allow for response B ‘Mode choice’, in addition to the above. They would thus typically cover responses A, B, part E and sometimes C.
- Most ‘conventional’ multi-modal urban transport models do not allow for:
  - response D ‘Vehicle occupancy’ changes
  - response F ‘Trip generation’
  - part response E ‘Trip distribution’ specifically, the longer-term induced land use effects.

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<sup>15</sup> The UK SACTRA report was primarily concerned with impacts on specific corridors affected by proposed new/improved trunk road schemes. It therefore focused on corridor impacts rather than network-wide impacts.

### A2.3 Travel behaviour and induced travel demand – an economic framework

A key issue in considering the induced travel phenomenon is its economic effects (from a societal welfare viewpoint) in various circumstances, and in particular when it can be considered 'good' or 'bad' in economic welfare terms. Understanding and interpreting this issue is critical to the economic evaluation of potential urban transport improvement schemes and to determining the appropriate policy responses to the phenomenon. This section therefore provides an overview of the induced travel phenomenon within an economic framework and outlines the policy implications of this.

The appropriate economic framework for assessing induced travel demand applies micro-economic theory on utility maximisation to consumers' transport decisions. The value of utility (satisfaction) that consumers place on a particular good or service (in this case travel) is reflected in what they are willing to pay for it; consumers act to maximise their utility from travel, subject to this utility exceeding what they pay, defined in terms of travel costs (see below).

The value that consumers place on travel is often expressed as their 'willingness to pay' (WTP). While consumers derive increased utility from increased consumption of most goods, including transport, their marginal utility (WTP) progressively decreases ('law of diminishing marginal utility'). The relationship between the demand for travel of consumers as a group and their willingness to pay for it is represented by a downward-sloping curve (ie the higher the price, the lower the demand).

If the demand for travel was unaffected by the price (an 'inelastic' demand curve), then there would be no induced travel. However, all the evidence indicates (for transport as for most other consumer goods) that demand is responsive to the price of travel (ie 'elastic' demand): hence induced travel occurs.

Demand curves for transport can be expressed as a function of money costs or time costs or a combination of the two. This 'generalised cost' incorporates the financial cost perceived by the traveller (petrol, fares, etc) and their valuation of their own time costs, including any quality aspects of the transport system (eg congestion, comfort). The generalised cost approach is usually used in economic analyses of transport demand.

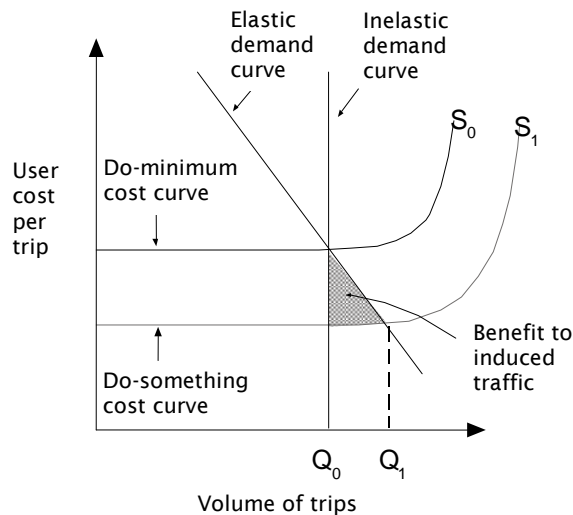
The generalised costs of travel to an individual are dependent on the specific conditions that pertain on the particular network. For road traffic, travel costs are minimised in situations where few people are travelling. As demand increases to a level close to the supply capacity, 'congestion' occurs – travellers are slowed down and their costs increase. The market supply curve (costs of travel versus demand) is reasonably flat at low levels of demand and then increases steeply as capacity is approached.

Supply and demand are in equilibrium where the supply curve and the demand curve intersect: this indicates the point at which consumers have balanced their willingness to pay for travel with the costs of the travel that they undertake. This point is where utility is maximised for a given market (but subject to certain conditions).

## A2.4 Impacts of induced travel on transport users and economic welfare

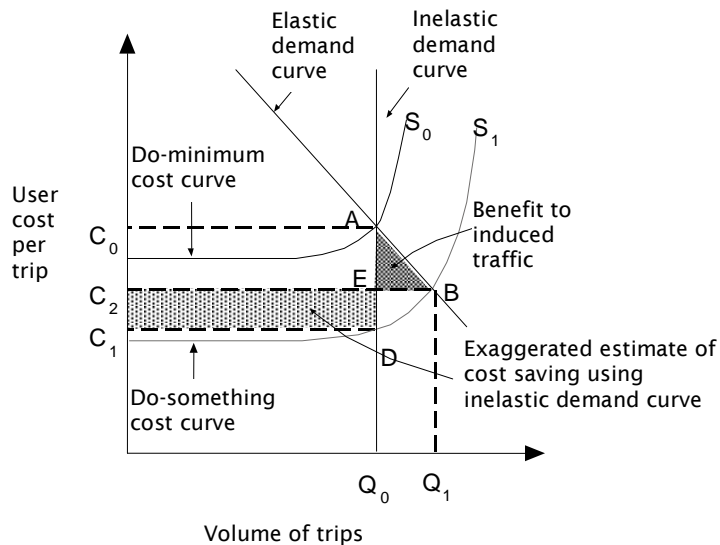
Figure A.1 provides a graphic representation of the economic effects of induced travel, illustrating the discussion above.

**Figure A.1(a) The economics of induced traffic – user benefits: addition of road space in uncongested conditions**



### A2.4.1 Uncongested conditions (figure A.1(a))

- This illustrates the impacts of increasing road capacity in uncongested situations. The road user cost vs volume curve moves from curve  $S_0$  ('do minimum') to  $S_1$  ('do something').
- If the demand were inelastic (vertical demand curve at  $Q_0$ ), each user would gain a benefit  $(C_0 - C_1)$  giving a total benefit  $(C_0 - C_1) * Q_0$ .
- In practice, the demand is somewhat elastic, represented by the downward sloping line. In this case, the elastic demand results in additional traffic ( $Q_0 - Q_1$ ). For small changes in traffic volume, the benefits to this traffic are represented by the shaded triangle, and approximate to  $\frac{1}{2}(C_0 - C_1) (Q_1 - Q_0)$ .
- In this case, the benefits to users in the inelastic case (above) have not been affected, and there is an additional benefit associated with the new (induced) users.
- The above represents the benefits as perceived by users. However, this may not represent the economic benefits to society, if users do not perceive the full costs of their travel: this effect is common for car travel, where most users make decisions on their travel without taking account of their true (variable) vehicle maintenance and depreciation costs and of the environmental costs they impose on society. Thus, to assess the benefits of the induced travel to society, those costs not perceived by users (often termed a 'resource cost correction') need to be subtracted from the triangle of perceived user benefits. The outcome may be either a positive or negative societal benefit associated with the induced travel.

**Figure A.1(b) The economics of induced traffic – user benefits: addition of road space in congested conditions****A2.4.2 Congested conditions (figure A.1(b))**

- In congested conditions, if demand were inelastic, then no traffic would be induced and the benefits would remain as above in the inelastic case, ie:

$$(C_0 - C_1) * Q_0.$$

- With congested conditions and elastic demand, the situation changes. The benefits to induced travel remain essentially as above, ie represented by the shaded triangle AEB, less any 'resource cost correction' adjustment.
- However, the induced traffic now slows down all the pre-existing traffic. The equilibrium position is now at cost  $C_2$ , instead of  $C_1$  previously. The benefits to the existing traffic reduce from rectangle  $C_0C_1DA$  to  $C_0C_2EA$ , ie there is a benefit loss represented by the shaded area  $C_2C_1DE$ .
- Thus the overall benefits associated with the induced travel are the net sum of:
  - induced trips benefit (shaded triangle AEB), adjusted for any 'resource cost correction'.
  - existing trip disbenefit (shaded rectangle  $C_2C_1DE$ ).
- The result may be a positive or negative net benefit associated with induced travel, depending in particular on the slope of the demand curve (elasticity) and the shape of the supply curve in the area of interest. Essentially, the more congested the network and the more elastic the demand, the more likely it is that the induced travel will result in overall disbenefits, to both users and society.

**A2.5 Some economic implications of the analyses**

The above conclusion is fundamental to understanding the economics of induced travel (for road traffic in particular), and hence to taking informed policy decisions relating to urban road investment and management. Various implications follow from these analyses:

- In uncongested conditions, the net benefits to society associated with induced road traffic may be positive or negative, depending on the extent of traveller misperceptions of their own costs and on the extent of any costs their travel imposes on society.

- In congested conditions, the net benefits to society associated with induced travel may again be positive or negative. However, they are likely to be negative in most congested urban situations, particularly when the market demand curve is elastic.
- Thus a 'typical' urban road capacity enhancement scheme is likely to generate substantial positive net benefits in its initial years after opening, assuming congestion is then modest. However, these benefits will tend to be eroded over time, as traffic volumes increase and congestion worsens, and the presence of induced travel reduces the overall benefits.
- Overall, in the majority of cases involving major urban road enhancement schemes, the net economic benefits when induced traffic is allowed for are significantly lower than if it is ignored in the transport modelling/evaluation process.

From the economic perspective, the disbenefits associated with induced travel are the result of potential travellers not being faced with the full (marginal social) costs associated with their travel decisions. These full costs comprise:

- travellers' own variable costs (eg vehicle maintenance)
- the congestion costs that each traveller imposes on other road users (through increasing their travel times)
- the costs that travellers impose on society as a whole (eg local environmental impacts, global/greenhouse gas emissions).

The second of these, the congestion costs, is the single largest cost component not borne by the individual motorist in typical urban situations, especially at peak periods.

The economist's approach to this problem would be to introduce a road pricing system based on users being charged prices approximating to the above marginal social cost components. This would result in net economic benefits being maximised, with traffic volumes (including induced traffic) being reduced to the economic optimum level consistent with this. Such a pricing policy would 'lock-in' the benefits of major road capacity investments as traffic demand grows. The policy implications of the induced travel phenomenon are addressed further in section A5.

## A3 The empirical evidence

### A3.1 Overview

This section summarises the international empirical evidence relating to the impacts of transport (road and PT) system improvements on travel behaviour, including induced travel and traffic levels. It comprises eight main sections, in the following five groups:

- Impacts of specific road improvement schemes on travel behaviour and induced travel – on traffic volumes (section A3.2), on travel behaviour (A3.3) and on travel times (A3.4).
- Response of road traffic volumes to changes in travel time, expressed as demand elasticities (A3.5).
- Evidence (from USA data) on the relationships between traffic volumes, levels of congestion and changes in road capacity at a regional level (A3.6, A3.7).
- Impacts of road improvement schemes on land use development and hence on traffic volumes, in the longer term (A3.8).
- Impacts of PT system improvements on travel behaviour and induced travel (A3.9).



## A3.2 Specific road improvement schemes – traffic volume impacts

### A3.2.1 Overview

This section summarises and comments on the evidence available from specific new and improved road schemes, in New Zealand/Australia and UK/Europe, on traffic volumes in the corridors concerned, as derived from before and after screenline traffic count information for the corridors.

### A3.2.2 Framework for reviewing induced traffic findings

The screenline traffic count approach is the dominant method used to assess induced traffic volumes: it is most relevant to the task of estimating the impacts of new and improved road schemes on traffic volumes in the corridor in question (which was the main issue of interest in the UK SACTRA (1994) report). However, it has major limitations as a means of estimating induced road traffic (VKT) or person travel (PKT) as generally defined, at a network level, because of several considerations:

- The measure of induced traffic derived from an increase in screenline flows covers several potential responses to road improvements (eg redistribution, modal switching, pure trip ‘generation’), and information is not available to separate these.
- The screenline measure takes no account of changes in trip lengths associated with traffic reassignment in the corridor, which may well be one of the larger components of VKT changes resulting from road improvements.
- Even aside from this point, the screenline measure gives no indication of the net traffic volume (VKT) effects likely on the network as a whole, as distinct from within the particular corridor (it would be expected that trip redistribution would increase traffic in the corridor affected but reduce it on the remainder of the network). These network-wide effects are of most relevance when considering overall fuel consumption, pollution etc, and they cannot be simply derived from the corridor effects.

Before examining the results from traffic screenline studies, it is therefore important to understand what is being measured through such studies and how the outputs of such studies relate to other, more comprehensive, measures of induced travel. This is done in the framework given in table A.2. The table shows, for each type of behavioural response to a new/improved road, how this response manifests itself in the corridor/screenline analyses and how it translates into aggregate network-wide impacts on total car travel (VKT) and total person travel (PKT). Key points to emerge from this assessment are:

- Additional traffic observed in screenline analyses includes:
  - effects of wide-area reassignment, redistribution, modal shift and trip generation (all primarily short/medium-term responses)
  - effects of transport-induced land use changes (primarily longer term).
- Screenline analyses do not fully reflect aggregate system-wide changes in VKT:
  - they do not capture increased average trip lengths due to reassignment
  - screenline traffic increases due to redistribution and land use changes will be partly offset by traffic reductions elsewhere on the network (but some net increases in VKT are likely).
- At the aggregate network level, increases in VKT are likely to result from:
  - reassignment (longer routes)
  - redistribution and land use changes (longer trips)
  - modal shifting (new car trips)

- ‘generation’ (new trips, by car).

In addition, time shifting will contribute to increased ‘peakiness’ of overall traffic profiles.

- Increases in PKT at an aggregate level will essentially arise from the same factors as above, but excluding the modal shift component.

### **A3.2.3 Expected influences on levels of induced traffic**

It could reasonably be expected that the level of any induced traffic, as measured through screenline analyses, would depend on:

- The extent of travel time (or cost) savings for those benefiting, directly or indirectly, from the improved facility (note that the relevant savings are related not just to the scheme concerned, but to the trip in total). However, there have been remarkably few (if any) studies that have assembled data on both changes in corridor traffic volumes and changes in travel times for specific schemes, so that relationships between the two factors could be established. The limited information available on travel time elasticities (refer section A3.4) has largely been drawn from other sources.
- The strength of other constraints (excluding travel time or costs) influencing travel decisions by those concerned (eg if there are severe parking supply constraints affecting potential trips, then these are likely to limit any induced traffic). Several of the specific studies reviewed discuss how broader transport policies (such as parking restraints) may well reduce any potential induced traffic effects. For this reason, induced traffic levels for radial routes into many major cities (eg London) could be expected to be less than those for circumferential routes (eg London’s M25) and for routes in less constrained situations.

A further factor likely to affect the level of induced traffic (as derived from screenline surveys) is the likelihood of significant switching from PT to car travel: this will be influenced by existing modal shares in the corridor in question, and the extent to which PT and car travel are close competitors in that corridor (refer also section A3.5.2).

Additional factors likely to affect the level of induced traffic will include:

- the mix of journey purposes: travel for recreational/leisure purposes would be more elastic, in terms of total trips, than commuter travel
- the scope for land use changes to take advantage of the improved road travel conditions: this would be affected by land availability, planning regulations, etc.

It will be apparent that there can be no simple rule of thumb for forecasting levels of induced traffic for any particular scheme, or against which any survey results can be compared. The following empirical evidence on induced traffic needs to be judged in that light.

**Table A.2 Summary of travel behavioural effects of road enhancement schemes**

Type of behavioural response	Manifestation in induced traffic (corridor/screenline) studies	Impacts on overall car traffic (VKT) and overall travel (PKT) <sup>(a)</sup>
<b>Reassignment (route shifting)</b>	<ul style="list-style-type: none"> <li>Generally part of base flows captured (no change in screenline volumes).</li> <li>Wide area reassignment may not be part of base flows, but part of additional traffic observed.</li> <li>Primarily short-term effect (within three months).</li> </ul>	<ul style="list-style-type: none"> <li>Generally some net increase in car VKT and in overall PKT (people choose longer routes to take advantage of travel time savings).</li> </ul>
<b>Redistribution (trip end shifting)</b>	<ul style="list-style-type: none"> <li>Part of additional traffic observed.</li> <li>Primarily short/medium-term effect.</li> </ul>	<ul style="list-style-type: none"> <li>Generally some net increase in car VKT and in overall PKT (redistribution results in people making longer trips to take advantage of travel time savings); but net increase less than gross (screenline) increase.</li> </ul>
<b>Modal shifting</b>	<ul style="list-style-type: none"> <li>Part of additional traffic observed.</li> <li>Primarily short/medium-term effect.</li> </ul>	<ul style="list-style-type: none"> <li>Increase in car VKT.</li> <li>Expect minimal change in overall PKT (car routing may be shorter/longer than PT routing).</li> </ul>
<b>'Trip generation' (new trips)</b>	<ul style="list-style-type: none"> <li>Part of additional traffic observed.</li> <li>Primarily short/medium-term effect.</li> </ul>	<ul style="list-style-type: none"> <li>New trips result in increase in car VKT and overall PKT.</li> </ul>
<b>Time shifting (trip rescheduling)</b>	<ul style="list-style-type: none"> <li>No effect on overall daily traffic level; but will increase peak traffic volumes relative to off-peak volumes.</li> <li>Primarily short/medium-term effect.</li> </ul>	<ul style="list-style-type: none"> <li>No overall effects on car VKT or overall PKT; but increased 'peakiness' in demand profile.</li> <li>'Reversion to the peak' likely to result in some overall increase in congestion, fuel consumption, pollution etc (and benefits to shifters) relative to absence of this response.</li> </ul>
<b>Land use changes</b>	<ul style="list-style-type: none"> <li>Part of additional traffic observed.</li> <li>Primarily medium/long-term effect.</li> </ul>	<ul style="list-style-type: none"> <li>Generally some net increase in car VKT and overall PKT (relocation occurs to take advantage of potential travel time savings, but with longer travel distances).</li> </ul>

Note: <sup>(a)</sup> VKT = vehicle kilometres of travel; PKT = person kilometres of travel (all modes).

#### A3.2.4 Summary and commentary on the evidence

Table A.3 provides summaries of induced traffic screenline analyses for 11 specific schemes (five in New Zealand/Australia, six in the UK/Europe) for which reasonably complete information in the required form could be derived.

The table shows, for each scheme:

- Scheme name (and opening date).
- Time period to which the analyses apply. (Generally our approach here has been to focus on the shortest possible before-after period, for which the relevant information is available. While longer 'after' analysis periods are useful in examining medium/longer-term impacts, typically any interpretation of such impacts is obscured by other background effects occurring over the longer period).
- Absolute traffic volume changes (between the 'before' and 'after' data), measured in vehicles/day (columns C, D, E) on:
  - the new or improved route
  - the full screenline selected by the analyst, covering the scheme and those routes either side of it on which traffic volumes are expected to be materially affected by the scheme (through reassignment)
  - the full screenline, but adjusted for any underlying trend changes in traffic volumes in the area in the absence of the scheme: these underlying changes have usually been derived from information from 'control' corridors, but in some cases by examining longer-term trends for the corridor in question.
- Proportionate changes in traffic volumes across the screenline (columns F, G, H):
  - Total traffic increase across the screenline relative to the 'after' traffic volume on the new route itself: this gives some measure of the level of induced traffic across the screenline relative to the traffic carried on the new/improved route.
  - Total traffic increase across the screenline relative to the total 'before' screenline traffic volume (unadjusted): this gives a measure of the level of induced traffic relative to the total corridor traffic.
  - The same ratio, but after adjustment of the screenline traffic increase for any underlying traffic volume changes (as above): this gives a more useful measure of the level of induced traffic in the corridor.
- Notes and comments on the results (column I).

Table A.3 Summary of traffic increase evidence from corridor/screenline surveys – new/improved road schemes

Scheme  (Opening date)	Analysis  Time period	Traffic volume changes (vpd)			% age changes			Notes, sources, reliability  I
		New/ improved route	Screenline total	Screenline adjusted <sup>(a)</sup>	Screenline increase: new route 'after' volume	Screenline increase: 'before' screenline total		
						Unadjusted	Adjusted <sup>(a)</sup>	
A	B	C	D	E	F	G	H	
AUSTRALASIA Sydney M4 motorway (May 92)	1991–93	+31,000	+21,000	+12,000	29%	12%	7%	<ul style="list-style-type: none"><li>Impacts largely within three months of scheme opening.</li><li>Some indications that up to/around half of adjusted traffic increases resulted from mode switching from rail services.</li></ul>
Sydney M5 motorway Stage 1 (1992) Stage 2 (1994)	1991–93 1993–96	+32,900 +5500	+25,000 +31,000	+18,600 +23,800	76%	8% 10%	6% 7%	
Sydney Harbour Tunnel/Gore Hill freeway (1992)	1991–93 (principally)			+9000	5% <sup>(c)</sup>	-	3.4%	<ul style="list-style-type: none"><li>Total PT trips across screenline reduced by c.22,000 persons/day (best estimate), as compared with 13,000 increase in car person trips. Thus strongly indicates that most of 'induced' traffic was result of modal shift.</li></ul>
Melbourne south east arterial (1988)	1985–95	+27,000 <sup>(2)</sup>	+28,000 <sup>(b)</sup>	-	36%	18%	-	<ul style="list-style-type: none"><li>Authors' assessment concluded that no significant induced traffic volumes, but some doubts as to quality of analyses.</li><li>Such a finding is not unexpected, given the (anecdotal) small time savings from the scheme and other constraints on radial traffic (eg CBD parking).</li></ul>
Tauranga Harbour Bridge – toll removal (2001)	2001	+7000	+7000	-	20%	15% (SD ± 6%)	-	<ul style="list-style-type: none"><li>Greater traffic increase in interpeak (c.17%) than peak (c.9%) due to peak capacity constraints.</li><li>Greater increase than average for commercial vehicles (30%).</li><li>Change largely stabilised within three months.</li></ul>
UK/EUROPE Amsterdam ring route completion (1990)	1990					8%	3%	<ul style="list-style-type: none"><li>Household survey (refer table A.4) indicates any growth in traffic was very small.</li><li>There was major 'reversion-to-peak' effect: car traffic across the screenline in AM peak 2 hours increased c.18% (and reduced in periods either side of peak).</li></ul>

The implications of road investment

Scheme  (Opening date)	Analysis  Time period	Traffic volume changes (vpd)			% age changes			Notes, sources, reliability I
		New/ improved route	Screenline total	Screenline adjusted <sup>(a)</sup>	Screenline increase: new route 'after' volume	Screenline increase: 'before' screenline total		
						Unadjusted	Adjusted <sup>(a)</sup>	
A	B	C	D	E	F	G	H	
London M40 (Westway) (July 1970)	SR <sup>(n)</sup> : May– Sept 70  MR <sup>(n)</sup> : Sep 70 –75	47,000  38,000	17,500  44,000	15,000  c.40,000	37%  52%	14%  35%	12%  c.30%	<ul style="list-style-type: none"><li>Major impacts within two months of opening.</li><li>Further strong increase in screenline volumes for next five years after opening (thereafter little change relative to control corridors).</li></ul>
London M11 (Epping) (1975–76)	1974–83	53,000	38,000	c.9000		38%	7%	
London A316 widening (1975–76)	1971–83	38,000	45,000	c.10,000		84%	11%	
London Blackwall tunnels and approaches (1968–69)	SR:1968– 69	10,000 <sup>(b)</sup>	11,000 <sup>(b)</sup>			15%		
London Rochester Way relief road <sup>(e)</sup> (1988)	1988–90	60,000 <sup>(d)</sup>	17,000 <sup>(d)</sup>		28%		8%	<ul style="list-style-type: none"><li>Also effective 6% adjusted traffic increase on parallel screenline.</li><li>Scheme analyses/results have been very controversial.</li><li>Also see interview survey (table A.4).</li></ul>

Notes:

<sup>(a)</sup> Adjusted figures are after allowing for 'underlying' traffic trends in the corridor in question or for trends in traffic volumes in 'control' corridors over the relevant time periods.

<sup>(b)</sup> Relates to 12-hour traffic volumes only.

<sup>(c)</sup> Relates to Sydney Harbour Bridge and Tunnel volumes combined.

<sup>(d)</sup> Relates to 18-hour traffic volumes only.

<sup>(e)</sup> Analyses relate to eastern transverse screenline.

<sup>(n)</sup> SR = short run (within first year after opening); MR = medium run (1-5 years after opening).

In interpreting the results in column I of table A.3, it needs to be noted that considerable professional judgement is involved in each case in choosing the extent of the screenline used (to cover the roads on which traffic volumes are 'materially' affected by the scheme in question): the induced traffic percentages shown in columns G and H in particular will be affected by the extent of the screenline selected.

The findings of most relevance from table A.3 are as follows:

- In most cases of new road links, where short run before-after data is available, the total traffic on the new link C is considerably greater than the traffic increase across the screenline overall D: this is as expected, reflecting traffic relief to the other routes across the screenline. Column F indicates the overall screenline volume increase is generally 20% to 40% of the traffic volume on the new route: this indicates that only a minority of the traffic volume on the new route will be induced, most is likely to be reassigned.
- However, the more useful measure of induced traffic is that in column H. For all cases where short run before-after data is available, the ratio of induced (adjusted) traffic to the total screenline volume is in the range 3% to 12% (unweighted average 7%). This gives the best guidance available on the 'typical' extent of short-term induced travel on a corridor/screenline basis for these schemes analysed: however, it is likely to understate longer-term induced traffic effects (see following). It also needs to be kept in mind (as discussed earlier) that numerous factors will affect the level of induced traffic associated with specific schemes, and hence the proportion of induced traffic would be expected to differ considerably between schemes (arguably there is no typical scheme in this regard).
- Where information is available on the time period over which the induced traffic response occurs:
  - in most cases the major changes appear to occur within the first three months (the reassignment response also appears to settle down within this period)
  - changes beyond this period are more gradual and difficult to distinguish from underlying trends
  - however, in at least one case (London M40) strong growth on the route continued for a further five years (an additional 30% to 35% traffic growth on the corridor relative to control corridors), but thereafter growth rates reverted to close to underlying levels<sup>16</sup>.
- In terms of the time of day of travel, where information is available, the net level/proportion of induced traffic in peak periods was generally greater than in non-peak periods, principally due to the 'reversion to the peak' effect (and despite the fact that most pure 'generated' trips are likely to be in non-peak periods).

As noted earlier, insufficient information is generally available to break down these induced traffic impacts into their component parts; to the extent that such information is available, this is examined in the next section.

### A3.3 Specific road improvement schemes – travel behaviour impacts

#### A3.3.1 Overview

The previous section examined the evidence on induced traffic effects in aggregate resulting from new/improved road schemes, principally as manifested through changes in corridor traffic volumes. This

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<sup>16</sup> The London M40 scheme provided substantial time savings in its corridor relative to all alternative routes: this may well be a factor behind the high initial level of induced travel (12% within two months of opening) and the subsequent continuing high growth rates.

section investigates the sources of the induced traffic, disaggregated by the different types of behavioural responses.

The evidence examined here comes from two principal groups of sources:

- Interview surveys of users of a new/improved road scheme about their before/after behavioural changes relating to their specific trips. This evidence is summarised in table A.4. Such evidence is valuable, as it potentially sheds light on the full range of behavioural responses, but it is very limited (we have been unable to identify any other surveys of this type).
- Before/after statistical (time trend) analyses of PT patronage in corridors affected by new/improved road schemes, to provide estimates of any change in PT usage relating to the introduction of the scheme. This evidence is summarised in table A.5. Such evidence is valuable in shedding light on the modal shift impacts of schemes, but is also very limited.

The following sub-sections summarise the findings that can be drawn from this evidence as to the various components of induced traffic.

#### **A3.3.2 Modal shift – public transport**

The main modal shift effect is likely to be people switching from PT to car, to take advantage of the relative improvement in car travel conditions in the corridor concerned. *A priori*, we would expect this response to be greatest in situations with:

- PT holding a substantial mode share in the corridor (implying that PT is a competitive alternative to car for many trips in the corridor)
- rail services, rather than bus services (in general, rail carries a higher proportion of passengers with a car available than does bus, particularly for longer trips).

Drawing from tables A.4 and A.5, we can summarise the strength of the PT-to-car modal shift (in the short term) for each scheme as follows:

- Sydney Harbour Tunnel – PT mode shift (principally from train) appears to account for the majority of total induced traffic (c.3% across screenline).
- Sydney M4 motorway – PT mode shift (from train) may account for up to/about half of total induced traffic (c.7% across screenline), but this result is not statistically robust.
- Amsterdam ring road – minimal shift from PT (this is an orbital route, serving dispersed origins/destinations, for which PT is not a strong competitor).
- Rochester Way relief road – PT mode shift (from train) estimated to account for 3% of ‘after’ trips and a significant proportion of overall induced traffic.
- Wellington Newlands interchange – small PT mode shift (from train), accounted for 2% of ‘after’ trips.
- London Hammersmith Bridge closure (a capacity reduction scheme) – switch to PT appears to be a significant proportion of overall response (insufficient detail available).



Table A.4 Summary of interview surveys of drivers using new/improved schemes

Scheme	Amsterdam ring route	Rochester Way relief road (London) <sup>(a)</sup>	Newlands interchange (Wellington)
<b>Scheme type</b>	Completion of orbital motorway	Local bypass for trunk route in London suburbs	Grade-separation to remove bottleneck on major radial route
<b>Opening date</b>	1990	March 1988	April 1998
<b>Survey type</b>	<ul style="list-style-type: none"> <li>Before (4 months) and after (2 months) panel household (telephone) survey.</li> <li>Households in areas where travel likely to be affected by scheme, focusing on affected trips.</li> </ul>	<ul style="list-style-type: none"> <li>After (4 months) telephone survey of car drivers using new route (intercepted on route, 1400–1700 weekdays).</li> </ul>	<ul style="list-style-type: none"> <li>After telephone survey of persons travelling to work along route in the 7am to 9am period (recruited by telephone in main commuter areas along corridor).</li> </ul>
<b>Samples</b>	<ul style="list-style-type: none"> <li>Selected individuals in c.5000 households.</li> </ul>	<ul style="list-style-type: none"> <li>184 completed interviews (24% response rate of those intercepted).</li> </ul>	<ul style="list-style-type: none"> <li>Small (c.100).</li> </ul>
<b>Travel time savings</b>			<ul style="list-style-type: none"> <li>Typically 7–10 minutes in peak periods.</li> </ul>
<b>Travel time variability reductions</b>			<ul style="list-style-type: none"> <li>Yes – significant.</li> </ul>
<b>Induced traffic level effects:</b> Route change Mode change Trip end change New trips	<ul style="list-style-type: none"> <li>25% (of drivers crossing screenline)</li> <li>Possible switch car pax to car driver</li> <li>No change</li> <li>No change</li> </ul>	<ul style="list-style-type: none"> <li>97% (to use new route)</li> <li>3% (assumed train to car)</li> <li>3%</li> <li>10% <sup>(b)</sup></li> </ul>	<ul style="list-style-type: none"> <li>10%</li> <li>2% switch train to car</li> <li>No change</li> <li>None</li> </ul>
<b>Trip retiming effects:</b> Reversion to peak Other responses to faster travel times: <ul style="list-style-type: none"> <li>later trip departure</li> <li>earlier trip arrival</li> </ul>	<ul style="list-style-type: none"> <li>29%</li> <li>N/a</li> <li>N/a</li> </ul>	<ul style="list-style-type: none"> <li>24%</li> <li>N/a</li> <li>N/a</li> </ul>	<ul style="list-style-type: none"> <li>10%</li> <li>29%</li> <li>44%</li> </ul>

Notes:

<sup>(a)</sup>Doubts regarding some of survey results – appear not fully consistent.<sup>(b)</sup>Original authors describe these as induced trips. However, we suspect they include some ‘new’ trips that did not occur prior to the scheme opening but related to changes in residential or job location, etc.

**Table A.5 Additional evidence on modal shift from new/improved road schemes**

Road scheme	Summary of modal shift evidence
Sydney Harbour Tunnel/Gore Hill freeway	<ul style="list-style-type: none"> <li>Modal shift from PT (principally train) to car appears to account for the major proportion of the (short term) induced traffic across the surveyed screenline.</li> <li>Appears to be a robust result.</li> </ul>
Sydney M4 motorway	<ul style="list-style-type: none"> <li>Modal shift from PT (train) to car may account for up to/about half of the (short term) induced traffic across the surveyed screenline.</li> <li>However, this finding is not robust in statistical terms.</li> </ul>
Melbourne south eastern arterial	<ul style="list-style-type: none"> <li>Some minor shift from PT (rail) to car may have occurred, but not statistically significant and likely to be very small.</li> </ul>
London Hammersmith Bridge closure <sup>(a)</sup>	<ul style="list-style-type: none"> <li>Following bridge closure, 16% of former car users across the bridge indicated they changed mode for their trip – to PT, walking or cycling.</li> </ul>

Note: <sup>(a)</sup> This scheme involved a reduction in road capacity, rather than the increases in other cases.

While it is dangerous to generalise from such a small and diverse sample of schemes in a range of countries, our (tentative) conclusion would be that, for main radial corridors in large cities, where rail-based PT services account for a substantial proportion of overall modal share, new/improved road schemes may induce modal shifts from PT (primarily rail) to car that account for:

- up to half or more of the total corridor induced traffic
- an overall increase in corridor traffic of up to 2% to 3%.

We would further comment that:

- These conclusions relate principally to short-term effects (within a few months of road scheme opening; in the longer term, the extent of mode switching may be somewhat greater.
- The limited evidence, but supported by wider market research, is that such PT mode shifts are primarily from rail services rather than bus services. This reflects that rail was usually the dominant PT mode in the corridors examined, and that generally a larger proportion of rail users had cars available.
- While the direct evidence is not available, we would expect that most of the modal shifting effect related to peak periods (when 'choice' travellers may have previously chosen train to avoid the car congestion) rather than off-peak periods (when congestion is much less of an issue). Hence the potential increase in corridor traffic of 2%–3% suggested above would represent a greater proportion of peak corridor traffic volumes.

### A3.3.3 Modal shift - other modes

Very limited evidence is available on any switching from modes other than PT in response to new/improved road schemes; we would in any event expect such behavioural responses to be very minor in most cases.

We note two pieces of relevant evidence:

- Amsterdam ring route – some evidence of a small switch from car passenger to car driver
- Hammersmith Bridge closure – indications of some switch from car to walking and cycling (as these modes were still allowed to use the bridge) – but no numerical estimates available.

It is not possible to draw any conclusions for other modes, beyond saying that these responses are likely to be very small (smaller than for PT) in most cases.

#### **A3.3.4 New trip generation and trip redistribution**

Table A.4 shows all the very limited information available on trip redistribution ('trip end shifting') and generation of entirely new trips. Our comments on this information are as follows:

- For all three schemes, the main scheme impacts (in terms of travel time savings) are in the peak periods, and any off-peak impacts would probably be smaller or insignificant.
- For peak periods, new trip generation from such schemes is likely to be negligible. Trip redistribution would probably be very small in the short term (within a few months of scheme opening); but maybe progressively larger in the long term, as people move jobs and residential location to take advantage of improved accessibility. Only the short-term impacts are reflected in the table A.4 results.
- Table A.4 shows new trips only in the case of the Rochester Way scheme: however, as noted, we suspect that these 'new' trips (10%) largely arise from ongoing changes in residential or job location independent of the road scheme.
- Similarly, for redistributed trips, the only apparent change relates to the Rochester Way scheme (3%); however, as above we would not place much reliance on this estimate being the result of the scheme.

Our conclusions on trip generation and redistribution are therefore as follows:

- From the empirical evidence, we would conclude only that both effects appear to be very small in the short term.
- For new generated trips, we would in any event expect minimal impacts from such schemes, which primarily affect travel times in peak periods. For other schemes which affect off-peak travel, greater impacts might be expected.
- For redistributed trips, we would expect any impacts would gradually increase over time, and would relate primarily to peak periods for these schemes, but also potentially to off-peak periods for schemes that affect off-peak travel times.

#### **A3.3.5 Trip retiming impacts**

Two distinct trip 'time-shifting' behavioural effects are covered in the bottom section of table A.4:

- 'Reversion to the peak' – where people change their time of travel to take advantage of the decongestion resulting from road schemes: this is the converse of 'active' peak spreading.
- Marginal changes in trip departure and/or arrival times, in response to the reduced travel times resulting from road schemes (ie 'stay in bed later' or 'get to work earlier'): this is the converse of 'passive' peak spreading.

While 'reversion to the peak' does not involve any change in overall traffic volumes, all the evidence indicates it is an important behavioural response (arguably second only to the reassignment response) to new/improved road schemes (DfT 2006). It can have major impacts on peak period congestion levels (ie they do not reduce as much as expected, particularly in the 'peak of the peak') and on scheme economic benefits ('decongestion' benefits may be less than expected, but evaluation should also take account of 'time shifting' benefits).

Table A.4 indicates that, for the three schemes, between 10% and 30% of motorists responded to the schemes by 'reversion to the peak'; these relatively large proportions highlight the importance of this response.

In terms of marginal changes in trip departure/arrival time, the one survey that addressed this (for AM peak commuters) shows that rather more people responded to the travel time savings by arriving (at work,

etc) earlier than by starting their trip from home later. These are short term responses and would not necessarily apply in the longer term (when other constraints on travel might change).

## A3.4 Specific road improvement schemes – travel time impacts

### A3.4.1 Overview

This section assesses the evidence, for major new road/improvement schemes, on the scheme impacts on travel times for motorists in the corridor in question. The purposes of this assessment were primarily:

- 1 To examine whether there is validity in the view that new road capacity will ‘fill up’ with additional traffic, within the short to medium term, and thus travel times will not reduce from previous levels.
- 2 Where possible, to relate travel time savings on particular corridors to the level of induced traffic in those corridors, in order to derive the effective induced traffic ‘elasticities’ with respect to travel time, on a corridor (rather than overall network) basis. This should provide additional travel time elasticity evidence, to supplement the network-wide estimates summarised in section A3.5.

In regard to purpose 1, the evidence is given in section A3.4.2 below. We note that, despite the very large expenditures involved in major road capacity enhancement schemes, there appears to be relatively limited systematic before and after monitoring of the effects of such schemes on travel times.

In regard to purpose 2, we have been unable to identify any case studies where before and after travel time changes and the extent of induced traffic in the affected corridor have both been determined (in such a way that the two effects may be compared). This is somewhat remarkable, given the extent of efforts made in the last 20 years or so, in the UK in particular, to investigate the induced traffic phenomenon.

### A3.4.2 Summary and commentary on results

Table A.6 summarises the information we have been readily able to identify on the travel time impacts of major road capacity enhancement schemes, particularly in New Zealand and Australia.<sup>17</sup>

The most comprehensive scheme information in the table relates to the Melbourne City Link project. The survey results (with the ‘after’ survey undertaken shortly after the scheme completion) indicate time savings in the order of 20 to 30 minutes in the peak period for traffic travelling the full length of the scheme and also (lesser) savings in most instances on the competing routes. It may be argued that the Melbourne City Link is an exceptional case, being a tolled route; however, it is notable that in most instances there are also time savings on the competing routes.

The other schemes summarised in table A.6 have also resulted in significant time savings (and, we suspect, a reduction in the variability of travel times, although there is little data on this aspect).

We are not aware of any major road capacity enhancement schemes internationally that have **not** resulted in significant travel time savings for their users.

We should stress that the table A.6 results and the comments above relate to the ‘short-term’ situation, within a few months of scheme opening in every case. Longer-term monitoring data is rarely, if ever, available. However, if induced traffic elasticities are substantially higher in the longer term (as indicated in

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<sup>17</sup> A comprehensive literature search would undoubtedly identify further schemes internationally for which before and after travel time data is available. However, this was not undertaken for this project, as such evidence on its own would not shed further light on the relationships between travel time savings and induced traffic levels. Table A.6 already provides sufficient evidence that new road capacity does not necessarily fill up with additional traffic, at least in the short term.

the earlier section), then it would be expected that some proportion of the short-term time savings identified here would be eroded over the longer term.

**Table A.6 Travel time impacts of road capacity enhancement schemes – summary of evidence**

<b>Scheme</b>	<b>Travel time savings summary</b>
City Link project, Melbourne	<ul style="list-style-type: none"> <li>Results from short-term before and after surveys (RACV)</li> </ul> <p><b>Western link</b></p> <ul style="list-style-type: none"> <li>Time savings on new/widened route up to 25 mins peak period/peak direction, 11 mins peak period/opposite direction, 6 mins interpeak period.</li> <li>Time savings on parallel route (Mt Alexander Road) up to 8 mins in peak period.</li> </ul> <p><b>Southern link</b></p> <ul style="list-style-type: none"> <li>Time savings on new/widened route up to 11 mins peak period/peak direction, 10 mins peak period/opposite direction and 9 mins interpeak period.</li> <li>Time savings on parallel route (Toorak Road) up to 13 mins peak period/peak direction, but losses up to 4 mins interpeak period.</li> </ul>
Newlands interchange, Wellington	<ul style="list-style-type: none"> <li>Travel time reductions for major road traffic in the range 7–10 mins in AM peak (inbound).</li> <li>Also reduced variability in trip duration.</li> </ul>
Mungavin Bridge duplication, Wellington	<ul style="list-style-type: none"> <li>Scheme was effective in largely eliminating previous long queues using the bridge in peak periods.</li> </ul>

## A3.5 Road traffic volumes – travel time elasticities

### A3.5.1 Overview

When a road improvement (or new road) scheme is implemented, any induced traffic essentially results from the travel time (and/or cost) savings associated with the scheme, not from the provision of additional road capacity per se. The induced traffic hypothesis is, in essence, that there exists a demand curve for travel – the cheaper the travel, the more will be demanded. ‘Cheap’, in the conventions of transport economics, generally relates to both time and money, the trade-offs between them usually resulting in time expenditures of greater magnitude and effect (certainly, at the margin, the benefits of road improvements to car users are predominantly time rather than money savings).

The slope of the demand curve may be measured through the elasticity of demand. The demand elasticity for car travel (VKT) with respect to car travel time (or cost) reflects the extent of the demand response to any level of travel time changes. This chapter examines the evidence on car travel demand elasticities, primarily with respect to travel time but also with respect to ‘generalised’ cost (ie the weighted sum of money and time costs).

Travel time and generalised cost elasticities provide a useful body of evidence, as the evidence indicates that such elasticities are reasonably stable and hence transferable (for a given market segment) between countries and situations. These elasticities are normally drawn from data on traveller behaviour at the aggregate (network-wide) level, and therefore represent overall network changes in travel, rather than changes on individual corridors. They can thus not be directly applied to estimate traffic volume changes on a corridor that is subject to road improvements.

### A3.5.2 The elasticity evidence and interpretation

Table A.7 provides a summary of international evidence on car travel time elasticities, from a range of UK/EU, USA and Australasian sources. These are largely aggregate elasticities, for both short-run and long-run situations. Limited information on disaggregate values by trip purpose/time period, level of modal competition, etc is available (but refer to the discussion below). Key findings on aggregate travel time elasticities from this evidence are:

- Typical short-run elasticities are in the range -0.2 to -0.35.
- Typical long-run elasticities are in the range -0.5 to -0.75 (ie around two to three times the short-run values).
- Goodwin's estimates are arguably the most robust of those available, being based on an extensive review of various sources of evidence. However, they tend to be significantly higher than most other estimates (ie -0.5 in short run, -1.0 in long run).
- This weight of international evidence indicates values broadly consistent with the UK WebTag estimates derived from fuel price elasticities.
- There is insufficient information available to explore any systematic differences in values by country.
- The values given relate primarily to urban situations (for which there is more evidence). There is some evidence that car travel elasticities (for both time and cost) are higher for rural travel (which involves generally longer and more costly trips) than for urban travel, perhaps by a factor of around 2.

The extent of any more disaggregated elasticity information is rather limited, although some reasonably robust evidence is available from the UK, in summary:

- Elasticities vary substantially by trip purpose (and hence time period).
- Time period switching is a very significant response; elasticities for response within a single time period are substantially greater than overall (all period) elasticities.
- Trip frequency changes (pure trip generation) account for only a modest proportion of overall responses.
- Elasticities also vary by the level of modal competition; in situations of 'high' modal competition, elasticities are in the order of twice as great as under 'low' competition. This illustrates that modal switching accounts for a substantial proportion of total induced traffic effects (based on UK evidence).

**Table A.7 Car travel time elasticities – summary of evidence<sup>(a)</sup>**

Source	Travel time elasticity estimates	Notes
De Jong and Gunn (2001)	<ul style="list-style-type: none"> <li>• Large scale review of available (Western Europe) evidence and model results for car kms elasticities wrt car travel time gave:               <ul style="list-style-type: none"> <li>– overall EU average -0.20</li> <li>– overall EU average -0.74</li> <li>– in both cases, apparently wide range of results by trip purpose and from different studies (no clear pattern evident).</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Largely model-based elasticities.</li> <li>• Noted that SR elasticities wrt car kms are 'more or less half' of long-term figures.</li> </ul>
Goodwin (1996), SACTRA (1994)	<ul style="list-style-type: none"> <li>• Average car km elasticities wrt car travel time is about -0.5SR, -1.0LR</li> </ul>	<ul style="list-style-type: none"> <li>• Goodwin's paper involved a review, recasting and updating of research undertaken for the SACTRA (1994) report: the values used are the same as those in that report.</li> </ul>

Source	Travel time elasticity estimates	Notes
		<ul style="list-style-type: none"> <li>Estimates derived from petrol price elasticities (c.-0.15SR, -0.30LR) and values of time etc, in UK conditions.</li> <li>Estimates result from a review of wide range of evidence (primarily UK-based). Author comments that these values are 'broadly consistent with just about all the disparate evidence'.</li> <li>Noted that the LR values imply that almost all time savings achieved through road improvements would be used for additional travel in the long term.</li> </ul>
Department for Transport (2006)	<ul style="list-style-type: none"> <li>LR car km elasticities wrt travel time values in range (by trip purpose):               <ul style="list-style-type: none"> <li>-0.14 to -0.35 in situations of low modal competition</li> <li>-0.22 to -0.60 in situations of high modal competition.</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Noted that SR values are lower than these LR values, by between 5% and 28% (depending on trip purpose).</li> </ul>
Wallis (2004)	<ul style="list-style-type: none"> <li>Car km elasticities wrt car travel time estimates, for use in New Zealand urban context, are:               <ul style="list-style-type: none"> <li>SR: best estimate -0.30 (range -0.15 to -0.50)</li> <li>LR: best estimate -0.60 (range -0.30 to -0.80).</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Based on review of Australasian and international evidence and its potential application to New Zealand urban situations.</li> </ul>
Luk and Chung (1997)	<ul style="list-style-type: none"> <li>Suggested car km elasticities wrt travel time in Australian conditions as about -0.35SR, -0.70LR.</li> </ul>	<ul style="list-style-type: none"> <li>Authors' estimates based on review of SACTRA (1994) and Goodwin (1996); with results adjusted pro rata to authors' assessment of relative SR fuel price elasticities in Australia (-0.12) and UK (-0.15).</li> </ul>
Cervero (2003)	<ul style="list-style-type: none"> <li>Car km elasticities wrt travel times (speeds) estimated at -0.24SR, -0.64LR.</li> </ul>	<ul style="list-style-type: none"> <li>Used 'path analysis' methods with USA data, to disaggregate the interactions between road capacity supplied, travel speeds, travel demand (VKT) and development activity, in both short and longer terms.</li> <li>Work discussed in Zeibots (2007). She suggests reasons why Cervero's estimates may be on the low side.</li> </ul>

Note: (a) LR = long-run; SR = short-run

### A3.5.3 Conclusions

From the above findings we would draw the following (tentative) conclusions relating to car travel (VKT) elasticities with respect to total travel times in the New Zealand/Australian metropolitan context:

- Typical overall elasticities are around -0.3 in the short run, -0.6 in the long run. This means that a 10% car travel time saving (between a trip's origin and destination) would induce an additional 3% car traffic in the short run, 6% in the long run. These elasticities cover all behavioural influences on traffic volumes, on an all-day basis.

- Elasticities for travel in a given time period (eg peak) may be significantly greater than these all-day estimates, an account of peak spreading/reversion-to-the-peak effects.
- Disaggregate elasticities will vary substantially with:
  - trip purpose (and hence period of day)
  - extent of modal (PT) competition
  - extent of other constraints on car use (eg parking restraint at trip end).

Clearly, the total induced traffic effects on any new road/improvement scheme will depend not only on these travel time elasticities, but also on the actual time savings from the scheme (as discussed in section A3.4).

### A3.6 Road traffic (regional) volumes – road capacity elasticities

A number of USA studies have investigated the relationships between the amount of road traffic (vehicle miles travelled—VMT, or vehicle kilometres travelled—VKT) in a corridor/area/region and the amount of additional capacity provided (typically measured in lane miles). Most of these studies have been undertaken at an area/regional level, involving regression analyses on up to 20 years' traffic data by area/region/county etc. The more sophisticated studies have used 'fixed effects' models, and have in some cases used lagged models to distinguish short-run and long-run effects.

The various study results are summarised in table A.8. Key findings are, in summary, as follows:

- Most of the studies report findings in terms of the elasticity of VMT with respect to lane miles or a similar measure of capacity.
- A wide range of elasticity values is found, between about 0.1 and 1.0.
- Substantial differences are apparent between short-run and long-run elasticity values.
- Where explicit short-run estimates have been made, typical values are in the range 0.15 to 0.3. 'Short-run' values in this context generally relate to a period within one to two years of the increase in capacity.
- Similarly, explicit long-run values are typically in the range 0.6 to 0.9. There are differences of view as to how long it takes until values reach long-run equilibrium levels: one study suggests that near equilibrium is reached within four years, while another suggests values are still increasing beyond at least 10 years.



**Table A.8 Induced traffic elasticities in response to regional road capacities – summary of evidence (USA)**

Source	Analysis basis	Estimated elasticities
STPP (1999)	<ul style="list-style-type: none"> <li>Analyses of Texas Transportation Institute data 1992–97, for 68 metro areas.</li> </ul>	<ul style="list-style-type: none"> <li>VTM elasticity wrt highway lane miles = 0.53.</li> </ul>
Hansen and Huang (1997) – literature review.	<ul style="list-style-type: none"> <li>Review of previous US studies into traffic-inducing effects of road improvements.</li> <li>(i) Kassoff and Gendall (1972): Analysis did not control for other variables – results suspect.</li> <li>(ii) Koppelman (1972)</li> <li>(iii) Payne-Maxie (1980)</li> <li>(iv) Newman (1989): Analysis did not control for other variables – results suspect.</li> </ul>	<ul style="list-style-type: none"> <li>VTM elasticity wrt route miles/capita = ‘below 0.58’.</li> <li>VTM elasticity wrt lane miles = 0.13.</li> <li>VTM elasticity wrt route miles of beltway = 0.12.</li> <li>VTM elasticity wrt road miles/capita = 0.70.</li> </ul>
Hansen and Huang (1993)	<ul style="list-style-type: none"> <li>Analysis of induced traffic impacts of 18 highway capacity expansion schemes on the Californian rural state highway network.</li> </ul>	<ul style="list-style-type: none"> <li>Segment traffic volume elasticity wrt increase in segment capacity estimated, by time from scheme implementation: <ul style="list-style-type: none"> <li>4 years 0.15 to 0.30</li> <li>10 years 0.30 to 0.40</li> <li>16 years 0.40 to 0.60.</li> </ul> </li> </ul>
Hansen and Huang (1993)	<ul style="list-style-type: none"> <li>Analysis of induced traffic impacts of capacity expansion schemes in 32 urban counties of California. Analysed state highway VMT (1973–90) as function of state highway lane miles and other variables. Allowed for diversion to/from parallel routes.</li> </ul>	<ul style="list-style-type: none"> <li>Traffic volume elasticity wrt lane miles was: <ul style="list-style-type: none"> <li>0.46 to 0.50 (intra-regional)</li> <li>0.32 to 0.33 (inter-regional).</li> </ul> </li> </ul>
Hansen and Huang (1997)	<ul style="list-style-type: none"> <li>Analysis of relationships between VMT and lane miles for Californian urban counties and metropolitan areas.</li> <li>Used a panel data set of annual observations for years 1973 to 1990.</li> <li>Applied a fixed-effects model, and lagged model formulation to capture long- vs short-term effects.</li> </ul>	<ul style="list-style-type: none"> <li>VTM long-run elasticity wrt state highway lane miles was 0.6 to 0.7 at county level, 0.9 at metro level.</li> <li>Short-run (within one year) elasticity values were c.0.2 in both cases; long-run effects occurred within four years.</li> </ul>
Fulton et al (2000)	<ul style="list-style-type: none"> <li>Analysis of county-level data for US mid-Atlantic states.</li> <li>Applied fixed effects models relating VMT to lane miles.</li> </ul>	<ul style="list-style-type: none"> <li>Average VMT elasticity wrt lane miles in range 0.2 to 0.6 (short/medium run).</li> <li>Strong indications of causality (change in lane miles causes change in VMT).</li> </ul>
Noland and Cowart (2000) – literature review	<ul style="list-style-type: none"> <li>Johnson and Curlan (1996) analyses, California</li> <li>Noland analyses, 50 states.</li> </ul>	<ul style="list-style-type: none"> <li>VTM elasticity wrt lane miles (over 3-year period) in range 0.6 to 0.9.</li> <li>VTM elasticity wrt lane miles in range 0.2 to 0.5 (short-run) and 0.7 to 1.0 (long-run).</li> </ul>
Noland and Cowart (2000)	<ul style="list-style-type: none"> <li>Analyses of Texas Transportation Institute database, covering 70 urbanised areas for period 1982–96.</li> </ul>	<ul style="list-style-type: none"> <li>Base model: VTM elasticity wrt lane miles in range 0.65 to 0.68.</li> <li>Lagged model: VTM elasticity wrt lane miles 0.28 (short-run) and 0.90 (long-run).</li> <li>Strong indications of causality (change in lane miles causes change in VMT).</li> </ul>

Based on the ranges of values given, we would conclude that:

- In the short run, the elasticities indicate that the induced traffic effect is relatively small: most of the 'theoretical' time saving and other benefits expected from road capacity enhancements (in the absence of induced traffic) will in fact be realised – although it will still be important to allow for induced traffic in scheme economic appraisals.
- In the long run, the induced traffic effect is quite substantial: a proportion of the short-run time savings may be lost, due to induced traffic – although of course such induced traffic will gain the benefits of improved accessibility.

### A3.7 Road 'decongestion' (regional) relationships

Two groups of USA studies have investigated directly the relationships between levels of congestion, traffic volumes and changes in road supply (lane miles). Both of these used a data set assembled by the Texas Transportation Institute (TTI), comprising annual data for 85 USA urban areas for the period 1982–2003:

- 1 The *Urban mobility report* divided the areas into three groups, according to their change in (traffic volume relative to road supply) over the period; and then derived the average change in level of congestion (delay time per VMT) for each group. For the group with the greatest change in traffic volume relative to road supply, it was found that congestion delays increased over the period by a factor of about 3.7; while for the group with the least change in traffic volume etc, congestion delays increased by a factor of 1.7. From these results the study concluded that:
  - a increases in road capacity relative to traffic volume resulted in lesser increases in travel times (congestion)
  - b to maintain constant travel times, road capacity had to increase at a rate close to but slightly faster than the growth in traffic volumes.
- 2 STPP (1999) also analysed the TTI data set, but in slightly different ways. It divided the 68 metro areas into three groups, according to their growth rate in road capacity/person over the period. In its 2001 analyses, comparing the group with 'high' increase in road capacity/person (average +17%) with the 'low' increase group (average -14%), it found very little difference in either absolute congestion levels or rate of change in congestion levels for the two groups. The report concluded that: 'Metro areas with the fastest-growing road systems are no less congested than areas that are adding the fewest roads, and have had only slightly greater success in keeping congestion in check'.

These two studies appear to draw essentially opposite conclusions from the same data set, in regard to whether providing additional road capacity will result in reductions (or lower rates of increases) in congestion levels. While both sets of study analyses recognise that induced traffic exists, they differ in regard to the magnitude of this effect:

- The UMR study indicates a relatively low elasticity (for VMT with respect to road capacity), implying that additional road capacity will be relatively effective in reducing travel times/congestion levels.
- The STPP study indicates relatively high elasticities, in the range 0.5 to 1.0, implying that much of the potential 'decongestion' benefits of additional road capacity will be off-set over time by induced traffic.

A more detailed appraisal of the analytical work of the two studies would be necessary to produce more definitive conclusions. In the absence of this, we are inclined to put greater weight on the findings from the induced traffic analyses in section A3.6.

## A3.8 Land use development impacts of road schemes

### A3.8.1 Overview

In the short run, the provision of additional road capacity will improve the relative accessibility of certain trip destinations (attractions) and hence tend to result in trip redistribution, eg a shopping trip from a given origin may switch to a shopping destination that has now become more accessible. Such a redistribution will result in additional (induced) travel in the new corridor used, offset by reduced travel in the corridor previously used: there is likely to be some net increase in VKT (in response to the improved network accessibility levels overall).

Similarly, in the long run, the addition of road capacity is likely to result in a redistribution of land development: improved accessibility associated with the new (or improved) road will make it more attractive for businesses and residents to relocate in the vicinity of the new road (in particular its interchanges). The increased attractiveness of these sites will tend to result in increased land values (rents), until a new equilibrium between land supply and demand is reached. The new developments will generate/attract additional traffic to the new road, most of which will be redistributed from other origins and destinations. This is the phenomenon of additional road capacity inducing land use changes, and generally increasing 'sprawling' of the city; these changes in turn will lead to increased demand on the new/improved road facility.

This section summarises empirical evidence on the impacts of road capacity expansion on:

- land use development, particularly in the vicinity of the new/improved route
- traffic volumes using the route corridor, in particular induced traffic resulting from the induced land use developments.

This is one of the most difficult aspects of induced traffic to investigate empirically, as the effects of interest typically appear over an extended period of time (both before and after implementation of the new road project), depend on numerous factors other than the scheme itself, and can be very difficult to distinguish from other (background) factors applying over the period of interest.

### A3.8.2 Evidence on land use/economic development impacts

Our research examined the evidence available from international case studies (mostly from the UK and Europe) on the impacts of new road schemes on land use and economic development. Its main focus was on empirical (before/after) evidence relating to situations where new roads have been built; but some of the evidence examined is from theoretical/modelling studies rather than direct observations. The evidence examined covers the impacts of new road schemes on land values, development pressures and actual development (including impacts on employment). Market research into the importance of transport factors in commercial/industrial location decisions is also noted.

The following are the main findings drawn from this evidence and other sources:

- New or improved roads that enhance accessibility of particular areas result in increased land values in these areas, whether the land is zoned for commercial, residential or other developments.
- The types of new developments which are particularly attracted to highly accessible locations associated with new roads in peripheral urban areas (eg land adjacent to motorway junctions) tend to be:
  - distribution/warehousing activities, serving national and regional markets
  - large mall (hypermarket) and superstore developments, that depend on large catchment areas

- high-technology growth industries
- offices requiring good access for employees and visitors, but not requiring central area locations.
- The evidence on factors influencing the location of commercial/industrial businesses is somewhat conflicting on the importance of transport factors. However there is evidence that good road access is a major factor influencing such decisions.
- Improving access to under-developed areas with previous poor access does not necessarily increase the development of such areas relative to other areas. There may be employment gains in some sectors, losses in others (eg distribution sector).
- Some theoretical studies suggest that enhanced access may result in substantial increases in employment in areas with poor access previously, eg the UK Severn Bridge/M4 study suggested an increase in employment in South Wales of some 4%. However such theoretical study results are often not substantiated by the empirical evidence, which tends to indicate much smaller impacts (even in gross terms).
- It is generally considered that improvements in accessibility to under-developed areas will not be a sufficient condition, and may not be a necessary condition, to stimulate economic growth in such areas. It is argued (Breheny 1995) that road investment will only make a significant difference where it is the only missing feature of a strong economy. New road infrastructure is likely to be more effective in stimulating development, in the context of a strong economy, where it removes a constraint to the spread of development pressures in the area/region concerned.
- There is very limited evidence, from either theoretical or empirical studies, on the net effects (as distinct from the gross effects in the area directly affected) on the development/employment effects of enhanced access. In general, it is likely that most of the gross effects represent transfers from other areas.
- Major new road schemes would generally 'induce' different patterns of land use development than would occur in the absence of the scheme. In particular, they may lead to re-zoning of parcels of land in the vicinity of the scheme (eg motorway intersections), which will be attractive to particular types of commercial development (as noted above). Such differential land use impacts should properly be taken into account when assessing the traffic, economic and environmental impacts of major road schemes.

### **A3.8.3 Evidence on traffic volume impacts**

It is self-evident that increased land use developments in the vicinity of, and as a result of new road schemes, will result in increased traffic volumes using the new road. This is perhaps particularly the case because many of the induced developments will be of the type for which access is important and which will tend to attract relatively large traffic volumes (eg large shopping malls).

However, very little 'hard' evidence is available on the extent of induced traffic resulting from land use developments associated with new road schemes, or on the proportion of total traffic or of all induced traffic that is accounted for by this induced land use category:

- In a study of traffic growth on UK motorways and trunk roads, Marcial Echenique & Partners concluded that land use effects made as important a contribution to traffic growth as transport effects (SACTRA 1994, p238).
- Modelling work by Rodier et al (2001) showed that 'the long term land use development effects can be a large additional source of increased VMT associated with highway expansion' (Noland and Lem 2001, p18).

Given the paucity of 'hard' evidence, all that can be concluded is the following:

- Induced traffic associated with land use development is primarily a medium/longer-term phenomenon; however, it may start when the new road is at the planning stage and gradually increase prior to and subsequent to the scheme opening.
- In the short term, this land use induced traffic is likely to represent a small component of all induced traffic and of total traffic in the corridor/area most affected. In the longer term, this induced traffic component may well exceed the total of all other induced traffic components, in some situations.
- It seems likely that induced land use will result in an overall net increase in traffic volumes in the region as a whole; the improved travel conditions resulting from a new road scheme will tend to increase overall traffic volumes. However, the net traffic effect from induced land use, over the whole region, is likely to be very much less than the gross effect in the corridor/area in question.

### A3.9 Public transport schemes

This section summarises the international evidence on the induced travel effects of new or improved urban PT services. It focuses on examining the proportions of users of such services that did not previously make the trip in question, ie truly generated trips.

The evidence has been grouped into three categories, according to the type of PT enhancements undertaken and is summarised as follows:

- Major corridor investment schemes. This category involves 14 major PT investment schemes in larger cities, in the UK, EU countries, USA, New Zealand and Australia. All but two of these schemes are rail (including tram) based: the exceptions are the Adelaide O-bahn and the Auckland northern busway.
- Service enhancement schemes. This category involves less capital intensive schemes to improve PT services, mostly involving the bus mode. Two sub-categories of scheme have been covered:
  - Adelaide 'TransitLink' bus services – involving enhancements to bus services in selected major corridors
  - Norwegian 'trial' service enhancements – part of an extensive national programme to trial and assess a range of enhancements to local bus services throughout Norway. Types of enhancements trialled included increased service frequencies, express services, smaller buses and 'service' routes.
  - Fare reductions. This category covers various fare reduction schemes on Norwegian bus services, as an additional part of the Norwegian national trial programme of bus service enhancements.

Table A.9 provides, for each of these categories, a summary of the evidence on new (generated) trips, expressed as a proportion of the total new PT trips using the enhanced services<sup>18</sup>. *Prima facie*, there are two very different sets of results here:

- The Norwegian trial schemes (bus service enhancements and fare reductions) indicate the 'did not travel' proportion of new PT trips to be in the range 6% to 8%.
- By contrast, the other data sources indicate 'did not travel' proportions as around 30% to 35% of the new PT trips.

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<sup>18</sup> Typically, between one-quarter and one-third of all trips using the enhanced services represented new PT users for that trip; the remainder would have previously made the same trip by PT.

While part of the difference in these results is likely to reflect the different natures and markets of the various schemes assessed, it seems unlikely that the true differences between sources are as great as the results imply. It seems probable that the non-Norwegian sources overstate the 'new trips' proportion, as they often include trips by people who changed workplace, school, etc after the introduction of the new scheme. Our view would be to place greater reliability on the Norwegian results than the other sources as a true measure of trips 'generated' as a result of the new scheme: the Norwegian trials were evaluated carefully, using a consistent framework covering all likely behavioural responses.

**Table A.9 Summary of evidence on generated trips as a proportion of all new PT trips**

Scheme type	Location	Generated trips: total new PT trips <sup>(a)</sup>	Comments
Major investment schemes	Various (Australia, Europe, USA)	30%	<ul style="list-style-type: none"> <li>May include a small walk/cycle component.</li> </ul>
Bus service enhancements	Adelaide	35%	<ul style="list-style-type: none"> <li>May include a small walk/cycle component.</li> </ul>
	Norway	6%	
Fare reductions	Norway	8%	

**Notes** <sup>(a)</sup> 'Generated trips' refers to completely new trips, ie the person concerned did not previously make a similar or equivalent trip. 'Total new PT trips' refers to all trips that were not previously made by PT (it is generally unclear how a trip that was previously made by PT to a different destination is allocated).

### A3.10 Summary

The following are the key findings drawn from the international review of empirical evidence relating to induced travel in section A3:

- The extent of truly new (generated) trips resulting from urban road capacity expansion schemes appears to be small, accounting for at most a few percent (certainly under 5%) of total corridor traffic.
- However, other behavioural responses can result in a much greater proportion of induced traffic on an improved corridor. These responses include: re-assignment over a wide area (spatial convergence), trip retiming (temporal convergence), mode switching (modal convergence) and trip redistribution in both the short term and the longer term (resulting from transport-induced land use changes). Given the range of factors influencing induced traffic levels, no simple rule of thumb (or simple mathematical formula) can be derived to forecast levels of induced traffic resulting from any specific scheme.
- However, the empirical evidence from the major road enhancement schemes examined indicates, in the short term and taken over the whole day (ie excluding trip retiming effects), an overall 7% average (range 3% to 12%) increase in screenline traffic volumes. It should be noted that these figures will tend to overstate the total short-term increase in VKT, as they include a component of trip redistribution from other corridors.
- Over the longer term, major road capacity expansion schemes in urban areas are likely to result in land use changes, particularly in areas where new development opportunities are available. Such land use changes will tend to induce further additional traffic in the improved corridor; while much of this may be redistributed from other locations, overall VKT is likely to increase, in response to the improved accessibility.

- For main radial corridors in large cities, where PT (especially rail-based) services account for a substantial proportion of overall mode share, up to half or more of the total induced traffic in the corridor when the road system is improved will be accounted for by people switching from PT.
- In the short term, most major urban road capacity expansion schemes result in significant time savings for their users, certainly at peak periods. Over the longer term, as total traffic volumes and their induced traffic component increases, these initial time savings tend to be eroded.
- In the case of urban PT enhancement schemes, typically in the order of one-quarter to one-third of scheme users, are new PT users for the trip in question. Of these new PT users the proportion that are truly generated trips (ie trips that would not have been made in the absence of the scheme) appears to vary in the range between 6% and 36%. Having regard to the survey issues involved, we consider that the true level of generated trips is generally towards the lower end of this range.

## A4 Review of international modelling and evaluation practices

### A4.1 Overview

This section provides a summary of the ‘state-of-play’ in terms of transport project modelling and evaluation methods relevant to travel behaviour issues, including induced travel, in the UK (generally regarded as the world-leading country in this respect), New Zealand and Australia. For each country, it outlines current policies and procedures (eg as in evaluation manuals), adopted practices and (where available) any research on the merits and impacts of different procedures.

The appraisal focuses particularly on transport modelling procedures (fixed vs variable matrix methods and different forms of variable matrix methods), but also addresses procedures for the (socio-) economic evaluation of transport benefits. Reflecting the emphasis in each country, most of the material presented focuses on induced traffic effects of projects and policies primarily affecting private/commercial road travel in metropolitan/urban areas; but, where information is available, comment is also given on induced travel impacts associated with PT projects and policies.

### A4.2 United Kingdom policies, practices and experience

#### A4.2.1 A brief history

In the UK (as in most other developed countries), the forecasting of future traffic volumes has long been at the heart of the planning process for new/improved road schemes. Such forecasts are used in:

- determining the needs and priorities for network improvements
- deciding on the appropriate scale for the improvement scheme (number of lanes, design of intersections, pavement thickness, etc)
- this scale in turn influences the extent to which traffic will be attracted to use the new scheme
- these assessments provide the inputs from which estimates of economic and environmental impacts are derived (SACTRA 1994).

In relation to the third of these points, there was a widespread belief in UK transport planning circles from at least the 1980s onwards that new/improved roads do ‘generate’ (or induce) additional traffic. However, this belief was not reflected in the planning of improvement schemes for major (trunk) roads: the UK

Department of Transport view at that time was that any estimates of 'generated' traffic would be very uncertain and would (for the most part) have a very small effect on overall traffic flows.

In 1989, the UK Secretary of State for Transport requested the Standing Advisory Committee on Trunk Road Assessment (SACTRA):

*To advise the Department [of Transport] on the evidence of the circumstances, nature and magnitude of traffic redistribution, mode choice and generation [resulting from new road schemes], especially on inter-urban roads and trunk roads close to conurbations; and to recommend whether and how the Department's methods should be amended and what, if any, research or studies could be undertaken.*

SACTRA addressed four key questions relating to its remit, as shown in the left-hand column of table A.10. In addressing these questions, it consulted widely and commissioned several pieces of new research. The Committee reported in December 1994: the right hand column of table A.10 summarises the key conclusions and recommendations reached in the Committee's report.

The SACTRA report was largely accepted by the Secretary of State for Transport (on behalf of the British Government). As outlined below, it led to:

- a change in DoT policy, to make it normal practice to allow for induced traffic in the assessment of trunk road schemes
- a significant research programme (still ongoing) into transport modelling (and evaluation) procedures that would best take account of induced traffic effects.

**Table A.10 UK SACTRA report – key questions and committee conclusions/recommendations**

Question	Conclusions/recommendations
A Does the provision of improved trunk roads and motorways give rise to induced traffic – is it a real phenomenon?	<ul style="list-style-type: none"> <li>• Induced traffic can and does occur, probably quite extensively, though its size and significance is likely to vary widely in different circumstances.</li> </ul>
B If so, are the consequences in terms of the planning, design and evaluation of such road schemes significant – does it really matter?	<ul style="list-style-type: none"> <li>• Studies demonstrate convincingly that the economic value of a scheme can be overestimated by the omission of even a small amount of induced traffic.</li> <li>• This matter is of profound importance to the value for money assessment of the road programme.</li> </ul>
C If so, for which types and categories of major highway improvement is induced traffic likely to be significant – where and when does it matter most?	<ul style="list-style-type: none"> <li>• Induced traffic is of greatest importance in the following circumstances: <ul style="list-style-type: none"> <li>– where the network is operating or expected to operate close to capacity</li> <li>– where the traveller responsiveness to changes in travel times or costs is high (as may occur where trips are suppressed by congestion and then released when the network is improved)</li> <li>– where the implementation of a scheme causes large changes in travel costs.</li> </ul> </li> <li>• There is a need for a change in appraisal practice (to take account of induced traffic).</li> </ul>
D How should the current forecasting and appraisal methods be amended to allow for induced traffic – what needs to be done?	<ul style="list-style-type: none"> <li>• Scheme appraisal must be carried out within the context of economic and environmental appraisals at the strategic area-wide level which take account of induced traffic through variable demand methods. Much more emphasis needs to be placed on the strategic assessment of trunk routes within a corridor or</li> </ul>



Question	Conclusions/recommendations
	<p>regional or urban context.</p> <ul style="list-style-type: none"> <li>Variable demand methods should now become the normal basis of trunk road traffic forecasts, and these forecasts must be carried through into the operational, economic and environmental evaluation of schemes in a systematic way. In particular, where networks are operating close to capacity, suitable procedures must be used to represent the constraint of traffic in the base case and the release of traffic growth in the do-something case as additional capacity is provided.</li> </ul>

#### A4.2.2 Current recommended procedures – use of variable or fixed trip matrix approaches

Following the SACTRA report, the UK DoT developed revised procedures regarding the approach to be taken towards induced traffic in modelling and evaluating the effects of trunk road and local authority road schemes (and major PT schemes having significant ‘decongestion’ impacts). These procedures focus around the use of fixed trip matrix (FTM) or variable trip matrix (VTM, allowing for induced traffic) approaches, and the current procedures may be summarised as shown in box A.1. It is seen that, for all schemes with capital costs of more than £5 million, VTM modelling methods should normally be applied.

##### Box A.1 UK Department of Transport procedures re use of fixed trip matrix or variable trip matrix methods for road scheme assessment

###### General

*A variable demand modelling approach should be used unless it can be robustly demonstrated that ignoring the effects of suppressed and/or induced trips and traffic will not affect the assessment of the economic, environmental or social impacts of the scheme.*

###### Smaller schemes

- For schemes with a capital cost of less than £5 million, it is generally acceptable to undertake a fixed trip matrix (FTM) assessment only (assuming the scheme has only modest effects on travel costs).

###### Larger schemes

- For schemes with a capital cost of more than £5 million, a variable trip matrix (VTM) approach should normally be used unless there exists a robust case for using a FTM approach only.
- Such a robust case is judged to exist if the (preliminary) benefit differences when applying a VTM v FTM approach are less than 10% in the scheme opening year or 15% in the forecast year (10 to 15 years later).
- The preliminary estimates of benefit differences required (to test the case) may be derived by comparing the benefit results for FTM and VTM tests, using elastic suppression/induction procedures for the VTM tests.
- In assessing whether a robust case exists for use of a FTM approach only, wider (including environmental) effects and possible alternative schemes also need to be considered.

Source: DfT (2006a; 2006b; 2006c; 2006d)

#### A4.2.3 Current recommended procedures – alternative variable trip modelling methods

In the light of its preference for the use of the VTM approach for most major road schemes, DfT has developed further guidance for practitioners on the most appropriate VTM methods, in particular distinguishing between:

- a full ‘variable demand model’ (VDM) – typically in urban areas a four-step multi-modal model.
- elasticity-based methods, where the initial demand matrix is adjusted according to changes in some measure of the ‘costs’ of travel (with and without the scheme being assessed), for each origin-destination movement.

Current UK DfT recommendations are for VDM methods to be used in general, with elasticity-based methods applied only in limited situations. Research on this topic is ongoing, but has highlighted several factors, including:

- Provided that elasticity-based and VDM methods are specified consistently, the benefit estimates from the elasticity models are typically within 10% to 30% of those estimated from VDM.
- Elasticity-based models are weakest in attempting to replicate the trip redistribution effects of VDM.
- Benefit estimates are often highly sensitive to the convergence of the demand and assignment model outputs: this aspect is often at least as crucial as the choice of elasticity vs VDM methods in estimating benefits accurately.

#### **A4.2.4 Extent of induced traffic and impacts on economic benefits – theory**

UK research undertaken since the publication of the SACTRA report has further examined evidence on the extent of the induced traffic phenomenon, and on how allowing for induced traffic affects the estimated economic benefits of road schemes. Significant findings include the following:

- In general, transport modelling work suggests that the extent of induced traffic is likely to be modest relative to the base level of existing traffic.
- However, this extent will depend on the size of the study area modelled, the scale of the schemes under consideration, the behavioural responses modelled and the values adopted for the model parameters.
- Typically, for schemes in congested urban areas, the induced traffic phenomenon causes:
  - relatively small (%) changes in traffic volumes
  - quite large (%) changes in economic benefits
  - even larger (%) changes in NPV.
- In congested situations, estimates of user benefits using a VTM approach may be greater or less than those using a FTM approach
- The difference between the VTM and FTM benefit estimates varies with the slope of the supply and demand curves.
- The errors associated with the FTM approach will tend to be greatest in situations with:
  - highly congested conditions (typically in urban areas, at peak periods)
  - high elasticity of demand with respect to travel costs (typically in urban areas, especially where alternative modes offer strong competition)
  - relatively large changes in travel costs (typically for larger, capacity-enhancing schemes).
- Where VDM methods have been applied to estimate the effects of trip redistribution and modal transfer, the apparent changes in benefits have generally been quite modest; typically demand models under-estimate the overall real-world responsiveness. Elasticity-based methods tend to result in larger changes (reductions) in benefits.

#### **A4.2.5 Extent of induced traffic and impacts on economic benefits – case study evidence**

Box A.2 summarises evidence from three sets of UK case studies on how the economic (user) benefits from selected road schemes are estimated to vary according to the transport modelling/evaluation methodology, ie essentially whether VTM or FTM methods were used. Key findings were, in summary:

- Assuming at least moderate levels of congestion, VTM benefits estimates were always less than FTM-based estimates.
- In most cases, VTM benefits were between 20% and 50% lower than FTM-based estimates.
- Benefit estimates (particularly in the VTM case) were sensitive to the basis on which the matrices were formulated.

**Box A.2 Differences between VTM and FTM-based benefit estimates – UK case studies**

- Studies reviewed for the SACTRA report found that, at moderate levels of congestion and demand elasticity, FTM benefit estimates typically exceeded VTM estimates by 20% to 50%.
- More recent analyses, using elasticity assignment methods with SATURN, indicated that, compared with the FTM estimates, user benefits decreased by about 20% with a GC elasticity of -0.5, and by about 35% with a GC elasticity of -1.0.
- A DfT post-implementation study of evaluations for three major English bypass schemes examined the effects on benefits of using either VTM or FTM methods, and using different bases for matrix formulation. The findings of particular relevance are:
  - Benefit estimates are typically in the order of 50% lower using VTM methods than FTM methods (in both cases using the same evaluation program). These results arise largely because the ‘base’ network is typically unrealistically congested under the FTM approach.
  - Benefit estimates are found to be sensitive to the basis on which the VTM matrices are constructed, and to the evaluation package used (in particular the assumptions it adopts for assessing benefits in highly congested situations).

### A4.3 Australian policies and practices

This section provides an overview of policies and practices in Australia, at both federal and state levels, relating to the treatment of induced travel in transport project modelling and evaluation

#### A4.3.1 Policies and practices relating to use of VTM and FTM approaches

Little formal consideration has been given to the choice between FTM and VTM approaches to transport demand forecasting and project evaluation in Australia. An examination of travel demand modelling in 2000 identified improvements needed in the use of transport demand modelling (Austroads 2000). While noting the inadequate reflection of real travel choice and land use behaviour and the inability to adequately reflect transport-land use feedback, including induced demand, the review made no specific recommendations regarding the use of VTM methods for demand forecasting and evaluation.

An informal review of demand modelling practice by state government transport agencies in Australia in 2004 indicated almost universal use of FTM methods, with some allowance made for changes in mode choice but no allowance for induced demand<sup>19</sup>.

At the current time, there is no formal guidance on the use of FTM and VTM in Australia. The most comprehensive guidance on transport planning at the Federal level, released in December 2006, contains one volume that addresses urban transport (ATC 2006). Part 2 of that volume addresses the development and use of computerised travel demand models for assessing urban transport initiatives, but makes no reference to the use of FTM or VTM other than to indicate that, as part of an audit process, users should ‘check for details on ... the matrix methods or techniques used – if variable matrix methods or growth

<sup>19</sup> Personal communication with Dr Peter Tisato, Department of Transport, Energy and Infrastructure, South Australia.

constraint techniques have been used, provide details on the method and parameters adopted and the justification for the approach'. That is, it places the onus on the user to justify the approach adopted.

Similarly, guidelines published by state or territory transport agencies generally provide no guidance on the use of FTM or VTM; the choice is left to practitioners. The usual approach taken in practice is to use FTM, with variable mode choice in some cases but with no allowance for induced demand. VTM has been used in some instances though usually in a limited form, for example to hold the total number of trips constant but to allow both mode choice and trip distribution to change, ie thus allowing for some induced demand if trip lengths should increase. There is no published Australian evidence of any significant use of VTM in which the full potential extent of induced travel demand has been taken into account.

#### **A4.4.2 Guidance on economic evaluation under VTM approach**

Consistent with the limited consideration given to the use of VTM in the modelling of travel demand, Australian transport agencies provide little guidance on the economic evaluation of initiatives with VTMs as against conventional FTMs. The ATC (2006, section 7.3) national guidelines describe the use of cross-loading as a means to estimate benefits where there is induced demand. There is no general discussion of the economic evaluation of projects with VTM in the guidelines, though volume 4 part 1 describes a methodology for the evaluation of urban PT projects that takes account of induced demand. It does this in general terms by identifying the need to base an evaluation of changes in travel in a network on the change, for each mode and time period separately, in the perceived cost of travel for each origin-destination pair, with appropriate resource corrections to take account of the difference between the economic and perceived costs of travel (ATC 2006, section 3.2).

In the case of PT schemes, the guidelines also describe the need to take account of induced road traffic that may occur in response to the diversion of some existing motorists to PT. They indicate for such schemes a short-cut means to estimate decongestion benefits resulting from any net reduction in road traffic, based on typical unit benefits derived from past work in Victoria and New Zealand (ATC 2006, section 6.6).

Other economic evaluation guidelines in Australia, for example Queensland Main Roads (1999) and NSW Roads and Traffic Authority (2006) do not provide any specific guidance on the measurement of benefits with VTM as against FTM.

### **A4.4 New Zealand policies, practices and experience**

#### **A4.4.1 A brief history and current procedures**

The NZTA sets out procedures to be followed by all New Zealand transport authorities (central, regional and local levels) wishing to receive government funding support. Its procedures for the evaluation of transport projects are contained in a detailed *Economic evaluation manual* (EEM) (NZTA 2010a and b).

Until 2008, the EEM policy relating to the choice between VTM and FTM approaches for the evaluation of road schemes was stated as:

*VTM techniques **may** be used to model the effects of induced traffic where high levels of congestion are expected in **both** the do minimum and project option networks.*

This implied there was no requirement on practitioners to use the VTM approach for any scheme evaluations.

The EEM policies and procedures relating to induced travel were reviewed in 2008 (Ian Wallis Associates 2008). One outcome of this review was a change in the previous policy. The revised policy to be adopted for road scheme assessments in New Zealand (that require central government funding support) is set out

in box A3. This was a very significant policy change, bringing the New Zealand requirements much more closely in line with the current UK requirements (box A1). In effect, the new policy is likely to require the use of the VTM approach for the evaluation of most urban road improvement schemes of any substantial size.

**Box A.3      NZ Transport Agency current procedures re use of fixed trip or variable trip matrix methods for road scheme assessments**

*Variable trip matrix models are to be used for all complex improvements, unless:*

- (a) *It can be demonstrated that:*
  - (i) *the congestion level expected throughout the analysis period in the do minimum or option will not be substantial; and*
  - (ii) *the peak period passenger transport mode share is less than 15%; or*
- (b) *Preliminary evaluation shows that the fixed trip matrix benefits are unlikely to differ by more than 10% from those from a variable matrix approach; or*
- (c) *NZTA approves the use of a fixed trip matrix approach for other reasons.*

*A substantial congestion level is such that the congestion (relative to a non-congested/free flow situation) would add at least 10% to the typical peak period trips (of typical trip length) travel times. A 10% travel time change equates to typical elasticities from a 5% traffic volume change. The evidence from various evaluations indicates that such a traffic volume change between do minimum and option has a substantial effect (at least 25%) on the benefits.*

Source: NZ Transport Agency (2010)

#### **A4.4.2      Current practices and practitioner views**

Despite there being no requirement until 2008 for the use of VTM approaches, leading New Zealand transport modellers had in practice been using VTM methods for several years for the modelling and evaluation of a number of major urban road projects. While the larger metropolitan/urban centres in New Zealand have strategic multi-modal urban transport models, it is often found that these models do not have sufficient road network (and matrix) detail for use on their own to evaluate major road projects.

Typically, the multi-modal model is used to generate an initial matrix (or matrices), which are then used as inputs to a more detailed road-only model for the corridor in question. The initial matrix is then 'elasticised' to produce different matrices consistent with the anticipated traffic conditions ('generalised cost' of travel between each origin-destination pair) with and without the project under evaluation. While this methodology is not ideal, it has proved a pragmatic and fairly successful method of applying the VTM approach making the best use of existing models.

As part of the Ian Wallis Associates (2008) review of New Zealand induced travel procedures, a survey was undertaken of leading New Zealand modelling/evaluation practitioners, to explore the then current practices relating to induced travel modelling and issues arising from this. The findings of most relevance here may be summarised as follows:

- Practitioners' choice between FTM and VTM methods tends to be driven by what models are readily available to evaluate the project in question.
- FTM methods are simpler and quicker to use, and simplify comparisons between evaluation results for different projects.
- VTM methods tend to be used for larger projects in more congested situations (where significant induced traffic effects might be expected).

- In practice, some practitioners regard the distinction between VTM and FTM methods as somewhat blurred: a VDM may be used to generate a matrix, which is then used for both 'do-minimum' and 'do-something' cases.
- Where VTM approaches have been adopted, in most cases these use the full regional transport models. In such cases, the greater 'refinement' of the VTM approach (over FTM) relates primarily to trip redistribution, and in a few cases also to mode switching and trip retiming.
- Elasticity-based models are used less often as a means of implementing the VTM approach. In cases where they are used, generalised time elasticity functions have been most commonly applied, with the elasticity values being taken from EEM or other published (international) sources.
- Very limited empirical evidence is available from respondents on the differences in estimates of benefits for specific projects using alternative (FTM/VTM) methods (see below).
- However, in congested situations, most practitioners consider that the benefit estimates are likely to be highly sensitive to the matrix assumptions made (and not just whether a FTM or VTM approach is adopted): with FTM methods, benefits may vary widely according to whether a matrix consistent with the do-minimum or do-something network is used (in both cases).

#### **A4.4.3 Impacts on benefit estimates – case studies**

The New Zealand evidence on the effects of adoption of VTM versus FTM approaches on scheme estimates is very limited (refer box A.2 for UK evidence).

Useful evidence was available for one scheme, the Tauranga eastern motorway. The assessment used a three-step model to compare the economic merits of this scheme: i) with fixed trip distribution (ie FTM); and ii) allowing the trip distribution to vary (ie partial VTM). The user benefits in the VTM case were 47% below those in the FTM case. Such a difference is towards the top end of the range found in the various UK case studies (refer box A.2).

### **A4.5 Summary**

This section has examined transport modelling and economic evaluation procedures and practices adopted in the UK, Australia and New Zealand to assess induced travel impacts associated with urban road schemes.

For scheme evaluation, in both the UK and New Zealand the recommended procedures are to use variable trip matrix (VTM) methods in general, with the exceptions being small schemes or those where the impacts of alternative methods on user benefits are shown to be small.

Evidence, primarily from the UK, from testing VTM and FTM approaches on specific schemes, indicates that user benefit estimates from applying the VTM approach are typically in the range between 20% and 50% lower than using the FTM approach. However, these relativities are sensitive to the bases used for the construction of the trip matrices under either approach, and to the specific modelling methods used.

Considerable research has been undertaken in the UK into the merits of different modelling methods within a VTM approach, in particular the merits of using a full VDM relative to an elasticity-based methodology. While this research has not yet concluded, current UK DfT recommendations are for VDM methods to be used in general, with elasticity-based methods seen as an appropriate alternative only in limited situations.

By comparison with the UK and New Zealand, in Australia the topic of the most appropriate transport modelling and evaluation methods for application in addressing induced travel effects for urban road

schemes appears not to have been addressed to any great extent. Neither the Federal Government nor any of the states provide procedures or guidelines to be followed by practitioners in this area.

## A5 Conclusions, implications and recommendations

### A5.1 Overview

This section draws on the findings from the earlier sections to present conclusions on the various travel behavioural responses to road schemes, and in particular on the importance of the induced travel phenomenon. In the light of these conclusions, it sets out the implications for the evaluation and selection of transport schemes in New Zealand metropolitan areas and presents recommendations relating to enhancements in transport modelling and evaluation procedures so as to provide decision makers with better information on travel behavioural effects.

### A5.2 The significance of induced demand

#### A5.2.1 Traffic volumes – the empirical evidence

The section A3 review of the empirical evidence indicates that the extent of additional traffic induced by new or improved road schemes is generally rather modest, certainly in the shorter term. Across a number of road schemes examined, in the shorter term the extent of induced traffic (across an appropriate screenline) in the corridor concerned was estimated at an average 7% additional to the previous corridor traffic volumes. In the longer term, the traffic volume increase in the corridor may be significantly greater, due to ongoing trip redistribution and induced land use effects, although the evidence on these impacts is rather weak. In the short term and more so in the longer term, much of this induced traffic in the corridor is likely to be redistributed from other origin-destinations, indicating that the total induced traffic on a network-wide basis will be significantly smaller than in the corridor directly affected.

#### A5.2.2 Economic impacts

In economic terms, the additional (induced) traffic resulting from a road network improvement will perceive a benefit through now being able to travel, taking advantage of the improved conditions; but this additional traffic will reduce the benefits for all other traffic if the road is at all congested. The balance between these two aspects, ie the net benefit associated with the induced traffic, will depend on the specific circumstances: in typically congested urban situations, there will be an overall net disbenefit associated with the induced traffic.

Further, in congested urban situations, relatively small (%) increases in traffic volumes will typically result in much larger (%) reductions in the economic benefits associated with schemes to increase road network capacity. The weight of evidence indicates that, for road schemes in moderately congested urban areas, the estimates of net user benefits are from 20% to 50% lower when induced traffic effects are taken into account than if these are ignored (ie a fixed trip matrix is assumed). This highlights the importance of allowing for induced travel effects in scheme modelling and evaluation.

Induced road traffic effects are of greatest importance for scheme economic evaluation in situations with:

- a high degree of congestion (typically in urban areas, especially at peak periods), and/or
- high elasticity of demand (typically in urban areas, especially where alternative modes offer strong competition), and/or
- relatively large changes in travel costs (typically for larger schemes providing substantially enhanced capacity).

For PT, induced travel effects are also most significant when similar conditions apply – that is, when demand is relatively elastic and increases in response to improved service, and when the service is already congested or crowded.

#### **A5.2.3 Environmental and social impacts**

In regard to the other components (environmental, health, safety, etc) which should be included in the evaluation process, in the absence of induced travel, urban road capacity-enhancing schemes would generally result in more freely flowing traffic and hence in reduced global (CO<sub>2</sub>) and local emissions and generally in reduced accidents<sup>20</sup>. There may of course be some disbenefits (negative effects), such as severance, disruption during construction and possibly noise. However, the existence of induced travel will tend to reduce the overall net benefits, through the additional traffic generating additional emissions and probably accidents.

The overall balance between these benefits and disbenefits will be situation specific, but this is an aspect in which the extent of high-quality research is surprisingly limited (both in New Zealand and internationally). The five New Zealand case studies undertaken for this research were generally unable to reach firm conclusions on this balance, largely because of data limitations (regarding changes in traffic volumes and on aspects such as fuel consumption/CO<sub>2</sub> emissions, noise and pollution levels). Internationally, very few post-evaluation studies were identified that provided comprehensive before/after information of the nature required.

Some more detailed case studies, in New Zealand or elsewhere, would appear desirable, in order to provide better evidence on the balance of benefits and disbenefits for selected major schemes. Such studies would apply enhanced modelling and evaluation methods where appropriate, as well as before/after data collection. In the New Zealand context, it is hoped that some of the proposed RoNS schemes, for which extensive before and after data collection is being proposed, would provide suitable case studies, for both shorter- and longer-term post-evaluation.

### **A5.3 Implications for transport and land use development**

#### **A5.3.1 Implications for transport policy development, project evaluation and selection**

It will be clear from the above and from earlier sections of this appendix that the induced travel (traffic) effect associated with urban road capacity enhancement schemes:

- is real
- can significantly affect traffic volumes on the route or corridor in question
- will bring economic benefits to new road users (who would not otherwise make the trip), but disbenefits to existing users in situations where there is any significant degree of congestion
- will tend in most situations to reduce overall user benefits over time, as traffic volumes increase and congestion worsens
- in such circumstances will significantly reduce net user benefits and hence scheme economic performance
- will generally reduce the environmental and social benefits that might otherwise result.

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<sup>20</sup> Such reductions will not occur in all cases: for example, CO<sub>2</sub> emissions are directly related to fuel consumption, which may increase in the case of higher-speed travel.



These adverse economic effects resulting from induced travel essentially arise because road users are not recognising the full marginal social costs (MSC) associated with their trips: these costs include the congestion-related costs and other externality costs (emissions, etc) that additional trips impose on other road users and society at large. These adverse economic effects could be 'neutralised' if road users were charged for the MSC they impose: this is the theory under-pinning (economic) urban road pricing (congestion charging).

The existence of the induced travel phenomenon does not invalidate the case for increases in road capacity in urban areas. Rather, it strengthens the need for:

- careful evaluation of the full range of impacts (including induced travel) of any such scheme, from the economic, environmental and social perspectives
- comparison of the merits of such schemes with options involving alternative modes and demand management policies, including road pricing policies
- consideration of the scheme as a component of an optimised 'package' of investment and management measures, which in particular would avoid or mitigate undesirable induced traffic volumes and would 'lock in' the potential benefits of the scheme package as travel demand increases over time.

This more holistic approach to examining the case for increases in urban road capacity should be reflected in evaluation procedures and practices. Under the current road project evaluation practices (in New Zealand as in many other countries) there is a danger of over-investment in expanding road capacity as a result of the present sub-optimal pricing arrangements. Some capacity expansion schemes which now appear warranted (in terms of their economic BCRs) would not be warranted if the road system was priced on an optimal (MSC) basis or some proxy for this<sup>21</sup>.

The UK Eddington (2006) report demonstrated that this is very significant issue, certainly in the UK context. It commented as follows:

*If widespread road pricing were introduced, the nature and location of challenges on the roads would be altered. Analysis undertaken to understand what this means for the case for additional infrastructure in the UK in the longer-term suggests that road pricing would significantly reduce, but not completely eliminate, the amount of additional road build for which there would be an economic case.*

*By looking at the returns from additional fixed infrastructure, it is estimated that instead of 2,900 to 3,350 lane kilometres, if national road pricing were introduced, this would fall substantially to just an additional 500 to 850 lane kilometres on the strategic road network between 2015 and 2025. This is a reduction of some 80%.*

*Such a package might cost around £5-8 billion and would generate annual welfare benefits in 2025 of some £30 billion. The vast majority of the benefits of this package of road build and pricing derive from the pricing element with only around £600 million of benefits generated by the road build.*

*This section has highlighted that, owing to the interaction of road pricing with the case for additional road build, robust long-term decisions on strategic road capacity can be better made if the case for capacity enhancements has been tested in an environment where pricing*

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<sup>21</sup> The economic benefits estimated for road schemes evaluated under optimal prices will generally be lower than those evaluated under existing prices; but there may be some conditions under which they will be higher.

*– localised or widespread – is approaching. Given the long lead times of such transport interventions, this will be particularly important when considering interventions to tackle challenges beyond 2015.*

The previous New Zealand (Labour) Government took up this point in its update of the New Zealand Transport Strategy (MoT 2008), in which it stated that:

*Meanwhile (while research on alternative charging systems is still proceeding), the evaluation of major infrastructure projects should consider the possible effects that different methods of generating revenue may have on managing future demand and therefore whether the need for that project remains.*

While the current New Zealand government has not come to any decision regarding the introduction of point-of-use charges on existing roads, there seems a significant possibility of some such charging arrangements being introduced well within the effective lifetime of major road capacity enhancement schemes currently under investigation. We therefore see merit in the NZTA modifying its current practices for the economic evaluation of major capacity-enhancing projects, to require their evaluation to be undertaken based on both existing pricing arrangements and assuming more economically efficient pricing arrangements.

#### **A5.3.2 Implications for transport/land use policy coordination**

The transport ‘system’ and the land use ‘system’ are intimately inter-related: land use disposition ‘drives’ the pattern of demand for transport, while the accessibility provided by the transport system is a major factor that ‘drives’ land use development. Despite this intimate dependency, land use planners and transport planners often do not recognise the strength of the second of these driving linkages, ie the impact of accessibility on patterns of land use development.

The strength of this relationship has been exemplified in numerous cases internationally. One well-known example of transport-induced land use development is that of London’s M25 Orbital route: this had major impacts on the pattern of commercial development throughout outer London over the medium term. An older example in New Zealand was the rapid development of Auckland’s North Shore following the opening of the Harbour Bridge.

‘Traditional’ four-stage transport models used in New Zealand, as in other countries, do not include any linkage (‘feedback loop’) between transport accessibility and land use development. We consider such linkages would be highly desirable in models for the New Zealand metropolitan areas, while recognising the difficulties in establishing and modelling the appropriate transport land use linkages. The current exception in New Zealand is the Auckland (ART3/ASP2) models.

In the absence of such models, it would be highly desirable for evaluation procedures for major transport proposals to address in a qualitative manner whether these proposals are consistent with and supportive of current/proposed land use plans. To the extent they are not, there may be a good case for either modifying the transport proposals; and/or modifying the land use plans to respond to both the pressures and opportunities likely to result from the improved accessibility associated with the road scheme.

### **A5.4 Requirements for enhanced modelling and evaluation procedures**

#### **A5.4.1 Transport model development aspects**

The range of behavioural responses typically resulting from changes in the transport system (infrastructure schemes, pricing, demand management, etc) was set out earlier in this appendix (table A.1). Current multi-modal (‘four-stage’) models used in the New Zealand metropolitan areas to

estimate the effects of transport system changes are relatively good at modelling some of these responses (eg assignment), but relatively poor at modelling other responses (eg trip generation or induction).

Table A.11 provides a provisional 'generic' summary, relating to multi-modal (four-stage) models in New Zealand, of those model aspects on which further development work would be desirable, so as to better reflect travel behaviour responses in general and induced travel responses in particular, and hence provide the basis for improved (ex ante) economic appraisals of urban transport schemes.

Table A.11's summary of development requirements is intended to provide an initial basis for discussions between the relevant parties, noting that not all the suggestions will apply to all the current New Zealand multi-modal models. We also recognise that some of the suggested model enhancements would be much harder to implement than others, in particular because of the paucity of data on some of the relationships involved (eg between transport accessibility, trip generation and land use development).

**Table A.11 New Zealand multi-modal model enhancements – potential development tasks**

Modelling stage	Development requirements
Trip generation	Development of a dynamic accessibility – trip generation interaction module, with trip generation rates sensitive to accessibility changes: <ul style="list-style-type: none"> <li>• short term - apply elasticity techniques</li> <li>• medium/long term - research and development to implement variable demand relationships</li> </ul> Also investigate/apply relationships between economic conditions (eg real disposable incomes, petrol prices) and trip generation.
Trip generation/ distribution – induced land use effects	Development of a dynamic transport and land use interaction module, with land use and demographic data sensitive to accessibility changes.
Trip distribution	Assess need for re-specification of trip distribution impedance functions, including for effects of economic conditions (also refer 'Trip generation').
Vehicle occupancy	Investigate development of a module incorporating changes in vehicle occupancy in response to changes in travel costs.
Trip re-timing	Incorporation of trip re-timing module to reflect that motorists may change their time of travel in response to both travel time differences (congestion) and cost differences (road pricing). Also needs to address peak spreading/contraction within the modelled peak period (important in economic terms).
Mode choice	Mode choice formulation to recognise captive nature of many trips (either to car or to PT).
Assignment (routing)	Generally satisfactory (subject to incorporating appropriate time and cost parameters).

#### A5.4.2 Economic evaluation aspects

For the (ex ante) economic appraisal (evaluation) of urban/metropolitan transport projects, the main weaknesses in capturing the range of behavioural responses are in the modelling process (as addressed above) rather than in the subsequent translation of model outputs into economic outputs.

The EEM (volume 1, section A11) now specifies:

- the circumstances in which variable trip matrix methods (incorporating estimates of induced travel and other behavioural responses) are to be applied

- the methods which may be used in deriving estimates of variable trip matrices for the do-minimum and option cases
- the methods for deriving economic benefits from these variable trip matrices.

This research has not identified any needs for enhancement of these sections of the EEM at this stage. However, if some of the modelling improvements suggested in table A.11 are implemented, then further consideration may need to be given to the associated economic evaluation methods – this would apply particularly if transport and land use interactions are to be incorporated into modelling practices (refer to further discussion in chapter 3 of the main report).

# **Appendix B: Social, environment, health and safety impacts: literature and practice review**

## **B1 Introduction**

### **B1.1 Context**

This appendix was prepared by Don Wignall with assistance from Martin Ward, as sub-consultants to Ian Wallis Associates on this NZTA research project. This appendix supplements the material in the main report, primarily chapter 4.

Social, environmental, health and safety effects are important and need to be considered alongside the economic and traffic reasons that underpin most road projects.

Social, environmental, health and safety effects are broad ranging and inter-connected topic areas. The precise boundaries between these and other topics, for example induced traffic effects and the environmental consequences of these, are often hard to define.

This appendix is part of the overall literature review contained within the main research report, which includes: travel behaviour (chapter 2), economic appraisal (chapter 3) and social, environmental, health and safety effects (chapter 4).

The purpose of appendix B is to:

- provide an outline review of transport-related social, environmental, health and safety issues
- underline the need to consider a balanced range of factors when assessing the implications of road investments
- highlight specific aspects from the review that are particularly relevant to current New Zealand practice.

This review considers recent approaches to assessing road project effects in terms of the following:

- social: distributional effects and severance
- environment: air pollution, greenhouse gas emissions and noise
- health: active modes and disturbance
- safety: road crashes and perceived safety.

The above topics have been selected in order to produce an illustrative cross-section of social, environmental, health and safety issues. This appendix does not therefore represent a complete and in-depth study of all potential effects.

Annex C notes the relevance to the review of each work referenced in this appendix.

It is important to remember that there is considerable overlap between social, environmental, health and safety topics, and this means that some references are relevant to more than one topic area.

### **B1.2 Methodology**

This appendix considers the localised effects of road projects, together with any associated wider network impacts and is primarily focused on the actual operational effects (rather than construction effects) of road projects, where possible confirmed by quantified pre- and post-implementation monitoring.

A selection of published literature and current New Zealand practice is included in chapter 8 of the main report, see sub-section 'Chapter 4 and appendix B'.

This appendix describes the following:

- 1 New Zealand monitoring related to the social, environmental, health and safety effects of the overall road network or transport system
- 2 Monitoring work in New Zealand specifically to assess the social, environmental, health and safety effects impacts of road projects
- 3 New Zealand monitoring/post-evaluation evidence (summarising 1 and 2 above) regarding the social, environmental, health and safety effects of road projects
- 4 International evidence on the social, environmental, health and safety effects of road projects
- 5 What needs to be done in New Zealand to provide better monitoring of the social, environmental, health and safety effects of road projects.

The requirements of the NZTA Transport Investment Online ([www.nzta.govt.nz](http://www.nzta.govt.nz)) represent the type of assessment required for current funding application purposes ([www.pikb.co.nz/assessment-framework](http://www.pikb.co.nz/assessment-framework)), which is based on the three factors of strategic fit, effectiveness and efficiency:

- The strategic fit assessment is undertaken on the basis of the priorities outlined in the *Government policy statement on land transport funding (GPS)* (MoT 2012).
- The effectiveness factor considers the contribution that the proposed solution makes to achieve the potential outcomes identified in the strategic fit assessment. Higher ratings are provided for those proposals that provide long-term, integrated and enduring solutions. Effectiveness is weighted lower than strategic fit but higher than efficiency in the assessment profile.
- The efficiency factor is mainly based on cost-benefit analysis (CBA) as defined in the NZTA *Economic evaluation manual* (EEM) (NZTA 2010) and specified ranges of benefit-cost ratio (BCR) (low <2, medium 2 to 4, high >4).

More detailed assessment, forecasting and monitoring methodologies are emerging for very large New Zealand road investments through the roads of national significance (RoNS) process. This work is well resourced and represents best current New Zealand practice in terms of assessing, forecasting and monitoring the implications of road investments. Although this research does not specifically address this scale of investment, the RoNS assessment and monitoring framework is termed an 'enhanced' post-implementation review (ePIR) and is likely to influence the way 'standard' PIRs are undertaken in the future for non-RoNS investments (see annex A).

The recent RoNS assessment for Waterview (NZTA 2012c) is representative of best current New Zealand practice in terms of the effects considered in this review, as discussed below:

- *Social:* The assessment of social effects report considers regional and local impacts, including severance, primarily using qualitative methods. Distributional effects issues are discussed on the basis of differential regional and local effects.
- *Environment:* Air quality and noise are the subject of separate quantified assessment reports. Greenhouse gas effects are not specifically addressed.
- *Health:* Health-related air quality issues are reviewed within the air quality report. Active modes are included briefly in the assessment of transport effects but only in terms of facilities provided rather than in demand terms. Potential disturbance from noise is only referred to in terms of construction

effects within the social assessment report. Some other aspects of health are discussed in general and qualitative terms in the assessment of social effects, which relies on an earlier regional scale health impact assessment (HIA).

- *Safety*: Actual and perceived safety effects are not specifically addressed in the assessment reports, although a safety audit has been undertaken.

The Waterview material indicates that current practice is focused on meeting the requirements of the Resource Management Act 1991 (RMA) which does not represent a comprehensive approach to the assessment and forecasting of road project effects.

The assessment of non-RoNS projects is more limited and is sometimes dominated by CBA (annex A). This focus on the BCR in current practice means that emphasis is placed on cost considerations and a limited number of monetised benefits, primarily those relating to travel time, vehicle operating cost (VOC) and safety.

## B2 Social

### B2.1 Introduction

The assessment of social effects can include:

- *Distributional effects*: the differential distribution of benefits (including mobility and accessibility) and other impacts (including costs and externalities).
- *Severance*: separation of people from facilities, services and social networks they wish to use within their community.
- *Community cohesion*: a state of togetherness and unity across diverse people in the community, with social engagement and participation.
- *Social connectedness*: the social interactions, relationships and networks that people have with others.
- *Displacement*: the relocation of residential and other activities.
- *Urban form*: changes in the density, pattern, function, attractiveness and relationship of activities.

Two of these have been selected for further discussion, namely: 'distributional effects' and 'severance', to illustrate relatively well researched areas, within the field of social impact.

### B2.2 Distributional effects

Distributional effects can be considered in spatial terms, between identified groups or on vulnerable users, but are not usually analysed or monitored as part of road project planning in New Zealand.

#### **i New Zealand monitoring related to the severance effects of the road network or transport system.**

None identified.

#### **ii Monitoring in New Zealand specifically to assess the distributional effects of road projects.**

- a *Pre-implementation*: The EEM volume 1 states: 'An analysis of the distribution of benefits and costs among different groups of people is not required for the economic efficiency evaluation of the activity. However, reporting of the distribution of benefits and costs, particularly where they relate to the needs of the transport disadvantaged, is part of the funding assessment'. In practice

however, such reporting is rare. The split of economic benefits, between time savings, VOC, safety, air pollution, noise, etc is useful, but this does not explain how these benefits are distributed.

- b *Post-implementation*: None identified. In fact currently envisaged monitoring frameworks for the RoNS do not appear to include any meaningful consideration of social effects post-implementation (MWH 2010).

**iii New Zealand monitoring/post-evaluation evidence (ie summarising i and ii above) regarding the distributional effects of road projects.**

None identified.

**iv International evidence on the distributional effects of road projects.**

Distributional effects (eg spatially, for identified groups or for vulnerable users) are regarded as important in some countries when assessing the differential impacts of projects. For example, a recent methodology from the UK contains the following advice: 'net monetised user benefits are an important justification for transport investment. However there is a concern that the users who benefit from the intervention are concentrated in higher income groups, and socially excluded groups do not experience a significant proportion of the benefits. The proposed approach to addressing these concerns should measure the distribution of benefits and hence reflect equity issues within the value for money assessment. This approach would enable a comparison between those who benefit and those who experience disbenefits such as severance or poorer air quality' (MVA 2010). This advice also discusses the distribution of air quality and noise effects.

**v What needs to be done in New Zealand to provide better monitoring of the distributional effects of road projects?**

Pre- and post-implementation monitoring of distributional effects is needed in locations, circumstances and project types where these effects are likely to be significant.

Incorporation of suitable techniques into social impact assessment (SIA) and PIR methodologies and monitoring requirements together with appropriate resourcing is also required.

The context for road projects needs to be considered when determining the potential distributional effects, for example:

- If a road project radically improves car mobility within a given corridor, relative to other modes, then those with access to cars and with the resources to fully use the travel opportunities created would be likely to receive the primary benefit from this investment.
- On a large scale, when road planning is based on (say) the strategic need for faster longer distance travel then this is likely to benefit at the expense of local communities through which the new roads are developed.
- At the local scale, if the design of new roads attempts (say) to avoid acquiring or impacting higher value activities, properties and land, this may have two effects. First, the lower socio-economic location could receive higher direct impacts from loss of land, facilities and community severance, and second these locations could also receive higher on-going traffic-related impacts of noise, vibration and dust.
- In higher socio-economic communities, road projects may have a disproportionate impact on vulnerable groups, such as the young, old and disabled.



### **B2.2.1 Distributional effects: findings**

Distributional effects, including changes in mobility, accessibility, costs and environmental conditions, especially for identified sub-population groups, such as vulnerable users, those with travel difficulties or those on low incomes, can be important factors in the assessment of road projects.

Distributional effects can include relative changes in access to employment or essential services, and are sometimes referred to as 'social exclusion' effects.

When distributional effects are likely to be significant, for example, for very large road projects such as major corridor improvements, quantified surveys and associated analysis are required.

However, currently little or no quantification of post-implementation distributional effects is undertaken in New Zealand.

## **B2.3 Severance**

Community severance has been defined as the 'separation of people from facilities, services and social networks they wish to use within their community; changes in comfort and attractiveness of areas; and/or people changing travel patterns due to the physical, traffic flow and/or psychological barriers created by transport corridors and their use' (Rose et al 2009).

### **i New Zealand monitoring related to severance effects on the wider road network or transport system.**

None identified in quantified terms.

### **ii Monitoring in New Zealand specifically to assess the severance effects of road projects.**

- a *Pre-implementation:* There is a requirement to address social and environmental management issues as described in the NZTA *Professional services guide* (PSG/13) (NZTA 2012b); however, this advice is very generalised and does not require the quantified analysis of social factors. Severance is also a recognised factor in the EEM, volume 1, A8.8 and is sometimes addressed in very general terms during the planning of major road projects.

Severance is usually discussed in qualitative terms (only), as part of a SIA, although these are only undertaken for a minority of road investment projects. Considerations of severance in SIAs are therefore inadequate and there is little evidence that the results of these studies are acted on.

- b *Post-implementation:* None identified.

### **iii New Zealand monitoring/post-evaluation evidence (ie summarising i and ii above) regarding the distributional effects of road projects.**

SIAs have been conducted for a number of major projects; however, these are often produced as part of consenting requirements and are not subject to post-implementation review.

Severance considerations tend to be qualitative rather than quantitative, for example: 'the construction of major new roads can result in severance effects potentially leading to a reduction in community cohesion. A prominent recent example in New Zealand was the severance of a refugee community in Auckland with the construction of SH20 Mt Roskill Extension. Yet new roads also present opportunities to introduce or support activities to enhance community cohesion through the addition of cycle or walk ways, or for placing existing roads underground in trenches/tunnels, for example. The Waterview Extension is a current example of a New Zealand road that may improve some aspects of community cohesion' (Quigley and Thornley 2011)

**iv International evidence on the severance effects of road projects.**

Quantifying changes to the interaction within and between local communities is important in assessing road project impacts, and this has been successfully introduced in several countries, including, the UK, Denmark and Sweden (Rose et al 2009; Tate 1997).

Severance can be measured in terms of physical changes in accessibility and also in perception terms, both of which may alter travel behaviour and associated activities.

Severance can be particularly important for more 'vulnerable' groups such as the young and elderly.

**v What needs to be done in New Zealand to provide better monitoring of severance in relation to road projects?**

Pre- and post-implementation monitoring of severance effects is needed in locations, circumstances and project types where these are likely to be significant.

Incorporation of suitable techniques into SIA and PIR methodologies and monitoring requirements together with appropriate resourcing are also required.

Enough information is available from the literature on this subject to allow standardised and relatively simple techniques to be applied to pre- and post-implementation monitoring. This would not necessarily embrace all aspects of severance but would provide some much needed quantification to improve current practice in this area.

**B2.3.1 Severance: findings**

The interaction within and between local communities often needs to be quantified in the assessment of road project impacts, particularly in terms of the potential severance (or the prevention or deterrence of local trip making) and the consequent changes to the strength of existing community connections.

Bypass type road projects often reduce severance effects in some areas and introduce them in others.

On-line upgrades may increase the level of actual and perceived severance effects.

Severance effects are particularly significant on vulnerable groups, such as the young, elderly and mobility impaired.

It is important to consider localised effects and also any wider community effects.

Severance can be estimated by analysing changes in local travel times, route availability and convenience with special reference to identified groups. This estimate is required when significant severance issues are anticipated, particularly in residential areas and also in situations where rural network connectivity is reduced.

Currently little or no quantification of pre- and post-implementation severance levels is undertaken in New Zealand.

## **B3 Environment**

### **B3.1 Introduction**

The assessment of environmental factors includes:

- *air pollution*: including NO<sub>2</sub>, CO, O<sub>3</sub>, PM<sub>10</sub> and SO<sub>2</sub>, sometimes measured in terms of NO<sub>2</sub> equivalence

- *emissions*: greenhouse gases such as CO<sub>2</sub>, CH<sub>4</sub> and NO, sometimes measured in terms of CO<sub>2</sub> equivalence
- *noise*: in New Zealand typically measured as 'dB(A) LAeq 24hr' (equivalent continuous noise level)
- *vibration*: often a significant construction issue
- *visual*: landscape, townscape and lighting
- *water*: runoff, groundwater and impact on water bodies
- *biodiversity impacts*: flora and fauna.

Three of the above have been selected for discussion, namely: air pollution (important in terms of the potential impact on human health), emissions (in terms of the relationship with climate change) and noise (sometimes regarded as a proxy for a range of other physical environmental factors).

## B3.2 Air pollution

Pollutants include NO<sub>2</sub>, CO, O<sub>3</sub>, PM<sub>10</sub> and SO<sub>2</sub>, sometimes measured in terms of NO<sub>2</sub> equivalence.

In the longer term, the overall absolute level of air pollutants generated by traffic is expected to fall due to the expected increased use of cleaner fuels and through improved engine efficiencies. However, whether this occurs and the rate at which conditions improve, are dependent on the rate of New Zealand vehicle fleet renewal and changes in the number and use of vehicles.

### i New Zealand monitoring related to air pollution on the wider road network or transport system.

Ambient air quality monitoring is the primary means of assessing compliance with current air quality standards, guidelines and targets. Regional councils have now implemented a programme of ambient air quality monitoring to determine compliance with the air quality standards. For example, Greater Wellington Regional Council monitors air quality at seven selected sites in the region for three key pollutants, namely: particulate matter (PM<sub>10</sub>), carbon monoxide (CO) and nitrogen dioxide (NO<sub>2</sub>).

This background monitoring provides a very useful context for more localised assessments, for example: '...the 2008/09 results show that PM<sub>10</sub> was the only air pollutant found to exceed the national air quality standard. The air in heavily trafficked areas of Wellington city has higher levels of some pollutants than suburban and rural areas. Roadside air quality was reported to "acceptable" or better with only (one) day in central Wellington where the PM<sub>10</sub> standard was exceeded' (McLeod 2008).

Annual, web-based national-level reporting of PM<sub>10</sub> in monitored airsheds was introduced in 2005. This includes data on concentration, methodology and accidents and can be accessed at the Ministry for the Environment's website ([www.mfe.govt.nz](http://www.mfe.govt.nz)).

A network of air quality monitoring NO<sub>2</sub> sites and annual reporting for the NZTA is currently in place (Water Care 2010) although the trend data currently available is limited.

The MoT undertakes national modelling of vehicle fleet changes, and Auckland Transport maintains a regional fleet emissions model. Any significant changes in levels of congestion, travel speeds and vehicle kilometres as a result of major road projects or investment programmes can be used as inputs to these models.

### ii Monitoring in New Zealand specifically to assess the air pollution effects of road projects.

- a *Pre-implementation*: Estimates of air pollution are usually derived using modelled/calculated techniques rather than through actual measurement.

- b *Post-implementation:* Specific post-implementation localised monitoring of the air quality effects of road projects is not usually undertaken, even when these effects are expected to be significant. In rare cases, RMA consent conditions may require post-implementation monitoring.

**iii New Zealand monitoring/post-evaluation evidence (ie summarising i and ii above) regarding the distributional effects of road projects.**

In some cases, air pollution monitoring sites coincide with the location of a major road project, for example the Basin Reserve in Wellington, the end point of the Wellington inner city bypass, which was opened in 2007. This site (WEL008) shows that the NO<sub>2</sub> concentrations at the Basin Reserve were medium (ie an annual average of between 30 to 40 µg/m<sup>3</sup>) in the three years 2007, 2008 and 2009 (Water Care 2010).

As might be expected, monitoring indicates a general relationship between air pollution and high traffic volumes (McLeod 2008).

**iv International evidence on road projects and air pollution.**

The literature, which is often model based, indicates that the effect of road building on air quality is dependent on circumstances and can be positive (Crow and Younes 1990; Noland and Quddus 2006) especially in the short term.

In congested networks where higher traffic volumes are generated as a result of a road project, in the medium to long term, major increases in road capacity are likely to lead to a worsening of air pollution (Hansen and Huang 1993; Noland and Quddus 2006; Stathopoulos and Noland 2003; Strand et al 2009).

The emphasis on reducing travel times in current road planning practice may generate high sub-optimal speeds that could also increase air pollution. It is also possible that maintaining fixed high-speed regimes (such as 100km/h) during congested peak periods could increase the impact of flow breakdown, with consequent impacts on air pollution (Hodge et al 2007; Strand et al 2009).

**v What needs to be done in New Zealand to provide better monitoring of the air pollution effects of road projects?**

Air pollution monitoring techniques are well established; however, they are not usually applied to the pre- and post-implementation monitoring of road projects.

More specific pre- and post-implementation monitoring of major projects where air quality is expected to be significant should be undertaken.

Some very useful analytical techniques are also available for air pollution and associated health effects, for example, MWH (2010) 'Toolkit for assessing discharges to air from transport emissions'. The toolkit was developed by Endpoint with funding from Land Transport NZ to be a quick, simple and straightforward means to assess roadway air pollution and the resulting health effects, eg due to planned roadways or modifications to existing traffic flows. It was intended to be used in conjunction with the *Good practice guide on assessing discharges to air from transport* (MfE 2008). Incorporation of such techniques into EA, HIA and PIR methodologies and monitoring requirements together with appropriate resourcing is also required.

**B3.2.1 Air pollution: findings**

The literature reviewed indicates that the effect of road investment can result in short-term reductions in air pollution, although this improvement tends to be counteracted by induced traffic. It is therefore important that the estimation of air pollution (generally at the local level) takes account of all types of

induced traffic effects, including diverted, re-timed, mode change, land use change and completely new trips, that may occur.

In the longer term, if higher capacity is introduced and continued traffic growth leads to a return to congested conditions, this may result in higher air pollution levels.

Air pollution levels can be derived either directly through measurement or indirectly by modelling and calculated estimation.

Currently, the quantification of pre- and post-implementation air pollution levels in New Zealand is undertaken through estimation rather than measurement in most cases.

### **B3.3 Emissions of greenhouse gases (GHG)**

GHG emissions include CO<sub>2</sub>, CH<sub>4</sub> and NO, sometimes measured in terms of CO<sub>2</sub> equivalence.

Transport-related GHG emissions are expected to increase in the future, on the basis of current trends and policies. This is because the effect of improved engine efficiencies will be counterbalanced to a large extent by increases in the overall amount of fuel consumed, due to increases in the number and use of vehicles.

#### **i New Zealand monitoring related to GHGs on the wider road network or transport system.**

National and regional monitoring of transport-related fuel use.

#### **ii Monitoring in New Zealand specifically to assess the GHG effects of road projects.**

a *Pre-implementation:* Estimates of current GHG emissions are usually based on traffic modelling which calculates probable fuel consumption.

b *Post-implementation:* GHG emissions are not subject to re-estimation post-implementation, nor is any detailed check made on the accuracy of pre-implementation forecasts.

#### **iii New Zealand monitoring/post-evaluation evidence (ie summarising i and ii above) regarding the distributional effects of road projects.**

No information has been identified.

#### **iv International evidence regarding the GHG effects of road projects.**

Traffic modelling often anticipates a short-term reduction in GHG emissions as a result of new road investment. In some cases road investment is tested as part of a comprehensive package of measures, including PT and demand management (Crow and Younes 1990; Lian 2005).

However, when road investments are tested in isolation and for the longer term, they are not predicted to result in substantial reductions in GHG emissions (Hansen and Huang 1993; Noland and Quddus 2006; Stathopoulos and Noland 2003; Strand et al 2009).

#### **v What needs to be done in New Zealand to provide better monitoring of the impacts of road projects on GHGs?**

Monitoring of transport-related GHG emissions requires some form of modelled or calculated estimate, probably based primarily on estimated fuel consumption.

Post-implementation estimates of fuel use and GHG emissions should be incorporated into EA monitoring and PIR methodologies and monitoring requirements together with appropriate resourcing in locations, circumstances and project types where GHG impacts are likely to be significant.

### **B3.3.1 GHG emissions: findings**

In general, road investments that induced additional traffic demand are likely to lead to increased GHG emissions. Often there is likely to be a reduction in localised congestion even if the amount of traffic increases.

In the longer term, despite forecast improvements in vehicle technology, GHG emissions are unlikely to be reduced as traffic levels rise, in part due to the provision of significant new road capacity. However, to put this in context, changes in GHG emissions due to the effect of road projects are likely to be relatively marginal compared with the overall changes in background GHG emissions.

The control of transport related GHGs is only likely to be possible if traffic growth is reduced or reversed, due to demand management measures (such as pricing or rationing) or changes in external circumstances (such as higher fuel costs) which would significantly reduce the fuel consumption of the transport sector.

Currently, the estimation of pre and post-implementation GHG levels in New Zealand is undertaken on the basis of calculated fuel use.

### **B3.4 Noise**

In New Zealand, noise is typically measured as 'dB(A) LAeq 24hr', which is the daily average, or the 'equivalent continuous', noise level. Current New Zealand practice in assessing the noise effects of road projects is based on evaluation on the noise threshold standard NZS 6806 (Standards NZ 2010) for new and altered roads. However, this does not represent a comprehensive assessment as it does not address the effects of the following:

- significant increases in residential noise levels within the assessed corridor that are below the defined thresholds
- increased noise on activities and land uses not covered in the standards, such as commercial premises, public open space or residential uses outside the threshold standards corridor (100m in urban areas and 200m in rural)
- increased noise affecting 'tranquil' rural areas, lanes and pathways.

The design response to identified noise issues is generally to introduce noise mitigation measures, such as barriers.

#### **i New Zealand monitoring related to noise levels on the wider road network or transport system.**

Noise monitoring is not routinely undertaken, but specific locations on the state highway or local network may be monitored from time to time if there is a particular reason to do so (MWH 2009).

#### **ii Monitoring in New Zealand specifically to assess the noise effects of road projects.**

- a *Pre-implementation:* Noise levels may be derived either through measurement, by calculated estimation or by a combination of the two.
- b *Post-implementation:* Noise measurements, the re-estimation of noise levels or detailed checks on the accuracy of pre-implementation forecasts are only undertaken occasionally.

#### **iii New Zealand monitoring/post-evaluation evidence (ie summarising i and ii above) regarding the distributional effects of road projects.**

Actual post-implementation monitoring data for New Zealand road projects is very limited, one exception being the Wellington inner city bypass, which found relatively neutral impacts in terms of increased noise levels in some streets and decreased noise levels on others, due to traffic redistribution effects.

**iv International evidence on the noise effects of road projects.**

A study from the UK also found that noise impacts following road construction were mixed, with locations close to the new road experiencing increased noise and locations on existing roads where traffic levels had been lowered, experiencing reduced noise levels (Atkins 2009).

The 'dB(A) LAeq 24hr' used in New Zealand is a useful measure, but is not sufficient for a number of considerations, including the assessment of sleep disturbance. It is also important to consider the night time (LAeq 8hr) average and also the presence of peak incidents against background noise levels (Ogilvie et al 2008).

**v What needs to be done in New Zealand to provide better monitoring of the impact of road projects on noise?**

Specific pre- and post-implementation monitoring and associated surveys are required in locations, circumstances and project types where noise is likely to be a significant issue.

In addition to 24-hour average noise levels, night time and peak noise levels should also be monitored.

This monitoring data would provide suitable quantified input to EAs and PIRs.

**B3.4.1 Noise: findings**

Noise is a relatively well researched area and is commonly monitored and considered in detail as part of the planning and assessment of road projects.

There are well established predictive models that estimate the noise impact of road projects and calculate the potential effects from alternative mitigation measures.

However, road project noise assessment in New Zealand focuses solely on the current standard (NZS 6806) and needs to be more comprehensively considered, particularly in terms of 'peak noise incidents' resulting in disturbance.

The effect of significant noise increases in important tranquil areas is also not considered in current noise assessment practice.

Noise monitoring of post-implementation conditions through measurement is reasonably straightforward; however, more post-implementation monitoring of actual conditions to confirm the accuracy of forecasts is needed.

In addition to 24-hour average noise levels, night time and peak noise levels should also be monitored.

Currently, the quantification of pre- and post-implementation noise levels in New Zealand is undertaken through estimation rather than measurement in most cases.

## **B4 Health**

### **B4.1 Introduction**

A number of transport-related effects have health consequences and these can be described in terms of different aspects of 'wellbeing', as follows:

- *Physical wellbeing:* Effect on physical health, including respiratory disease, cardio-vascular disease and obesity, one contributory factor to physical health is the level of active mode use. Air pollution is discussed in B3.2. Road injuries are discussed in B5.2.

- *Mental wellbeing:* Actual and perceived effects on mental health include disturbance, annoyance and stress. Noise effects are discussed in B3.3.
- *Social wellbeing:* This includes social cohesion, connectedness, cultural effects and severance. The latter aspect is discussed in B2.3.
- *Spiritual wellbeing:* This includes effects on belief systems and associated significant places.

Where transport-related health reviews or studies have been undertaken, they have tended to identify a broad range of potential health impacts (Egan et al 2003; Public Health Advisory Committee 2005; Saelens et al 2003).

In future, more health studies will need to be undertaken comprehensively and thoroughly in order to reach more definitive conclusions.

A comparison of approaches to review practice in the health and transport sectors is contained in annex B.

Approaches to the assessment of to a contributory factor to physical 'active modes' and a contributory factor to mental wellbeing 'disturbance' are discussed below:

## B4.2 Active mode use

Active modes include walking, cycling and other non-motorised/human powered modes, such as skateboarding and skating in urban areas and horse riding in rural areas.

Public transport (PT) can also be classified as an active mode due to the increased physical activity involved in getting to, from and between PT services.

The estimation of walking, cycling and PT demand as part of road planning is often limited, as forecasting is usually based on the use of road traffic models, which do not describe active mode use.

The design of new road projects is predominantly based on the need to achieve increased efficiency and a better level of service for private vehicle movements. This often results in the design of indirect, inconvenient and ineffective facilities for active modes, whose levels of service are not usually assessed.

In addition to the health effects of changes in active mode use, changes in other non-active modes also have potential health repercussions (Hoehner et al 2012).

### i **New Zealand monitoring related to the use of the road network or transport system by active modes.**

General use is recorded (in the NZ Census and MoT National Household Travel Survey) but walking and cycling activities only tend to be counted on an occasional and localised basis.

PT boardings are recorded, but this information is often subject to confidentiality restrictions, and information concerning the use of walking and cycling to or from PT is not usually available.

### ii **Monitoring in New Zealand specifically to assess the effect of road projects on active modes.**

- a *Pre-implementation:* Walking and cycling surveys are sometimes undertaken, but rarely in any depth. Demand forecasting is also usually either basic (for example if included in a conventional transport model) or non-existent.
- b *Post-implementation:* Surveys to establish active mode use post-implementation are rarely undertaken.



**iii New Zealand monitoring/post-evaluation evidence (ie summarising i and ii above) regarding the distributional effects of road projects.**

Limited conclusions can be drawn from more general monitoring of the transport system except there is a strong correlation between increased vehicle use and declining active mode use.

Although pre-implementation surveys are sometimes undertaken, actual post-implementation from New Zealand road projects appears to be limited to checking if planned facilities (such as footways or cycleways) have been provided, rather than their level of use.

**iv International evidence on the effect of road projects on active modes.**

Comprehensive techniques to monitor active mode use and the linkage of this to health have been developed in the UK (Ogilvie et al 2006 and 2008). Published evidence in this field is rapidly growing, especially in the field of preventative medicine.

**v What needs to be done in New Zealand to provide better monitoring of the effect of road projects on active modes?**

Pre- and post-implementation monitoring of active mode use is needed in selected cases where effects may be significant.

This data is needed for HIAs and PIRs in locations, circumstances and project types where the change in active mode use is likely to be a significant issue.

If road projects are expected to lead to i) a significant reduction in the level or growth in active mode use and ii) mode shift to higher private car use, then both of these potential health effects should be taken into account when assessing the effects of projects. In economic evaluation terms, this means that if negative health effects are identified due to the implementation of a road project, then this needs to be accounted for by including the disbenefits in the cost-benefit analysis for the project (Hoehner et al 2012; Genter et al 2008).

**B4.2.1 Active mode use: findings**

Changes in active mode use, especially walking, cycling and the effect of PT in encouraging increased walking and cycling activity to access PT services, are important when assessing the health effects of road projects.

Monitoring of post-implementation active mode use through counts and surveys is reasonably straightforward; however, little pre- and post-implementation monitoring is undertaken at present.

## **B4.3 Disturbance**

### **B4.3.1 Introduction**

Disturbance to individuals in local communities may range from mild annoyance to severe sleep deprivation, and may be caused by a range of effects including, noise, vibration or fumes (Egan et al 2003).

The effect of sleep deprivation has been linked to several negative health outcomes, including children's learning, depression, blood pressure, heart disease and overall mortality (EOHSP 2007).

In New Zealand the assessment of how disturbance is influenced by road investments has only been attempted at a general overview level and for demonstration projects (Ball et al 2009; Ogilvie et al 2008).

There is no current New Zealand requirement to undertake a quantified assessment of disturbance effects when planning major road projects (for example by conducting a project based health impact assessment) nor any has any detailed methodology yet been developed in New Zealand for this purpose.

The NZS 6806 noise threshold standards (Standards NZ 2010) for new and altered roads states that the upper category (C) ‘...provides a backstop against adverse health effects such as sleep disturbance’. However, the use of noise threshold standards is not sufficient to identify levels of disturbance for two main reasons, first: disturbance is not solely noise related (other factors, such as vibration and fumes need to be considered) and second: the noise standard is only an average value and only extends to a subset of affected properties.

The extent of disturbance associated with a road project can only be determined by comparing pre- and post-implementation monitoring surveys.

**i New Zealand monitoring related to the disturbance effects of the road network or transport system.**

None identified.

**ii Monitoring in New Zealand specifically to assess the disturbance effects of road projects.**

a *Pre-implementation*: No disturbance surveys or forecasting of future disturbance levels are currently undertaken.

b *Post-implementation*: No post-implementation surveys of disturbance are undertaken.

**iii New Zealand monitoring/post-evaluation evidence (ie summarising i and ii above) regarding the distributional effects of road projects.**

None identified.

**iv International evidence on the impact of road projects on disturbance.**

Further and more rigorous international research in the field of transport-related health impacts is underway, often lead by the health sector rather than the transport profession (Egan et al 2003; HM Government 2011; Saelens et al 2003). From this research, better techniques are emerging, which have the potential to be applied to the assessment and evaluation of road investments.

A summary of disturbance analysis techniques and study findings is contained in Egan et al 2003. This found that major urban roads increased levels of disturbance and that bypasses have the effect of reducing disturbance in bypassed areas but of increasing disturbance in proximity to the bypass itself.

**v What needs to be done in New Zealand to provide better monitoring of the impact of road projects on disturbance?**

Pre- and post-implementation monitoring of disturbance is needed in selected cases where effects could be significant.

This would provide a quantified basis for HIAs and PIRs in locations, circumstances and project types where disturbance is likely to be a significant issue.

**B4.3.2 Disturbance: findings**

Disturbance has a variety of causes (including noise, vibration and fumes) and is an important health issue with links to a number of negative health outcomes.

No pre- or post-implementation of disturbance levels is currently undertaken in New Zealand.

The extent of disturbance associated with a road project is not sufficiently addressed through the consideration of compliance with current noise standards, and can only be determined by comparing pre- and post-implementation monitoring surveys.

It is important to consider localised disturbance effects and also any associated effects on the wider community.

Currently, very little, if any, pre and post-implementation quantification of disturbance levels is undertaken in New Zealand.

## B5 Safety

### B5.1 Introduction

Road safety is sometimes considered under a health category, but in this review it has been treated separately, due to the direct nature of the impacts of road traffic. Road safety monitoring information is comprehensively collected and is a relatively well researched field making analysis of changes, in terms of before and after comparisons, relatively easy.

In contrast, detailed monitoring information on perceived safety is not usually available. Perceived safety is therefore a more difficult research topic, but is of particular importance in terms of influencing travel behaviour and associated outcomes.

Actual road crashes and perceived safety issues are discussed below:

### B5.2 Road crashes

Road crashes contain details of actual fatalities, serious, slight casualties and non-injury crashes that occur in New Zealand.

The crash analysis system (CAS) represents a high-quality source of data and associated analytical capability and this means that pre- and post-implementation data is available to allow the comprehensive review of implemented road projects.

In some cases, the unintended consequences of road projects, can lead to sub-optimal or even negative outcomes, especially on unaltered parts of the road network that experience changes in traffic volumes and/or speeds.

#### **i New Zealand monitoring related to the safety of the road network or transport system.**

Crash and casualty records are comprehensively captured and available from the CAS computer programme maintained by the MoT.

The safety performance of the road network is extensively analysed and reported in New Zealand.

#### **ii Monitoring in New Zealand specifically to assess the road safety effects of road projects.**

- a *Pre-implementation:* CAS data is reviewed for all road projects considered to have a potential safety impact. Exceptions to this include urban projects which are reliant on time savings for the vast majority of their benefits and in these cases safety may either be ignored or a simplistically a nominal safety improvement (say of 5%) is assumed for CBA purposes.
- b *Post-implementation:* Changes in conditions or the accuracy of forecasts have only been checked (historically) for a sample of small to medium-sized road projects. A limited number of post-implementation reviews for larger road projects are understood to be in process. See also New Zealand case studies undertaken as part of this research for Auckland Airport B2, Auckland southern motorway ramp signalling, Auckland northern busway, Tauranga Harbour link and Wellington inner city bypass.

**iii New Zealand monitoring/post-evaluation evidence (ie summarising i and ii above) regarding the distributional effects of road projects.**

A 2006 study found that a cross section of road projects was successful in achieving a major reduction (57%) in road safety related social cost. However, a 2008 study based on a number of PIRs, found that potential safety benefits from road projects are not being fully captured. This study concluded that overall, a sample of projects only delivered 26% of their forecast safety benefits (NZTA 2010).

Project safety reviews or audits usually concentrate on new design aspects. There is also a need to consider wider potential effects on the existing network to ensure that the unintended consequences of altered travel patterns and speed changes do not erode the safety benefits generated by new road investments. For example:

- 'Black route' or area-wide treatments and safety programmes, which allow for crash migration, are likely to be more effective than more isolated 'black spot' treatments (Hill and Starrs 2011; MoT 2009).
- If (say) a road with a poor safety record is relieved of traffic due to the construction of a bypass, in the absence of any countervailing measures, speeds on the 'old road' are likely to increase. This can mean that even if the absolute number (or 'frequency') of crashes is reduced on the old road, it is possible that the 'rate', 'severity' or that the overall social cost of crashes could increase (Elias et al 2006; NZTA 2010).

**iv International evidence on the road safety effects of road projects.**

The literature indicates the need for a comprehensive analysis of road project impacts on the wider network rather than a narrow focus on project design-based safety audits.

Studies have found that new road projects improve safety (Elvik et al 2010) but sometimes only in marginal terms, partly due to the influence of increased travel and higher travel speeds (Elias et al 2006; Metz 2006; Noland 2001).

**v What needs to be done in New Zealand to provide better monitoring of the road safety effects of road projects?**

The existence of the CAS system means that detailed post-implementation monitoring of all significant new road projects can be undertaken (NZTA 2010; Egan et al 2003).

More comprehensive network wide pre- and post-implementation safety analysis is needed to supplement project-related safety reviews and audits. This wider monitoring provides feedback to improve safety assessment and forecasting techniques (Atkins 2009; Hauer 2007). A range of safety analysis techniques is discussed in Noland (2001).

Of particular importance is the need to avoid a narrow approach to safety that focuses only on road project design-based safety audits. Safety audits based on conventional engineering design standards are unlikely to fully optimise safety. For example, safety audits may require expensive modifications to designs in order to achieve high-speed or visibility standards. In many circumstances it may be possible to get better safety performance through reducing design speeds or by accepting other departures from standards (Austroads 2006; CIHT 2010; Millot 2008).

More consistent, rigorous and standardised methodological approaches to multiple project and theme based analyses are also required.

### **B5.2.1 Road crashes: findings**

As might be expected, in most cases, new road investments have been found to improve safety. However, it cannot be assumed that all new roads will automatically lead to substantial improvements in safety or that all potential safety benefits will be captured. Both of these aspirations are frequently unrealised in practice.

Safety needs to be considered comprehensively, and complacency avoided, through considering past crashes and any forecast changes in speed, traffic composition and volume.

It is important to avoid the use of over-simplified assumptions or the use of 'default rates' when forecasting future conditions.

Specific measures are likely to be needed in order to 'lock-in' potential safety benefits and 'bespoke' solutions are required.

Quantified pre- and post-implementation safety information is comprehensively available in New Zealand.

## **B5.3 Perceived safety**

### **B5.3.1 Introduction**

Perceived safety can be defined as an estimated risk of physical harm due to crashes arising from the use of the transport network. Personal security is a related term that also includes other causes of potential harm such as crime.

Safety perceptions affect travel behaviour which in turn affects a series of other outcomes, including health, social activities and the economy.

Given the importance of perception in influencing travel behaviour this is an under-researched topic area in New Zealand.

#### **i New Zealand monitoring related to perceived safety on the road network or transport system.**

General surveys of perceived safety are undertaken in some regions. This indicates the PT system is viewed as safe by the majority of respondents (90%) but the proportion regarding walking (50% to 70%) and cycling (20% to 30%) as safe activities is much lower (MSD 2007).

Some general information is also available in terms of the national quality of life survey (MSD 2010). This indicates 70% of respondents regarded dangerous driving as a problem and 26% regarded traffic as the main reason children could not play unsupervised in their neighbourhood.

#### **ii Monitoring in New Zealand specifically to assess the perceived safety effects of road projects.**

a *Pre-implementation:* Monitoring of perceived safety levels is not usually quantified or formally analysed as part of New Zealand practice in the planning and design of road projects.

b *Post-implementation:* No post-implementation monitoring of changes in perceived safety levels is undertaken.

#### **iii New Zealand monitoring/post-evaluation evidence (ie summarising i and ii above) regarding the distributional effects of road projects.**

The limited information available in New Zealand (from regional sources) points to a strong sense of perceived safety for motorised travel with the opposite being true for walking and cycling.

**iv International evidence on the perceived safety effects of road projects.**

The approach to perceived safety and the interpretation of results requires considerable care. In particular, a low actual injury rate is not necessarily a good indicator that a road network should be viewed as being perceived as being 'safe' (Hill and Starrs 2011).

In New Zealand, walking and cycling are perceived to be unsafe activities (MSD 2007) but internationally it has clearly been demonstrated that this does not have to be the case, providing appropriate network management is introduced and suitable facilities are provided (Pucher and Buehler 2008).

A discussion of perceived safety issues affecting women is contained in TRB (2010).

**v What needs to be done in New Zealand to provide better monitoring of the perceived safety effects of road projects?**

Pre- and post-implementation monitoring of perceived safety is needed in selected cases.

This would provide a quantified basis for consideration within SIAs and PIRs in locations, circumstances or project types where perceived safety is likely to be a significant issue.

An accurate assessment is needed to locate pedestrian, cyclist, PT and emergency service facilities as part of road project design. This assessment will assist in answering design questions such as:

- Is the planned design likely to improve safety concerns on the existing network?
- How will the new project be perceived in safety terms?
- Are any non-motorised facilities likely to be viewed as safe?
- What type of local crossing facilities should be provided, for example: none, at-grade formal, at-grade informal, footbridge or underpass?
- What degree of lighting should be provided to meet perceived safety needs?
- Should walkways and cycleways be located immediately next to busy roads?

**B5.3.2 Perceived safety: findings**

Perceived safety is an important influence on travel behaviour and the actual road safety record associated with a particular network or travel mode is not necessarily a good indicator of whether or not they are perceived as being safe.

When assessing levels of perceived safety it is important to establish the context involved and to assess both the actual and the perceived degree of risk involved. Particular issues are likely to arise when planning for more vulnerable users.

It is important to consider perceived safety aspects of new designs together with any associated wider network perceptions associated with changes in conditions elsewhere.

The extent of perceived safety is not sufficiently addressed through the consideration of actual road crashes, and can only be determined by comparing pre- and post-implementation monitoring surveys.

No pre and post-implementation quantification of perceived safety levels is currently undertaken in New Zealand.

## **B6 Conclusions**

### **B6.1 Overview**

There is considerable scope for further research and the adoption of better analytical, forecasting and monitoring methodologies across a range of topics in order to more fully assess the effects of road projects.

The review recommends more comprehensive pre- and post-implementation analysis and monitoring of topics, based on the location, project type and circumstances involved in each particular case.

The conclusions for each of the topics reviewed are described in summary form as follows.

### **B6.2 Distributional effects**

Distributional effects, including changes in mobility, accessibility, costs and environmental conditions, especially for identified sub-population groups, such as vulnerable users, those with travel difficulties or those on low incomes, can be important factors in the assessment of road projects.

Distributional effects can include relative changes in access to employment or essential services, and are sometimes referred to as 'social exclusion' effects.

When distributional effects are likely to be significant, for example for very large road projects such as major corridor improvements, quantified surveys and associated analysis are required.

### **B6.3 Severance**

The interaction within and between local communities often needs to be quantified in the assessment of road project impacts, particularly in terms of the potential severance (or the prevention or deterrence of local trip making) and the consequent changes to the strength of existing community connections.

Bypass type road projects often reduce severance effects in some areas and introduce them in others.

On-line upgrades may increase the level of actual and perceived severance effects.

Severance effects are particularly significant on vulnerable groups, such as the young, elderly and mobility impaired.

It is important to consider localised effects and also any wider community effects.

Severance can be estimated by analysing changes in local travel times, route availability and convenience, with special reference to identified groups. This estimate is required when significant severance issues are anticipated, particularly in residential areas and also in situations where rural network connectivity is reduced.

### **B6.4 Air pollution**

The literature reviewed indicates that the effect of road investment can result in short term reductions in air pollution, although this improvement tends to be counteracted by induced traffic. It is therefore important that the estimation of air pollution (generally at the local level) takes account of all types of induced traffic effects, including diverted, re-timed, mode change, land use change and completely new trips, that may occur.

In the longer term, if higher capacity is introduced and continued traffic growth leads to a return to congested conditions, this may result in higher air pollution levels.

Air pollution levels can be derived either directly through measurement or indirectly by modelling and calculated estimation.

## **B6.5 GHG emissions**

In general, road investments that induced additional traffic demand are likely to lead to increased GHG emissions. Often there is likely to be a reduction in localised congestion even if the amount of traffic increases.

In the longer term, despite forecast improvements in vehicle technology, overall GHG emissions are unlikely to be reduced as traffic levels rise, in part due to the provision of significant new road capacity. However, to put this in context, changes in GHG emissions due to the effect of road projects are likely to be relatively marginal compared with the overall changes in background GHG emissions.

The control of transport-related GHGs is only likely to be possible if traffic growth is reduced or reversed, due to demand management measures (such as pricing or rationing) or changes in external circumstances (such as higher fuel costs) which would significantly reduce the fuel consumption of the transport sector.

## **B6.6 Noise**

Noise is a relatively well researched area and is commonly monitored and considered in detail as part of the planning and assessment of road projects. There are well established predictive models that estimate the noise impact of road projects and calculate the potential effects from alternative mitigation measures.

However, road project noise assessment in New Zealand focuses solely on the current standard (NZS 6806) and needs to be more comprehensively considered, particularly in terms of 'peak noise incidents' resulting in disturbance.

The effect of significant noise increases in important tranquil areas is also not considered in current noise assessment practice.

Noise monitoring of post-implementation conditions through measurement is reasonably straightforward; however, more post-implementation monitoring of actual conditions to confirm the accuracy of forecasts is needed.

In addition to 24-hour average noise levels, night time and peak noise levels should also be monitored.

## **B6.7 Active mode use**

Changes in active mode use, especially walking, cycling, and the effect of PT in encouraging increased walking and cycling activity to access PT services, are important when assessing the health effects of road projects.

Monitoring of post-implementation active mode use through counts and surveys is reasonably straightforward; however, little pre- and post-implementation monitoring is undertaken.

## **B6.8 Disturbance**

Disturbance has a variety of causes (including noise, vibration and fumes) and is an important health issue with links to a number of negative health outcomes.

Very little, if any, pre- or post-implementation of disturbance levels is currently undertaken in New Zealand.



The extent of disturbance associated with a road project is not sufficiently addressed through the consideration of compliance with current noise standards, and can only be determined by comparing pre- and post-implementation monitoring surveys.

It is important to consider localised disturbance effects and also any associated effects on the wider community.

## **B6.9 Road crashes**

As might be expected, in most cases, new road investments have been found to improve safety. However, it cannot be assumed that all new roads will automatically lead to substantial improvements in safety or that all potential safety benefits will be captured. Both of these aspirations are frequently unrealised in practice.

Safety needs to be considered comprehensively, through considering past crashes and any forecast changes in speed, traffic composition and volumes.

It is important to avoid the use of over-simplified assumptions or the use of 'default rates' when forecasting future conditions.

Specific measures are likely to be needed in order to 'lock in' potential safety benefits and 'bespoke' solutions are required.

## **B6.10 Perceived safety**

Perceived safety is an important influence on travel behaviour and the actual road safety record associated with a particular network or travel mode is not necessarily a good indicator of whether or not they are perceived as being safe.

When assessing levels of perceived safety it is important to establish the context involved and to assess both the actual and the perceived degree of risk involved. Particular issues are likely to arise when planning for more vulnerable users.

It is important to consider perceived safety aspects of new designs together with any associated wider network perceptions associated with changes in conditions elsewhere.

The extent of perceived safety is not sufficiently addressed through the consideration of actual road crashes, and can only be determined by comparing pre- and post-implementation monitoring surveys.

## **B6.11 Conclusions overview**

New Zealand has undertaken research into a number of topic areas, and has been able to apply some of this into current practice. However, there remains a number of research gaps and no comprehensive framework has been developed to analyse, forecast, assess and monitor the social, environmental, health and safety effects of road projects.

Some topics are currently analysed solely or primarily in qualitative terms, such as severance and health effects, and in these areas more supportive quantification and analysis is needed. Other aspects are currently not subject to any project-related analysis, forecasting or monitoring, for example distributional effects or perceived safety, despite the potential importance of these topics in particular circumstances.

A number of topic areas are currently subject to detailed pre-implementation assessment in New Zealand, including air quality, noise and safety, but these are rarely supported and verified by appropriate and quantified post-implementation monitoring and analysis.

The effects of road schemes in New Zealand are occasionally monitored in terms of the achievement of the forecast BCR and compliance with the RMA. This approach is very limited and a more comprehensive approach is required in order to identify the full range of significant road scheme-related effects.

There is considerable scope for the adoption of better analytical, forecasting and monitoring methodologies across a range of topics in order to more fully assess the effects of road schemes.

However, it is not recommended that fully comprehensive and standardised monitoring procedures be introduced across all road schemes: this is unnecessary and would also be wasteful in resource terms. Rather, it is suggested that pre- and post-implementation monitoring and analysis is undertaken of 'core topics' (say to cover travel time, traffic volume, HCV composition and safety) for all road schemes.

Additional monitoring and analysis is recommended to be undertaken for larger schemes on a bespoke basis, to address specific issues identified by stakeholders.

In some cases, for example to estimate post-implementation changes in GHG levels, predictive modelling rather than actual measurement of conditions will be required.

It is possible that in some cases a very wide range of potential effects should be considered, for example, in the case of a major new road scheme being constructed in the a large urban centre. However, such cases are expected to be rare and it is more likely that additional monitoring would typically only be required for (say) two or three additional issues for any particular road scheme. An exception to this is represented by monitoring for larger projects such as the roads of national significance (RoNS) monitoring, see the discussion in chapter 4 of this report.

A (selective) expansion of post-monitoring/evaluation effects should not be regarded as an end in itself (in the 'nice to know' category). It needs to be accompanied by a greater focus on systematic feedback from the monitoring findings to improve New Zealand practices in the planning, design and pre-appraisal of candidate road schemes.

One of the limitations in current post-implementation monitoring practice is the fact that often only short-term changes in conditions are analysed, typically one to five years after opening. Only rarely are longer-term changes monitored. More long-term monitoring would be desirable, for a sample of major projects, although we recognise the inherent difficulties with identifying longer-term effects.

The primary reason for recommending further research and increased post-implementation monitoring is to improve feedback to improve the planning and design of road projects in New Zealand.

## **B6.12 Recommendations**

- 1 Specific and quantified pre- and post-implementation monitoring is recommended in locations, project types and circumstances where project effects are expected to be significant.
- 2 'Core' pre- and post-implementation monitoring is recommended to be undertaken for all road projects, to cover: travel time, traffic volume, HCV composition and safety.
- 3 Additional monitoring and analysis are recommended to be undertaken for larger projects on a bespoke basis focusing on specific issues identified by stakeholders. The additional issues selected for monitoring will relate to the particular circumstances in any given case, potentially including one or more of the following: severance, air pollution, GHG emissions, noise, active modes, disturbance and perceived safety.
- 4 In addition to individual project monitoring, multi-project monitoring and associated analysis are also recommended to establish trends, patterns and overall performance of road project investment.

Summarised conclusions and recommendations are provided in table B.1.

**Table B.1 Social, environmental, health and safety effects: conclusions and recommendations**

<b>Issue</b>	<b>Conclusions</b>	<b>Recommendations</b>
<b>Quantification of effects</b>	This review found that New Zealand has undertaken research into a number of environmental topic areas, including air quality, noise and safety and these are now applied in current practice. However, these are rarely supported and verified by quantified pre- and post-implementation monitoring.	Specific and quantified pre- and post-implementation monitoring and analysis is recommended in all locations, project types and circumstances where project effects are expected to be significant.
<b>Core monitoring requirements</b>	The effects of a sample of smaller road schemes in New Zealand are currently monitored in limited terms	'Core' pre- and post-implementation monitoring and analysis is recommended to be undertaken for all road projects, to cover: travel time, traffic volume, HCV composition and safety.
<b>Additional monitoring requirements</b>	A comprehensive approach to appraisal and review is required in order to identify the full range of significant road scheme related effects. Current approaches in New Zealand are often limited to BCR or RMA consent conditions. Some potentially significant effects are either omitted or unquantified in current practice	Additional monitoring and analysis is recommended to be undertaken for larger projects on a bespoke basis focusing on all potentially significant impacts, including specific issues identified by stakeholders. Additional issues considered should be determined by particular circumstances, but could include: severance, air pollution, GHG emissions, noise, active modes, disturbance and perceived safety.
<b>Multi-project and longer-term effects.</b>	Consideration of individual project effects in current New Zealand practice is not sufficient to identify wider effects.	In addition to individual project monitoring, multi-project and longer-term monitoring and associated analysis is also recommended to establish trends, patterns and overall performance of road project investment.

## Annex A: Summary of PIR and ePIR requirements

Factor	Standard PIR	Factor	Enhanced ePIR
<b>Objectives</b>	Identification of objectives and assessment of the risk of non-achievement.		
<b>Assessment profile: strategic fit, effectiveness, efficiency</b>	Assessment of the appropriateness of the Transport Investment Online assessment profile.		
<b>Traffic growth/volumes</b>	Assessment of the significance of traffic growth in terms of the forecast net benefit and application of a <20% materiality threshold test.	<b>Traffic volume/composition</b>	Local road AM, PM and average daily traffic volumes for monitoring and control sites. Traffic composition for Auckland state highways.
<b>Travel time</b>	Assessment of the significance of travel time savings in terms of the forecast net benefit and application of a <20% materiality threshold test	<b>Congestion travel times (including PT)/ trip reliability (including PT)</b>	Biannual reports on average travel time and travel time variability for general traffic for the AM, IP and PM periods for SH and regional arterial roads.  Average bus travel time and travel time standard deviation of bus services travelling between the Auckland Harbour Bridge and Fanshawe Street in the AM peak and PM peak.
<b>Modal</b>	None	<b>Mode split(s)/vehicle occupancy</b>	2009/10 regional cordon screen line surveys as measured by the Auckland Regional Council
<b>Vehicle operating costs</b>	Assessment of the significance of VOC in terms of the forecast net benefit and application of a <20% materiality threshold test.		
<b>Safety</b>	Do CAS records show anything unexpected? Assessment of the significance of accident cost saving in terms of the forecast net benefit and application of a <20% materiality threshold test.	<b>Traffic crash rates and severity</b>	Reported injury and non-injury crashes on monitoring and control sites.
<b>CO<sub>2</sub>/particulates</b>	Assessment of the significance of CO <sub>2</sub> and particulates in terms of the forecast net benefit and application of a <20% materiality threshold test.	<b>Emissions</b>	Carbon monoxide and nitrogen dioxide.  Airborne fine particulates – ending 12 months after project completion, as condition of consent
<b>Comfort</b>	Assessment of the significance of comfort in terms of the forecast net benefit and application of a <20% materiality threshold test.	<b>Road roughness</b>	Road roughness through St Mary's Bay and Victoria Park

Factor	Standard PIR	Factor	Enhanced ePIR
<b>Other benefits</b>	Assessment of the significance of other benefits in terms of the forecast net benefit and application of a <20% materiality threshold test.	<b>Water quality</b>	Report on actual stormwater discharges as monitored at specified locations in the Auckland Harbour.
		<b>Traffic noise</b>	Ambient noise levels were measured at 10 residential and commercial locations near the VPT site
		<b>Land value</b>	Time series of capital values (CV) for properties adjacent to the VPT project compared to control zones.
		<b>Land use</b>	Time series of earnings from Linked Employer-Employee Dataset (LEED) for employers accessed via VPT project compared to control zones.
<b>Costs</b>	Actual outturn costs	<b>Costs</b>	Actual outturn costs
<b>BCR</b>	Indicative post-implementation BCR and ratio of post-implementation to pre-implementation BCR.		

Note: The above details are summarised from NZTA 08 v2 PIR spreadsheet and from the EPIR monitoring of VPT table 2.

## Annex B: Health sector comparison

### Introduction

The purpose of this annex is to describe changes in health sector review practice that may have application to the transport sector.

In the health sector, experience of dealing with the public has demonstrated that a 'secretive' approach (in other words seeking to hide flaws in the system) had not proved effective and tended to lead to resentment, complaints, litigation and poor public relations/publicity.

The alternative of adopting a more open approach and admitting problems (whilst at the same time endeavouring to improve matters) was found to result in far better outcomes by defusing many potential problems and improving the overall public satisfaction with the service.

The health and transport sectors have a number of similarities, for example:

- Both are governed by a mixture of policies and guidelines (issued by national organisations) and regional/local interpretation of these policies and guidelines.
- Both sectors have substantial levels of capital and operational expenditure, the Treasury report that government spending on health is currently \$14b pa and on transport around \$3.5b pa.
- Funding allocation is therefore an important function within both sectors: involving prioritisation, capacity/capability building and 'rationing' (sometimes involving long 'waiting lists').
- Both sectors undertake satisfaction surveys and performance monitoring.

- There are areas of common interest between the sectors, for example, transport interventions (policies, strategies, plans and major projects) are recommended to take account of potential health impacts (Public Health Advisory Committee 2005).
- Both sectors set performance targets (for example, maximum waiting times in emergency departments or procedure success ratio targets based on recognised standards).
- Incentives and disincentives to deliver policies, guidelines and to achieve targets in each sector are difficult to enforce. In the health sector potential sanctions include limiting funding to the regions from central funds or ultimately the removal/replacement of regional health board.
- To control more specific problems in individual cases, the reporting of poor practice to the Health and Disability Commissioner, legal action to obtain compensation in certain cases and possible discipline by professional bodies are all potentially available.

## Health sector

The health sector does, however, have a very powerful positive asset in the daily interaction of the 'frontline' workforce with the general public. The advantage of this is the 'reality check' provided by the public who experience the reality of the health system and provide constant feedback to many health professionals.

The approach adopted by the health sector includes the following:

- An open communication/open disclosure policy with patients about problems and mistakes, leading to less litigation and more positive outcomes for the sector. Most mistakes are not caused by negligence or incompetence, but rather are system based faults which can be corrected through better management and professional practice.
- High professional standards and high quality training systems are in place and accreditation and continuous professional development is required.
- A safety culture is encouraged, to identify system based problems, reducing the feeling that professionals will be singled out if they admit problems or mistakes. Individual accountability does have to be maintained however for the rare cases of negligence or criminal activity, so an entirely 'blame free' approach is not possible.
- Discrepancy meetings to review morbidity issues can be registered as a protected quality assurance activity. Comments at these meetings are not attributed, but the overall findings and recommendations from these meetings are made available to supervisory bodies, to enable lessons to be learned, feedback provided and action to be taken.
- Surveys, sampling audits review and forecasting procedures are undertaken on a systematic basis to analyse issues and to quantify problems
- Record keeping in the sector is essential and this is mainly held electronically. This data can be accessed by authorised personnel, through web-based methods.

## Transport sector

Despite the many similarities with the health sector, the transport sector tends to operate in a fundamentally different way, as follows:

- Processes in the transport sector often exhibit a lack of openness, possibly due to the absence of requirements to be open and accountable, and possibly also out of a fear of creating 'political'

problems which could have repercussions on individual careers. Examples of this include the difficulty in obtaining access to data, models or reports held within the transport sector.

- Most transport professionals have very little contact with the travelling public, information is often not provided when problems occur<sup>22</sup> and public discussion forums are very limited.
- Mistakes and problems are not openly admitted and known faults and failings are rarely recorded or corrected. Professionals often feel that they may be disadvantaged in career terms if they openly admit to problems or mistakes.
- The transport sector does not require professional qualifications, training is undertaken (generally) on an ad-hoc basis and for many positions no 'continuous professional development' is required.
- Meetings to transmit findings and recommendations from current practice are not commonly held, meaning that lessons learned and feedback are not provided to supervisory bodies.
- The quality of target setting is generally poor and is often not measured or complied with fully.
- Surveys, audit and (limited) post-implementation review procedures are undertaken to identify some sector based outcomes, however, forecasting capabilities are very limited.
- The sampling of individual project performance is partial and sporadic and therefore effective feedback to the rest of the sector is not currently possible.

The exception within the transport sector to the above statements is the aviation industry, from which the health sector has used as the basis for its open approach, in terms of adopting a 'no blame' model<sup>23</sup>.

## Implications

Although significant improvements have occurred in the health sector since an open communication/disclosure approach was adopted, a number of issues remain and there is a need for the further development of health specific approaches<sup>24</sup>.

Both the aviation industry and health sector focus on safety as the primary objective of their open communication/disclosure processes. Safety is also highly relevant for the wider transport sector, but other important objectives also need to be considered, although there seems no reason why these would not also benefit from a more open approach being adopted.

There would therefore seem to be merit in the wider transport sector adopting a more open approach to communication, problem identification and problem solving.

A useful way to begin this, would be through:

- permitting more open access to data, modelling and reporting within the transport sector
- making the post implementation review (PIR) process more transparent through the publication of individual and aggregated performance reports.

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<sup>22</sup> Rail passenger [www.stuff.co.nz/national/3987935/Passengers-refuse-to-pay-after-breakdown](http://www.stuff.co.nz/national/3987935/Passengers-refuse-to-pay-after-breakdown)

<sup>23</sup> Can aviation-based team training elicit sustainable behavioral change? Abstract, Archives of Surgery, December 2009. [www.ncbi.nlm.nih.gov/pubmed/20026831](http://www.ncbi.nlm.nih.gov/pubmed/20026831)

<sup>24</sup> Patient safety: What can medicine learn from aviation? [www.ama-assn.org/amednews/2010/06/14/prsa0614.htm](http://www.ama-assn.org/amednews/2010/06/14/prsa0614.htm)

## Annex C: Reference notes

Reference	Notes
<b>SOCIAL</b>	
Atkins (2009)	'A common view amongst residents is that with reduced traffic volumes, speeds increase and parking becomes a problem. There was a view that more traffic calming/restraint is required on the old roads and in some instances the promised measures had not been implemented.' (p11)
Deakin (2010)	Looks at long-term structural changes due to the interstate network rather than short-term impacts.
Forkenbock and Benshoff (2001)	Report reviewing factors and associated methodologies with an associated guidebook.
Jones et al (2010)	Recommends explicit recognition of the importance of places and links and how to identify priorities in different circumstances.
Ministry of Social Development (2010)	Broad survey of social factors in selected New Zealand cities.
Murto et al (2002)	This study identified a range of positive social and economic benefits arising from the development of a new, motorway corridor.
MVA (2010)	Methodology to identify the impacts of eight indicators including distribution of user benefits; distribution of noise; distribution of air quality; road safety; personal security; severance; accessibility; and personal affordability or financial impacts.
Oxera (2005)	Case study based advice on post evaluation and monitoring of a range of impacts, including severance.
Quigley and Thornley (2011)	Definitions and indicators for transport planning and monitoring. Recommendation that future work is undertaken on 'social connectedness'.
Read and Cramphorn (2001)	Recommends using contingent valuation methods to establish willingness to pay values for changes to access arrangements for pedestrians and cyclists in particular.
Rose et al (2009)	'In New Zealand, private vehicles have long been prioritised as the mode of personal transport in land transport planning policy'. (p191) ...'To monitor changing levels of accessibility and mobility, and the impact they have on social inclusion, requires a better understanding of the aspirations for accessibility and participation held by different groups and the transport-related barriers experienced by those at greatest need'. (p201)
Social Exclusion Unit (2003)	Recommends a new approach to reducing exclusion by basing planning on accessibility to key opportunities and services.
Stevenson (1995)	Recommends an eight-step methodology to comprehensively assess social impacts to improve to reduce impacts and to reduce potential delays to project approval and implementation.
Tate (1997)	Recommends a framework to assess severance based on: identifying severance potential, valuing direct impacts, using proxy measures for intangible.
Transit NZ (2007)	Recommends road treatment based on a matrix of frontage and through traffic requirements. (p25/25)
<b>ENVIRONMENT</b>	
Atkins (2009)	Finding was that 86% of predicted impacts were accurate (p7) based on consultations, perceptions and a limited amount of actual quantified monitoring.



Reference	Notes
Baughan and Chinn (1997)	This looked at the overall assessment of programme impacts, including air quality and noise. The difficulty of doing this was recognised but a way forward was suggested based on assessing the impact of a package of road measures.
Crow and Younes (1990)	This looked at the impacts of a bypass and found that the forecast benefits, including air quality improvements were realised.
Hansen and Huang (1993)	This model based study estimated that increases in road capacity was likely to result in reduced emissions in the short to medium term, effectively, until network volume to capacity ratios increased to their current levels.
Hodge et al (2007)	Review of a range of interventions in terms of air quality effects, including the effects of speed management, see for example p120.
Lian (2005)	This mainly looks at traffic impacts but also concludes that the package of road investment, pricing and alternative modes provision has significantly reduced environmental problems.
McLeod (2008)	This initial review indicated a relationship between NO <sub>2</sub> concentration and traffic volumes.
MWH (2009)	Comprehensive review of environmental practice with respect to network management and scheme implementation in an area.
MWH (2010)	Review of current practice (including environmental aspects) with respect to RoNS monitoring requirements.
Noland and Quddus (2006)	This paper examines whether road schemes that increase the availability of road space or which smooth the flow of traffic result in increased vehicle pollution. The paper found that increased traffic will 'quickly diminish any initial emission reduction benefits'. (abstract)
Sinclair Knight Merz (SKM) (2009)	Based on a mixture of demand management and further road capacity, economic, social and environmental benefits are forecast.
SINTEF (2007)	'When cities are larger than a certain size, it is more or less impossible to solve the traffic problems by increasing the road capacities'. (p9)
Stathopoulos and Noland (2003)	'Two scenarios for improving traffic flow are simulated... Short-run and long-run emissions of CO, HC, NO <sub>x</sub> , and CO <sub>2</sub> and fuel consumption are estimated. In the short run, with traffic volumes held constant, results demonstrate that the smoothing of traffic flow will result in reduced emissions. Long-run emissions are simulated by synthetically generating new trips into the simulated networks to represent potential induced travel. ...Results indicate that, in most cases, long-run emissions reductions are unlikely to be achieved under the two scenarios evaluated'.
Standards NZ (2010)	NZS 6806 does not set rigid noise limits. It gives categories (A, B and C) of noise criteria, and requires that the Best Practicable Option (BPO) be identified to mitigate road-traffic noise. (NZTA circular)
Strand et al (2009)	This concludes that road building increases GHG emissions particularly if traffic levels rise, speeds are increased (above 80 km/h) and the mode share of private car traffic is increased.
Water Care (2010)	Only three sites were found to exceed the 'high' threshold (WHO annual NO <sub>2</sub> guideline of 40µg/m <sup>3</sup> ) although the general trend appears to be for NO <sub>2</sub> concentration levels to be increasing which the report says... 'may be due to increased congestion as well as changes in the vehicle fleet. While modern vehicles generally have lower emissions than older vehicles, the proportion of NO <sub>x</sub> emissions that are emitted directly from the exhaust as NO <sub>2</sub> may be increasing'. (6.3)

Reference	Notes
<b>HEALTH</b>	
Ball et al (2009)	The research describes HIA as being ...”underpinned by a social model of health. This understanding of health is similar to everyday concepts of wellbeing or quality of life and incorporates a wide range of ‘determinants’ or factors that help people stay well or increase their risk of becoming ill”. The findings of the research include a number of problems with current practice, including: a “failure to identify positive, indirect, unintended and long-term impacts on wellbeing” and a “failure to address equity issues such as the effects of the distribution of impacts and transport for people on low incomes.”
Canterbury Regional Council (2010)	This is a wide ranging literature review and contains commentary on road impacts stressing the need for comprehensive consideration of effects: ‘ Traffic engineers already have advanced technical knowledge of safety issues for vehicular traffic but are not always aware of the potential for new roads to have negative effects on the wider determinants of health’... (pv)
Egan et al (2003)	This review looks at 32 case studies with respect to health and wellbeing of those most immediately affected by the new road. ‘Overall, there was little evidence that new major urban roads significantly reduce the incidence of injury accidents... New major urban roads appear to increase noise disturbance and severance effects in local communities’. (p1468)
European Observatory on Health Systems and Policies (2007)	This contains a case study of a major new road proposal where a methodology for a rapid HIA was trialled looking at the potential impact on the ‘already vulnerable’ in terms of potential pollution, noise and physical effects’. (p45)
Forkenbrock and Sheeley (2004)	This approach is based on identifying the differential effects on the general population and on ‘protected populations’. Methods of analysing a range of topics including: community cohesion, air quality, noise and safety.
Genter et al (2008)	Recommends placing a monetary value per km on active modes. Also refers to (i) extension of this approach to PT where this increases walking and cycling and (ii) acknowledging the potentially negative effects of road investments that have the effect of reducing active mode share. (p58)
Harris-Roxas et al (2011)	Discussion of health impact typologies and the need to consider equity in HIA – an example of a rapid HIA as applied in Australia.
HM Government (2011)	The recommendations on physical activity from the four Chief Medical Officers of England, Northern Ireland, Scotland and Wales make clear that ‘for most people, the easiest and most acceptable forms of physical activity are those that can be incorporated into everyday life. Examples include walking or cycling instead of travelling by car, bus or train’.
Hoehner et al (2012)	American Journal of Preventative Medicine, USA. Commuting distance was adversely associated with physical activity, CRF, adiposity, and indicators of metabolic risk
Ogilvie et al (2006)	Preliminary study confirming that thorough evidence is rarely available on the health impacts of road projects and other transport interventions.
Ogilvie et al (2008)	‘Altering the urban landscape may influence walking and cycling in ways that vary between individuals, may be inequitable, and may not be predictable from quantitative data alone. A more applied ecological behavioural model may be required to capture these effects’.’ (abstract)

Reference	Notes
Ouis (1999)	'The important factors to take into consideration in this context are the number of isolated events and their level relative to that of the background noise. Considering this latter case, it has been found that at the extreme of producing arousal reactions in sleeping subjects, the emergence of peaks from the background noise is definitely more important than the peak level. Moreover, continuous and intermittent noises, although of equal $L_{eq}$ , have different effects on the different stages of the sleep cycle'.
Public Health Advisory Committee (2003)	'While the roads may be safer for car users, they are not safer for cyclists and pedestrians. Safety should not be represented simply by rates of road traffic injury, because road crashes are mediated by human action and exposure'. (p16)
Public Health Advisory Committee (2005)	Useful methodology for application in New Zealand at the policy level, but with applications at a more localised level, such as the assessment of a new road project.
Saelens et al (2003)	'...there is substantial evidence that environmental variables, whether assessed objectively or subjectively, are consistently related to physical activity'. (p89)
Swedish National Institute of Public Health (2005)	This used a health matrix technique – populated by a working group - for the study of impacts of a major road project – recognising positive and negative impacts.
Thomson et al (2008)	Concludes that the impact of transport in health terms is less established than of some other factors and more attention needs to be paid to the relationship between transport and health.
VTPI (2011)	'Studies find significant health benefits from increased walking and cycling activity (Cavill et al 2008)' (p11) 'The 2010 Bicycling and Walking Benchmark Report (ABW 2010) shows a negative relationship between walking and cycling activity in a region and rates of obesity and related illnesses such as diabetes and high blood pressure'. (p12)
<b>SAFETY</b>	
Atkins (2009)	'The 29 schemes included in the analysis at the One Year After stage show outturn accident savings vary significantly against the predicted levels in the opening year compared to the forecast. The total outturn accident saving is 28% lower than the predicted levels in the opening years'. (p18)
Amundsen and Elvik (2004)	'...the nine arterial road projects from which evidence was summarised resulted in a net induced traffic of 16%, and a net reduction in accident rate (accidents per million vehicle kilometres) of 18%. These effects almost cancel each other, leading to a very small net change in the expected number of accidents. (abstract)
Austroroads (2006)	'The guide includes chapters on legal liability, costs and benefits, the audit process, safety principles and technical issues which need to be considered in road safety engineering. The guide includes updated checklists for use in assessing road designs and inspecting project sites at the different stages of a project's development'. (Austroroads webpage)
CIHT (2010)	Recommends taking an overall approach to determining design standards rather than the simplistic application of visibility and other geometric 'requirements' on safety grounds.
Elias et al (2006)	This illustrates how development is stimulated on bypassed roads which may account partly for the continuation of high accident rates on the road network following bypass implementation.
Elvik et al (2010)	This looked at a range of bypass studies and concluded accidents were reduced by between 19% and 25% as a result of bypass implementation.

Reference	Notes
Hauer (2007)	'The main obstacle is the near absence of professionals who can be the carriers and providers of factual road-safety knowledge. The second important obstacle is the weakness of the knowledge in which these professionals would have to be trained. Both obstacles stem from the same source; in a society in which it is acceptable to deliver road safety on the basis of opinion, intuition, and folklore.' (p1)
Hill and Starrs (2011)	This recommends a long term approach to road network investment rather than isolated black spot treatments, and states that best practice is to: '...remain watchful of local clusters' and to '...focus on proactive assessments removing known high risks along routes'. ... nor are large road schemes considered to be an effective approach to road safety: ... 'The vast majority of major road schemes derive their benefits from journey time savings'... 'Major projects which must be completed over many years before they achieve their benefits run significant risks of cost overrun in construction and poor performance when eventually open for service. In contrast, a major safety programme is highly modular with short lead times and quick, certain returns'.
Hillman (1992)	The paper questions the accuracy of safety information particularly in terms of under reporting, asks if the achievement of improved safety of the road system is real or if the behavioural response to increased danger has created an illusion of safety – and also questions the logic of branding more sustainable modes as 'dangerous'.
Metz (2006)	'The value of accident savings is commonly an important element of the economic benefit of a road improvement scheme, as estimated by standard cost-benefit methodology. The other important economic benefit is supposed to be the value of travel time savings. However, average travel time has remained constant for many years, which suggests that in the long term the benefits of road improvements are taken in the form of additional access to more distant destinations at higher speeds, rather than in the form of time savings. Such additional travel will result in extra accidents, which are not adequately taken into account in conventional economic appraisal methodology. The value of such extra accidents has been estimated for a number of UK highway schemes. On average the value of these accidents exceeds the value of the accident savings claimed for the schemes. Road improvements designed to reduce accidents therefore need to avoid increasing traffic speeds'. (abstract).
Millot (2008)	'In literature evaluations are often based on quantitative approach, in particular for road safety. But the improvements studied may involve new practices and new uses which may modify road accident types'. (abstract)
Ministry of Social Development (2007)	'Feeling and being safe is a key to overall health in the community. Safety and perceptions of safety feature highly in people's view of their living environment, their sense of wellbeing and quality of life'.
MoT (2009)	Quantification of available TMIF indicators.
NZTA (2010)	Cross sectional reviews of the safety outcomes of new road investments are usually positive but overall are significantly less than predicted.
Noland (2001)	'Conventional traffic engineering would not question the assumption that "safer" and newer roads reduce fatalities. However, this type of approach tends to ignore behavioural reactions to safety improvements that may off-set fatality reduction goals. For example, if a two lane road is expanded to four lanes, then many drivers will travel at higher speeds, potentially leading to no gains in safety. Of course, increased speeds allow increased mobility benefits even if the costs associated with crashes are not reduced'.

Reference	Notes
Pucher and Buehler (2008)	'the Dutch do not perceive cycling as a dangerous way to get around..' (p505).
TRB (2010)	'Fear and anxiety about personal security impedes women's mobility. The session on women's transportation safety and personal security, presided over by Jeanne Krieg, explored gender differences in-crash rates, injury severity, licensing, and personal security needs'. (p23)
Wang et al (2011)	'Traffic incidents cause approximately 50 per cent of freeway congestion in metropolitan areas ...' (abstract) ....'Traffic accidents have significantly longer incident duration than other types of incidents'. (pxiv)

## Appendix C: Assessment of New Zealand post-implementation review procedures and practices

### C1 Overview

#### C1.1 Introduction

This appendix was prepared by Don Wignall as sub-consultant to Ian Wallis Associates on this research project. It supplements the material in the main report, primarily chapter 6: Review of New Zealand post-evaluation procedures.

The NZTA post-implementation review (PIR) programme selects a sample of completed investment projects measured against the initial project objectives, costs and economic justification (NZTA (2008b) *Planning, programming and funding manual* (PPFM), E5.19). The PIR process focuses on whether the project outturn findings are consistent with the post-implementation predictions: it does not examine any wider scheme impacts that were not covered in the pre-implementation evaluation. Historically, the PIR programme has focused on relatively small new road projects.

The original research proposal did not include a specific review of PIR procedures and practices: the main focus of its work on post-evaluation aspects was to be a 'case study' appraisal of the impacts (forecast or actual) of selected major New Zealand roading projects. Once the research was underway, it became apparent that a review of the PIR procedures and practices would be useful: as an outcome of discussions with NZTA's Performance Monitoring Unit (PMU)<sup>25</sup> (through its Technical Audit Manager) this research project was extended: 'to review the current NZTA PIR process in terms of its stated objectives as defined in the PPFM'. This appendix focuses on the work undertaken to meet this objective (completed in September 2010) and covers the following:

- current NZTA PIR procedures
- project types covered by PIR
- application of procedures
- overall performance of projects
- feedback mechanisms from the PIR process to the pre-implementation evaluation procedures, as in the NZTA (2010b) *Economic evaluation manual* (EEM).

The PIR research component of the work reported below has drawn on:

- a series of interviews with NZTA (PMU/IMU and other) staff and external personnel
- review of documentation on the PIR procedures and processes
- appraisal of results for a number of PIRs for specific projects implemented during the period 2001–10.

#### C1.2 Background

Originally, the process now being studied was called a 'post construction audit' or 'post construction review'. In 2007/08 the name was changed to 'post-implementation review' to reflect the increased diversity of project types, some of which do not directly involve construction. However, the PIR process is

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<sup>25</sup> Now Investment Monitoring Unit (IMU)

still primarily applied to new road projects and for ease of reference, all reviews in this appendix are referred to as PIRs.

PIRs have been undertaken for a decade (2001/02 to date) and the results from this work (available up to 2009/10 at the time of undertaking this assessment) now represent a valuable information source.

PIRs make an important contribution to funding accountability, especially in view of the scale of investment (\$8.7 billion) currently being made in transport over the three-year National Land Transport Programme (NLTP) period 2009–12.

The current PIR process contributes to NZTA funding process accountability for small and mid-sized new road projects, by providing a ‘reality check’ on the value for money being obtained.

PIRs are not specifically named as a legislative requirement, but are undertaken by the NZTA in part fulfilment of legislative provisions in the Land Transport Management Amendment Act 2008 (LTMAA).

Relevant LTMA provisions include:

- Section 95 (1) (e) (ii), which lists one of the functions of the NZTA as being “auditing the performance of approved organisations in relation to activities approved by the Agency”.
- Section 96 (1) (b) regarding value for money and d(i) regarding the application of scrutiny to NZTA’s own activities.
- Section 101 (1) (a) regarding sampling that is required by the Ministry.

These legislative references are interpreted by the NZTA through the procedural and technical audit functions (PIRs being part of the latter) as described in sections E5.1, E5.19 and E5.20 of the PPFM.

Options also exist for the future development of the PIR process. For example, PIRs could continue to review a proportion of small and mid-sized new road project expenditure or alternatively, the PIR process could be extended to embrace more projects and/or other parts of the NLTP, depending on the role and scope of the PIR process in the future.

Whatever the ultimate role of PIRs is likely to be, a phased approach to the implementation of the study recommendations is likely to be required, in order to build consensus through a process of incremental improvements.

### C1.3 Current PIR process

PIRs check the actual performance of projects after completion, against their forecast costs and performance at the time of funding approval.

The PIR process is intended to include an annual sample of new capital road projects, with costs of between \$0.5m and \$30m.

Approximately 30 individual PIRs are undertaken each year. Of these, around half of the PIRs undertaken are for state highways and half for local roads.

PIRs are primarily concerned with CBA, although other relevant aspects, such as safety and assessment profiling<sup>26</sup>, may also be picked up during the course of the review, depending on the resources available and on the experience of the reviewer.

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<sup>26</sup> NZTA assessment factors: strategic fit, effectiveness and efficiency as defined in the PPFM.

The method used for the PIR is for the NZTA to complete the review in draft and then to issue this to the submitter (either an approved organisation (AO) or to the NZTA Highway Network Operations Unit (HNO)) for information and comment.

The PIR relies on records from the original evaluation being available, although a site visit and the interrogation of safety records from the crash analysis system (CAS) are also usually undertaken by the reviewer. The time and resources available for PIRs of smaller projects are, however, only sufficient for the application of simplified assumptions and factoring type analysis techniques. Often the potential value of PIRs is greatly diminished because of the non-availability of the original project-related data and documentation.

The finalised PIRs are summarised and used internally by the NZTA for periodic and confidential performance reporting purposes, for example, to describe the proportion of projects found to be delivering predicted economic benefits (Land Transport NZ and NZTA 2005–9).

At the time of the PIR review there was a total of 22 activity classes, consisting of 19 NZTA classes and three administered on behalf of MoT. Of these classes, only four were subject to PIRs. There was also a total of 67 work categories. At the time of the review (September 2010) only eight of these work categories were subject to PIRs.

It should also be noted that in addition to PIRs, the NZTA also undertakes a number of other closely related technical and procedural audit functions.

## C2 Sampling

### C2.1 Current sampling methods

The NZTA's stated intention is to sample approximately 10% (by number rather than value) of new projects completed each year above a cost threshold of \$0.5m. However, the sample is taken from all completed projects (from relevant work categories) between 2001 and the date the sample is selected. The 10% sample is an informal target and in practice the number of projects sampled can vary. For example, in 2008/9, 29 capital road projects/programmes (with costs between \$0.1m and \$17.2m) were subject to a PIR. Of these projects/programmes:

- 15 projects/programmes were from AOs representing \$19.64m out of the total AO funding of \$93.68m. This sample represents around 12% of all AO projects/programmes (with a last claim date in 2008) by number and 21% of AO projects/programmes in the same year by value.
- 14 were NZTA HNO projects. It is not possible to calculate the actual sample rate for HNO projects from the information currently available.

It is also worth noting that the 2008/9 sample actually represents 34 individual projects in the available worksheet database and 39 projects in the end of year report (Land Transport NZ and NZTA 2005–9).

In other years lower numbers of projects were sampled, as shown in table C.1.

**Table C.1 PIR sample sizes**

Year	2001/2	2002/3	2003/4	2004/5	2005/6	2006/7	2007/8	2008/9	2009/10	Total
Sample size	12	10	10	17	12	19	20	34	29	163

The NZTA increased the number and proportion of projects subject to PIR, following a report reviewing the LTMAA 2008, Section 101 requirements (MoT 2008).



Sampling road projects is not an exact science as, for all sorts of practical reasons the information available to select the sample is not always complete and programmes may include several generic, rather than individual projects.

The potential weakness of using the same target sample percentage across all project types is that the resources used for PIRs will tend to be proportionate to the number of completed projects in each category, rather than to the total expenditure on the projects in each category. Thus, for instance, a particular project type sub-category sample may account for 50% of all improvement projects but only 5% of the total improvement budget. In this case, the proportion of PIR resources allocated to this project type will tend to be around 50% of total PIR resources; whereas the PIR efforts to improve evaluation would be more effective (giving better value for money) if only around 5% of resources were allocated to this project type.

Another stated intention by the NZTA is for the sample to consist equally of AO projects and state highway projects each year. While historically this may have been appropriate, it seems likely that AO expenditure in the relevant cost range (approximately) \$0.5m to \$30m, is currently significantly less than 50%. although this is difficult to verify from the information currently available; however, the 2009-12 NLTP indicates that local roads are forecast to account for only 24% of the overall expenditure on new, improved and renewed roads.

Other issues raised by current sampling are as follows:

- In practice, the project (after) cost range of the current PIR sample database is \$0.3m to \$64.0m for state highways and \$0.1m to \$14.1m for local roads.
- The average cost of state highway projects subject to a PIR is \$6.1m, while the average cost of local road projects subject to a PIR is only \$1.8m.

The population list from which the sampled projects are drawn from is a very long one and this raises a number of queries:

- Sampling takes place on a two-tier basis, first the programme is included in list form for random sampling purposes and then subsequently, one or more projects may be hand-picked from a sub-list of projects within the programme.
- Some entries appear to be duplicated and it is not clear which of these are individual projects (although many are clearly not).
- Some projects in the population lists are either not yet implemented or have not received final funding.
- It is not clear whether the status of the funding entries in the list represents application estimates, funding approvals or actual outturn costs.
- It is likely that the current annual sample rate is insufficient to allow firm conclusions to be drawn from the annual comparison of PIR results: generally, useful conclusions can only be drawn by pooling results from several years.

The quality and accuracy of the original population lists are critically important for selecting samples that are:

- clearly derived and consistently obtained
- responsive to population distribution characteristics
- representative in terms of size (ie meeting confidence level and confidence interval requirements).

Despite the fact that some aspects of practice have changed, PIRs represent a reasonably consistent approach over a long period of time and have generated a substantial overall sample of 163 projects since 2001/02.

Furthermore, the simple and basic nature of the current process means that it does represent a very useful 'top level slice of reality' over a range of road projects. This means that a number of important issues and trends are picked up as result of the PIRs undertaken. It is important that this value and continuity is maintained into the future, irrespective of the introduction of any future changes intended to improve the system.

PIRs are sometimes wrongly perceived as being overly critical rather than positively assisting organisations to improve their processes. This indicates a need for better presentation of results as well as better feedback processes.

To summarise, various problems concerning sampling procedures were observed, including difficulties with using Transport Investment Online to establish reliable project status lists. Even so, it is possible to make significant improvements to current sampling methods to make them more representative and to improve comparison between the performance of different project types.

## C2.2 Potential for improved sample procedures

The project lists available for selection need to be more thoroughly screened prior to sampling occurring. It is important that project lists are compiled on a rigorous basis and that the reasons for the inclusion or exclusion of projects are clearly stated.

### C2.2.1 Recommendations

The questions to be asked by the PIR process need to be explicitly determined, for example:

- What proportion of the NLTP by value needs to be sampled to reflect value for money conclusions in programme terms? How many projects need to be reviewed to reflect diversity and ensure conclusions are robust in each major category? Should regional differences in the performance of projects or consultants be investigated? Are AO projects performing differently from similar sized state highway projects? What differences do procurement methods make in terms of outturn benefits and costs?
- What needs to be known about project performance, individually and in aggregate? What are the performance expectations for the projects to be reviewed? Which projects should be selected for review in any particular year? What sort of review should each project be subjected to?
- Should PIR sampling be extended to other funding categories? In future, will PIR sampling be extended to cover other funding categories, potentially including new PT capital expenditure, new PT services, travel demand management (TDM) and walking and cycling<sup>27</sup>. What degree of confidence in the results is required?

Define sample size, stratification and procedures:

- The sample size can only be determined once the above questions have been defined. If the required sample sizes (based on required confidence levels and confidence intervals) are not feasible, then some iteration and adjustment of the number and type of questions may be required. The timeframe to develop a suitable sample may take several years, unless earlier PIR data can be used.

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<sup>27</sup> At present, only small numbers of suitable TDM, PT and walking and cycling projects are available for review.

- The samples also need to be suitably stratified in order to address the required questions. It has been shown (Highways Agency 2009) that significant differences can be observed between projects of different scales (small, medium and large) and also between projects of different types, for example, AO and state highway for comparable project scales (NZTA 2010a).
- The project lists that samples are 'selected from' need to be screened prior to sampling. It is important that the basis used for compiling project lists is explicitly stated, for example, projects of defined types, above and below defined cost thresholds or implemented within particular periods.
- The reasons for the inclusion or exclusion of projects should be clearly stated. Records of population lists, sampling methods and assumptions should be maintained.

Broaden and increase the PIR sample:

- Include a selection from all capital projects (for example large road projects and PT projects). Subject to resources, complexity should not normally be regarded as a barrier to the inclusion of large projects in the PIR sample.
- Include a selection from all new non-capital projects (including TDM and PT services).
- Continue to exclude maintenance, operational and ongoing PT support expenditure, as these are (or should be) picked up by other technical audit and monitoring techniques.
- The overall impact of RoNS is being considered separately from the study through an enhanced PIR (ePIR) process<sup>28</sup>. This is because RoNS are the equivalent of long-term multi-project strategies rather than representing individual projects. However, the individual project components of RoNS should be suitable for evaluation via a conventional PIR.
- Increase the sample size, based on required PIR scope and stratification, for example, in terms of project scale, type, region, time period and/or other factors.

## C3 Input information

### C3.1 Required project information

Various project-related information is required for PIRs (NZTA 2008a) as follows:

- any time delays (in project delivery) with reasons
- changes in project scope
- reasons for not actioning safety audits
- reasons for inconsistencies with maintenance strategies or route/network development
- reasons for variations in designing or constructing required standards
- with the benefit of hindsight would the project manager have done anything differently?
- explanation of any changes to project funding
- breakdown of actual costs and ratio of final costs to pre-approved budget
- differences in costs between road controlling authority and NZTA records
- pre-implementation breakdown of forecast net benefits

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<sup>28</sup> This was supervised by the Performance Monitoring Unit.

- reasons for material differences between the actual and forecast traffic volumes or benefits (travel time, VOC, safety, comfort, CO<sub>2</sub>, particulates and other) with reasons
- comment on the achievement or otherwise of 'immediate' benefits
- accuracy of pre-implementation estimate in future (maintenance/operational costs) or in the estimate of do-minimum costs, with reasons for any variation).

### C3.2 Information sources

The key information sources potentially available for PIRs to draw on include:

- submitter liaison meetings and discussions, project files, site observations and associated indicative surveys
- project feasibility reports (PFRs) and scheme assessment reports (SARs), which should contain all material factors and provide a baseline for the PIR, ideally including suitable project economic evaluations updated to the time of first significant construction funding approval.
- Transport Investment Online funding application and any supporting documentation (either produced by the submitter or the NZTA) for the funding application
- cost approval and variation records. NZTA records on construction funding (Board approvals, NLTP review group delegations and PROMAN.
- safety audit results, MoT regional safety trend data, before and after CAS road safety data based (ideally) on five years of post-opening data
- traffic count data (if available). Before and after traffic counts, ideally in terms of volume, composition and flow profile, using daily/peak/nonpeak flows, depending on what basis the SAR and associated CBA was undertaken.
- other background/trend data, including NZTA Smartmovez, RAMM and PT data.

In practice, the information needed for PIRs is often incomplete, which substantially reduces the potential quality (and hence the value) of the PIRs undertaken.

Currently, there is a NZTA requirement (section E5-1 of the PPFM 'Supply of Information between approved organisations and the NZTA') but this presupposes that the submitter has the information fairly readily to hand, which is often not the case.

There is no systematic requirement to collect and record specified information as projects are planned, developed and implemented. AOs or HNO are not currently required by the PPFM to collect and maintain documentary records or to collect post-implementation data at all stages of the project lifecycle.

### C3.3 Future information requirements

An appropriate document and data recording and retrieval system (capable of audit) is really needed to provide accountability and should be linked to the entire project life cycle to ensure that appropriate information is collected, recorded, maintained and accessible at all stages.

In the short run, an increase in PIR survey budgets is probably required to enable more reliable post-implementation data to be gathered.

In the medium term, new PPFM information gathering requirements for projects could be introduced that would reduce the need for specific PIR-related surveys. This should be undertaken on a selective rather

than a universal basis. In other words, above minimum baseline requirements any additional information requirements would be tailored to the individual project concerned.

In the long run, new PPFM information gathering requirements are likely to add significant value, by providing a 'black box recorder' type capability that would allow all projects to (potentially) be available for PIR selection, either as part of a random sample, or to investigate issues arising during the course of the project. This PPFM information requirement is more likely to influence behaviour than the actual PIRs that are undertaken, useful and essential though these reviews are.

### C3.4 Recommendations

Introduce a requirement in PPFM for documents to be maintained and post-implementation data to be obtained for PIR purposes:

- Apply this requirement throughout the project lifecycle (including post completion for a defined period) to ensure that data and documents are available in an appropriate form for reviewers, when required.
- Ensure this requirement does not involve any significant additional effort or cost on the part of submitters as most of the documents and data required is already produced, the main problem being that information is often not conveniently available.
- Ensure this requirement is limited to core elements and to any other particular factors relied on for funding justification and approval.
- Develop and introduce the automated recording of documents and data using Transport Investment Online, say, through its enhanced entry and reporting facilities. If done well this would improve information quality and reduce compliance costs.

## C4 PIR methodology

### C4.1 Current methodology

The following methodology is used by the reviewer to complete the PIR worksheet form (NZTA 2008a):

- Identify objectives and assess the risk of non-achievement.
- Assess the appropriateness of the Transport Investment Online assessment profile.
- Assess the significance of: traffic growth, travel time savings, comfort, VOC, CO<sub>2</sub>, particulates or other benefits, subject to application of a materiality threshold test that the category accounts for at least 20% of total estimated benefits to trigger inclusion in the review.
- Do CAS records show anything unexpected? Assess the significance of crash cost saving in terms of the forecast net benefit (and application of the >20% materiality threshold test) to supply more detailed information and calculation of ratio of actual to forecast crash cost saving.
- Provide indicative post-implementation BCR and ratio of post-implementation to pre-implementation BCR.

Final comments from the reviewer are requested on the:

- project scope and purpose
- reviewer's summary.

The PIR worksheet form is supported by PIR guidance notes (NZTA 2008a) the first part of which provides some additional background on the thinking behind the PIR process and the definition of some of the terms used. The second part of the PIR guidance notes is in tabular form and relates to particular questions and sections of the spreadsheet. The PIR guidance notes provide some useful general pointers but do not discuss methodology aspects in any detail.

The PIR worksheet form and guidance notes require updating, for example to make work categories consistent with the current PPFM and remove references to Land Transport NZ.

The form and notes also require adjustment to improve clarity, by removing duplication and ambiguity, and to standardise techniques where there is a risk of individual reviewers reaching different conclusions.

To summarise, the current methodology is broadly consistent with similar procedures in other countries. However, some updating, more detailed advice and standardisation on when and how to apply appropriate techniques would all be helpful in improving the quality and consistency of PIR outputs.

## **C4.2 Current practice**

### **C4.2.1 Study area**

The estimated area of influence of the project is often narrowly drawn, to cover just the new/improved route and the main alternative route(s) from which traffic is predicted to divert.

The implications of such a narrow study area are that wider effects (relating to traffic changes outside the defined study area) may be ignored. Where this is the case, this could result in under-estimation of total effects leading either to an under-estimation of benefits (for example, where travel time savings occur on the wider network) or to an over-estimation of benefits (if adjacent bottlenecks are ignored or if accident migration occurs beyond the study area boundary).

There is a need for appropriate and consistent area of influence definitions to ensure pre- and post-implementation comparisons are valid.

### **C4.2.2 Traffic volumes**

Generally, post-implementation estimates of traffic volumes appear to rely on traffic volume data (AADT) derived from traffic counters (where available), compared with the pre-implementation forecasts of traffic volumes. The ratio of these two figures may then be applied in PIRs to factor the prior estimates of traffic growth.

Relatively little investigation appears to be undertaken of cases where post-implementation traffic volume estimates differ significantly from the pre-implementation forecasts. Thus there is little investigation of induced traffic or peak-spreading effects.

Where no other evidence exists, PIRs tend to assume that the traffic volume growth rates in percentage terms over the project life estimated in the pre evaluation forecasts continue to be applied in the post evaluation.

### **C4.2.3 Travel times**

Post evaluation surveys of travel times do not appear to be undertaken in most PIRs. Typically, estimates are made (by visual assessment or a simple drive through) as to whether the forecast travel times are being more or less achieved. However, for most projects, significant congestion would not be expected in the early years.

It is likely that current PIR practice does not allow adequately for migration of queuing or congestion.

#### **C4.2.4 Vehicle operating costs**

Separate 'after' assessments of VOC savings are generally not undertaken either for project monitoring or for PIR purposes. Current practice tends to a default assumption that the pre-implementation estimates of savings per vehicle are being achieved post-implementation, although in some cases, total VOC benefits may be factored by the ratio of actual to forecast traffic volumes.

#### **C4.2.5 Crash costs**

In recent years (since 2007/08), for projects for which crash benefits were predicted to be a significant (>20%) proportion of total benefits, the post-evaluation data for crash numbers and corresponding costs have usually been derived from CAS records. Pre- and post-crash estimates are then derived on a consistent basis, allowing for under-reporting, etc. Current crash cost rates are applied (if cost rates have increased substantially during the implementation period). Some differences may occur in methodology between the original social cost forecasting methods and the actual check on post-implementation social costs undertaken by a PIR. These differences could include area of influence definitions and the allocation of causation for any identified changes in social cost.

#### **C4.2.6 Current practice comments**

It appears that in PIR cases (the majority) where individual benefit categories account for less than 20% of the pre-evaluation estimate of net project benefits, the post-evaluation estimate of benefits is assumed to be unchanged from the pre-evaluation benefit forecast.

The PIR methodology essentially compares the pre-evaluation forecasts of scheme benefits over the evaluation period; with an adjusted set of estimates taking account of actual traffic volumes, travel times and crashes in the first few years after scheme opening. Beyond this the reviewer must make an assumption about future rate of growth and future conditions in order to estimate an outturn BCR.

Thus the estimated change in overall benefits takes account only of the observed changes shortly after opening, not of any revised forecast changes over the remainder of the evaluation period (for example, due to new estimates of future populations, fuel prices or economic growth).

It is important that PIRs have access to the original methodologies and assumptions used to produce the pre-implementation project forecasts.

#### **C4.2.7 PIR timings**

PIR timings tend to focus on two options:

- 1 Around 12 months after opening, by which time initial traffic patterns will have stabilised
- 2 Around five years after opening, to allow sufficient data for crash analysis.

There would be merit in undertaking some 'follow-up' PIRs say 10 years after scheme opening, although such cases would require some caution in interpretation of results due to the potential for significant non-transport changes to have occurred over the period.

### **C4.3 Possible changes to future methodology**

#### **C4.3.1 PIRs for large/complex projects**

Particular difficulties have been encountered in the post-implementation evaluation of 'large' projects arising from the problems of assessing impacts in large complex urban networks.

From the NZTA's database of projects subject to PIR since 2001/02, it appears that no projects with pre-evaluation costs exceeding \$25M have been subject to PIR up to 2009/10. This implies that a very large

proportion of the total roading improvement expenditure is effectively being excluded from post-evaluation (through PIR or otherwise).

The NZTA has undertaken a study on the potential methodology for pre- and post-evaluation of roads of national significance (RoNS) projects (MWH 2010).

#### **C4.3.2 Recommendations**

Confirm and refine as necessary basic PIR requirements:

- Confirm the scope and purpose of the PIR process.
- Develop better techniques for checking the quality and consistency of assessment profiles, including non-monetised and important non-BCR issues relevant to funding decisions.
- Include all economic benefits rather than only benefits over a certain threshold (currently >20% of total forecast benefits) to assist with the monitoring of benefit-related target performance.

Adjust existing form and supporting notes:

- Improve the structure and clarity of the form and supporting notes to reflect the scope and purpose of PIRs.
- Update the form and supporting notes to make consistent and to reflect current circumstances.
- Incorporate succinct advice (plus further references) on the standardisation and application of techniques.

Widen the scope of PIRs for selected projects, in a bespoke way on a project-by-project basis:

- In all cases, a core PIR should be undertaken (covering travel times, traffic volumes/composition, safety, the BCR and assessment profile).
- Review any additional issues (in addition to the core PIR factors) likely to be involved from known project information, potentially including one or more of the following: economic development, accessibility, health, or environmental issues.
- Discuss and confirm with stakeholders at the pre-implementation stage whether any additional factors or investigations (over and above core PIR requirements) should be included and if so make arrangements for early data capture.

Improve and implement the PIR methodology as follows:

- Stratify PIRs into simple and complex projects.
- Increase the depth of analysis undertaken for PIRs.
- Allow adequate resources to undertake PIRs and provide feedback to the sector.

## **C5 PIR results analysis**

### **C5.1 Current PIR summary analysis**

#### **C5.1.1 Overview of before/after evaluation estimates**

From the PIR results, the differences between pre- and post-evaluation infrastructure (capital) costs are greater than the equivalent differences in benefits. Prima facie, this is surprising, although we note that the post evaluation cost figures are precise, whereas the post-evaluation benefit figures are estimates only, and appear to have a bias towards being unchanged from the pre-evaluation forecasts.



All the aggregated reporting available focuses on average results across the relevant projects, with (explicitly or implicitly) each project being given an equal weighting. For example, this applies to analyses of:

- Proportion of completed projects with BCR within 80% or 90% of the prior BCR estimates. (This is consistent with the NZTA SOI target which is also defined in terms of the proportion of projects, not the proportion of expenditure.)
- Year-by-year summaries of average percentage cost change, benefit change and BCR change. These percentage averages appear to be the unweighted average of the percentage changes across the projects reviewed, with no allowance for project size. It is important that the reporting of BCR averages is undertaken on a weighted rather than an unweighted basis.

Revising the reporting approach in this way would help to better focus on efforts to improve the value for money from the overall capital expenditure programme.

### C5.1.2 Costs

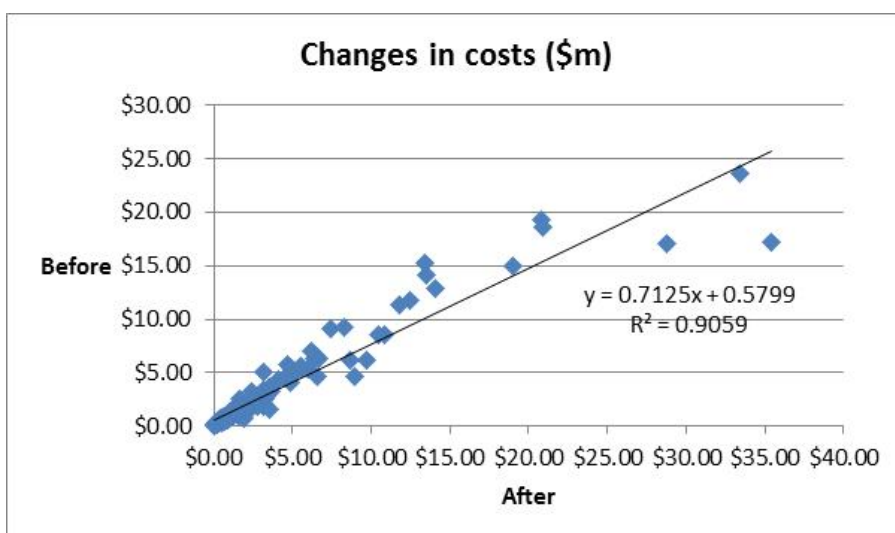
An overall analysis of PIR results indicates that post-implementation capital costs have been recorded in most cases (88%), as shown in table C.2.

**Table C.2 Recorded cost changes**

	2001–10 PIRs	Percentage
After costs recorded	143	88%
After costs assumed identical	3	2%
No cost estimate	0	0%
Not yet completed	17	10%
<b>Total</b>	<b>163</b>	<b>100%</b>

As might be expected, there is a close correlation between estimated ‘before costs’ and recorded or assumed ‘after costs’ for individual projects as illustrated in figure C.1.

**Figure C.1 Comparison of before and after costs**



The overall PIR results 2001–10 indicate that recorded and assumed ‘after costs’ are on average around 16% higher than estimated ‘before costs’.

This is reasonably consistent with international experience (Flyvbjerg 2002; Highways Agency 2009).

### C5.1.3 Benefits

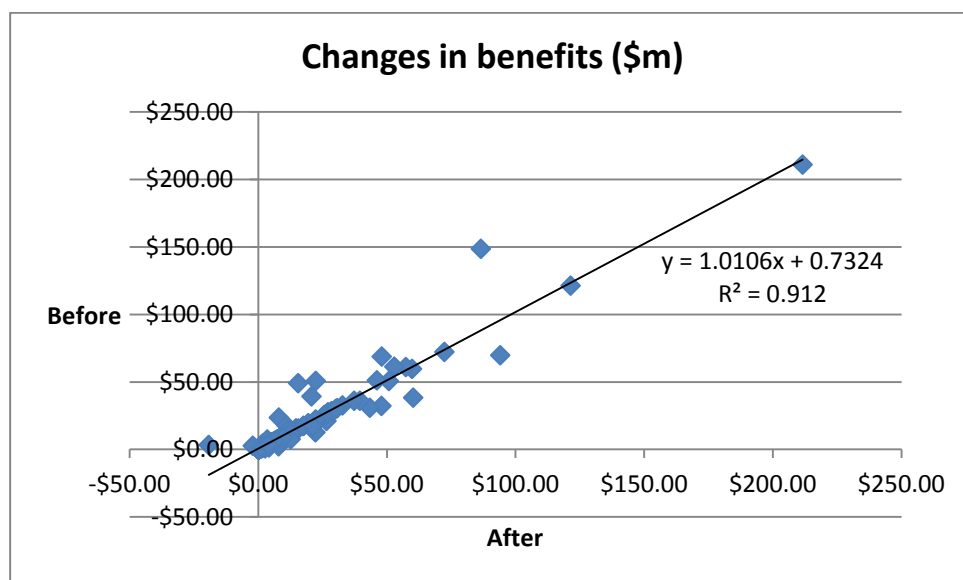
In contrast to costs, the post-implementation benefits could only be estimated in less than half (46%) of project reviews listed in the PIR database, as shown in table C.3.

**Table C.3 Estimated benefits post implementation**

	2001-10 PIRs	Percentage
After benefit estimated	75	46%
After benefit assumed identical	66	41%
No benefit estimate	5	3%
Not yet completed	17	10%
<b>Total</b>	<b>163</b>	<b>100%</b>

There is also a close correlation between 'before' forecasts of benefits and estimated/assumed 'after' benefits for individual projects, as shown in figure C.2.

**Figure C.2 Comparison of benefit estimates, before and after implementation**

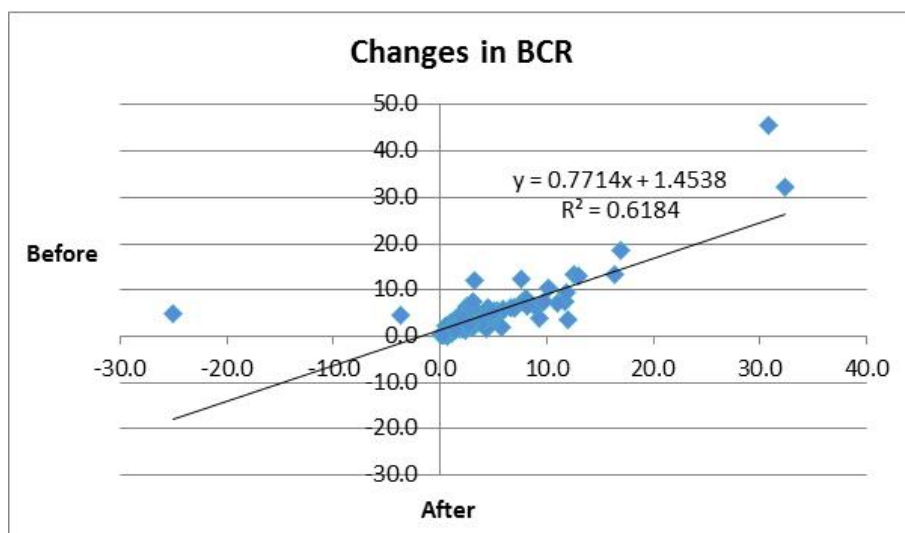


From the overall PIR results 2001-10, the estimated and assumed 'after benefits' were on average 94% of the before forecast of benefits. If true this would be exceptional in international terms, (Flyvbjerg 2004; Highways Agency 2009).

However, many of these benefits have been assumed rather than estimated and it is also worth noting that many of the benefits have been assumed on a very simplified basis. This calls into question the value of the process and analyses as currently carried out.

### C5.1.4 Benefit-cost ratio (BCR)

The correlation between 'before' and 'after' benefit-cost ratios for individual projects is shown in figure C.3.

**Figure C.3 Comparison of BCR estimates, before and after implementation**

The correlation between, before and after BCR values is lower than the correlations for costs or benefits separately. This reflects that the BCR represents the ratio of the two variables.

From the above distribution it is clear that a number of outlier projects warrant more detailed investigation.

The tendencies for 'after costs' to be higher than 'before estimated costs' and for 'after benefits' to be lower than 'before forecasted benefits', combine to mean that the overall cumulative 'after BCR' is 11% lower than the 'before predicted BCR'.

Putting this in context, it represents a reduction in average BCR terms from 4.6 to 4.1<sup>29</sup>.

Multi-project analyses are needed to identify and investigate overall performance and to establish trends.

These analyses can be undertaken in a variety of ways and the methods, assumptions and questions used may significantly affect the conclusions drawn from the work. This means that some degree of standardisation is required for multi-project analyses.

### C5.1.5 Discussion

These results usefully illustrate some issues as follows:

- A number of projects appear to perform significantly different than forecast (in terms of the distribution of benefits and costs in % terms) and further investigation seems warranted in these individual cases to see why this has occurred.
- The BCR is not a suitable target measure to be used in isolation or in terms of the proportion of projects achieving a certain threshold, as BCRs fluctuate significantly compared with cost and benefit performance.
- When looking at individual benefit categories, based on real data, other problems are apparent. For example, an investigation found that most projects only appeared to be delivering on a small proportion of their intended safety benefits. This also resulted in a 20% shortfall in overall benefits for the projects considered.

<sup>29</sup> However it should be noted that these 'average' figures from the PIR sample have not been weighted by project costs.

- Information on other benefit categories such as travel time, VOC and CO<sub>2</sub> was not available at the time of writing. It should also be noted that the application of the 20% threshold in the current PIR methodology means that analysis of individual benefit categories may be difficult with the current data set.
- From the analysis of PIR results, it also appears that the performance of state highways and local road projects is diverging. However, these are essentially for different project types and sizes so it is not possible to be definitive. A more satisfactory comparison would be to compare small AO with small state highway projects, mid-sized AO projects with mid-sized state highway projects, and to also make allowances for other differences likely to affect results, such as whether the projects were urban or rural. There is also a need to rule out the possibility that state highway project performance has been declining in absolute terms either because of changing sample techniques or due to differences in analytical approaches.
- Over time, overall performance also seems to be getting worse year-on-year, but again further investigation is warranted to confirm if this is a 'real issue' or if it is connected to other factors. For example, out of the 10 PIRs undertaken in 2002/3, eight assumed that actual benefits would be identical to those that had been forecast.

To summarise, analysis of PIR results has been undertaken over a number of years and this has provided useful summaries of overall project performance and associated trends. Improved stratification of the results (by scale and type of project) would allow further value to be derived from the existing database.

## C5.2 Multi-project analysis example

### C5.2.1 Introduction

There is a role for multi-project post-implementation reviews to be undertaken to consider specific themes (such as the effects of projects on safety or travel time) and also to review trends over time.

For illustrative purposes, two examples of multi-project analysis are described below. The studies were both undertaken with the aim of establishing whether or not new road projects had been delivering effectively in terms of safety benefits.

The analyses were undertaken two years apart and both samples were intended to represent a cross section of non-safety focused road investments.

It is also likely that there would have been some variation in the post-implementation data periods between projects, although this is not clear from the information available.

The analyses were both undertaken professionally/competently and the results in both cases were useful.

Despite these similarities, the studies reached strikingly different conclusions and the discussion below explores why this occurred and how such multi-project analyses could be appropriate in the future.

### C5.2.2 2006 review (Transport Futures 2010)

The 2006 study undertaken for Transit NZ considered post-evaluation safety impacts for 18 new road projects on the basis of crash records

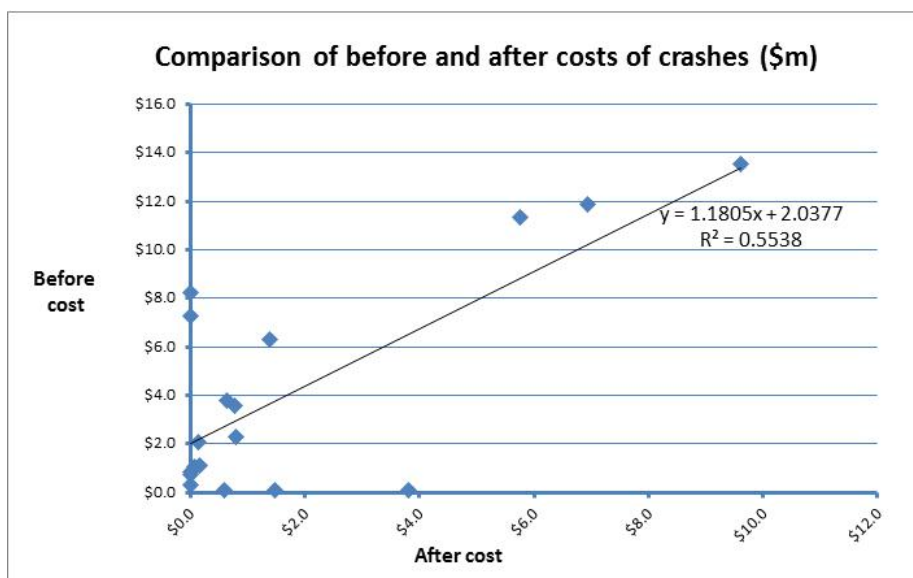
The results from the 2006 analysis indicate that:

- 15 of the 18 projects led to an improvement in road safety costs whilst three projects led to increased social cost.
- The overall social cost of crashes was more than halved as a result of the road projects reviewed.

- As a result of the analysis the current project planning and implementation practice for assessing the safety impacts of projects was given a 'clean bill of health.'

The 2006 analysis is illustrated below in figure C.4.

**Figure C.4 Comparison of before and after social costs**



Some aspects of the analysis undertaken were not available, for example:

- the precise way in which sampling was undertaken
- the scale and precise types of project included.

It should be noted that, unlike the 2008 analysis described below, this work did not compare forecast safety costs with actual changes in safety costs.

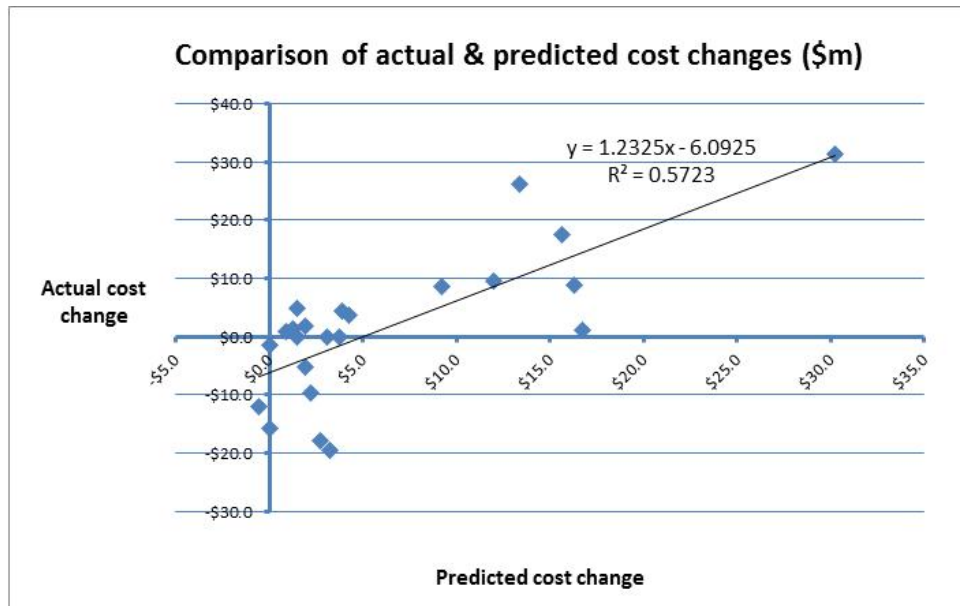
### C5.2.3 2008 review (Transport Futures 2010)

The 2008 analysis undertaken for Land Transport NZ reviewed 23 road projects in terms of their forecast<sup>30</sup> safety benefits compared with actual benefits, and found that in practice, five of these projects exceeded forecasts, three met forecast and 15 were below forecast.

The 2008 analysis is illustrated in figure C.5.

<sup>30</sup> From the cost benefit analysis undertaken for funding application purposes.

**Figure C.5 Comparison of actual and predicted social costs of crashes**



The results from the 2008 analysis indicate that:

- overall, the projects only delivered 26% of their forecast \$144.7m safety benefits
- in a number of cases, significant crash savings were predicted, but were not achieved
- a number of projects resulted in large increases in actual road crash costs
- crash savings were within 20% of the predicted level for only 39% of the projects examined, while they were less than half the predicted level for 48% per cent of the projects.

Some aspects of the analysis undertaken were not available, for example:

- the precise way in which sampling was undertaken
- the precise types of project included
- the approach to crash identification and forecasting (in terms of the identification of relevant crashes and the assumptions used for future crash estimation).

Sensitivity testing undertaken shows that removal of the five worst performing sites would mean that the residual projects would capture over 80% of forecast benefits.

It should also be noted that, unlike the 2006 analysis described in section C5.2.2, this work focuses on a comparison of predicted and actual crash costs after scheme implementation, not a comparison of before and after crash costs.

#### **C5.2.4 Discussion of results**

The 2006 and 2008 analyses asked different questions, namely:

- The 2006 study was concerned with the difference between before and after social costs.
- The 2008 study looked at whether or not forecast safety benefits were achieved.

The studies highlight the need for consistent, rigorous and standardised methodological approaches to multiple project and theme-based analyses.

### C5.3 Future analysis

In the future it would be useful if more analysis and interpretation were undertaken to identify issues and potential problems.

This analysis and interpretation could include:

- further analysis of the information gathered to date via PIRs
- additional and more detailed investigations into significant problems or areas of interest to confirm and quantify evidence.

### C5.4 Recommendations

Expand the focus of PIRs from 'reporting on what' has happened to also 'analyse why' it has happened:

- Continue reporting on a factual basis (ie to describe 'what' has happened).
- Apply additional analytical methods to investigate identified problems (and to investigate 'why' these may have happened).
- Standardise and improve multi-project theme type analysis. Current safety analysis may not be perfect, but if everything came up to these standards (in terms of data, audit, research and analysis) this would represent a very significant advance on current practice.
- Develop recommended analysis procedures for larger and more complex projects. Such analysis is commonly undertaken in other countries with equally complex networks. If an evaluation on a large project has been well undertaken for funding purposes, then in the vast majority of cases it will not be 'too complex' to undertake post-implementation analysis.
- The analysis and techniques used for individual PIRs should be reviewed on a case-by-case basis, recorded and made available for audit.

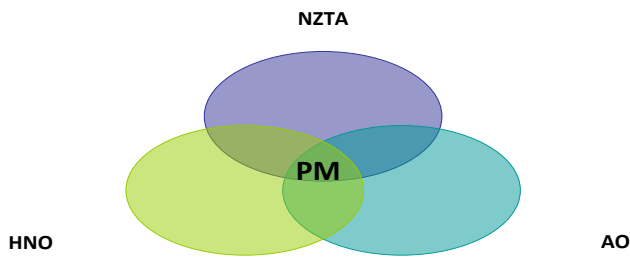
## C6 Feedback

### C6.1 Current feedback

The PIR process is managed by the NZTA Investment Monitoring Unit (IMU) (formerly the Performance Monitoring Unit) and the PIRs themselves are undertaken by IMU staff and/or their consultants.

The PIR process is based on the IMU reviewing a selection of projects submitted for National Land Transport Fund (NLTF) funding and subsequently implemented by NZTA HNO and AOs. Figure C.6 shows the organisations involved in the PIR process.

**Figure C.6 Organisations in the PIR process**



(HNO: Highway Network Operations responsible for state highways, AO: approved organisations responsible for all other investments)

An important component in this research project and its development of findings and recommendations was to obtain responses from a range of practitioners in the transport sector (from the NZTA, AOs and consultants) on the subject of PIRs.

The purpose of contacting practitioners was to:

- understand how PIRs are currently viewed by the sector
- see if there is any consensus on issues raised by the current approach to PIRs
- identify potential improvements to the PIR process.

The questions asked of respondents focused mainly on:

- the methods used in selecting and investigating a sample for PIR purposes
- the potential interpretation and application of results obtained.

The response obtained internally from within the NZTA and externally, from submitters and consultants, was good and of a consistently high quality.

From this work, it was established that the present feedback to submitters is very limited: during the course of conducting a PIR only the draft findings are currently issued to the submitter and there is little if any follow-up to address any problems identified.

Feedback to other NZTA sections is better, as follows:

- An annual summary of the findings from PIRs and any overall comments on issues arising are issued by PMU/IMU in memo form to management (Land Transport NZ and NZTA 2005–09).
- Informal discussions (often arising from PIR findings and analysis) also take place between IMU staff, the PIR consultants and other NZTA staff on an issue-specific basis. However, in the last five years, no issues have been identified where feedback from the PIR process or results has been used in amending the EEM.

In summary, feedback could be improved at two levels:

- Individual reporting and advice back to submitters could be extended to provide the final review findings and to arrange follow-up meetings, advice and support to remedy identified problem.
- Key information and recommendations from the PIR process could be released (in a suitable and agreed form) to others within the NZTA and also to the wider transport sector to increase awareness of PIR findings.



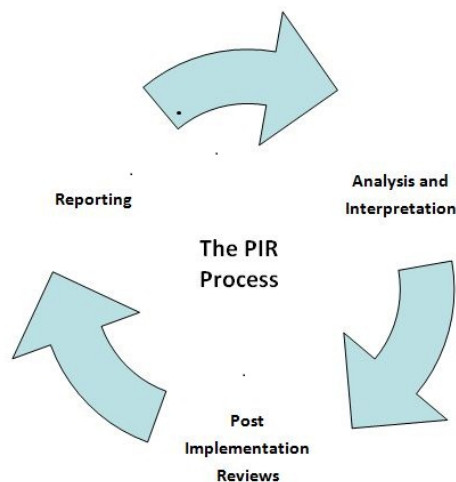
## C6.2 Possible changes to future feedback arrangements

The PIR process is represented in figure C.7, and there is potential to strengthen the reporting, analysis and interpretation elements of it in order to provide better feedback to submitters, other NZTA sections and to the wider transport sector.

Potential improvements in feedback need to include:

- dissemination of information (more visible and accessible)
- identification and specification of required remedial actions.

**Figure C.7 Stages in the PIR process**



## C6.3 Recommendations

Using current procedures and existing data, demonstrate the value of the PIR process to other parts of the sector:

- Consider technically, organisationally and methodologically what needs to be done internally (within the NZTA) to investigate issues in more depth and to complete required feedback loops. This appears to be a responsibility that sometimes falls between IMU and other NZTA sections.
- Provide final feedback on the PIR to submitter, by identifying good practice and areas where the NZTA will work with the submitter to improve processes or outcomes. This should be aimed at providing feedback to submitters to assist them improve their project development, evaluation, forecasting and monitoring.
- Use some existing PIRs as 'demonstration projects' to look in more depth at any 'lessons learned' and how feedback might be used to illustrate and explain issues and also to build consensus and support for better practice.
- Publish summary and theme-based studies, in a suitable and agreed form, to identify common issues and trends for the benefit of internal dissemination within the NZTA and externally to the wider transport sector.
- Ensure that findings from the PIR process and its results are used in the development of enhancements to the EEM, as appropriate.
- Use the above findings for increased and enhanced internal and external training programmes.

## C7 Indicators and targets

### C7.1 Statement of intent 2009–12

The indicators and associated targets in the *NZ Transport Agency Statement of intent (SOI) 2009–2012* (NZTA 2009) at the time of the commencement of the PIR review are shown in table C.4.

**Table C.4 Formal performance targets**

NZTA SOI performance measures target	2009/10	2010/11	2011/12
Post construction reviews (% of sample size) (realisation of benefits Yes/No)	>90%	>90%	>90%

It should be noted here that even in circumstances where actual total cumulative benefits were exactly equal to forecast benefits, this could still mean that half the projects would ‘fail to achieve’ their forecast benefits due to the optimism bias in cost estimation and benefit forecasting. In fact, from the available PIRs undertaken (2001–09), only about half (49%) had estimated post opening benefits<sup>31</sup> that realised their forecast benefits.

The reason for this is that the above benefit target is ‘project based’ and the accuracy of economic analysis is such that a very conservative approach would need to be taken to forecasting in order to achieve it.

If benefits were very cautiously estimated (at the very low end of the forecast range) then it might be possible to achieve the target, but this would be on the basis of unrealistic benefit forecasts with consequent reductions in forecast BCRs. Another problem with a threshold type approach when used in isolation is that it does not identify inaccuracies and variability in forecasting and estimation. In other words, where target thresholds have been achieved mainly because benefits forecasts have been greatly under estimated or because costs have been over estimated.

Furthermore, this method used to undertake PIRs is not really suitable to ascertain whether or not the (former) SOI target was being met. This is because the application of thresholds of ‘materiality’ used in the current PIR methodology means that if a particular benefit is not ‘at least 20%’ of the total pre-implementation benefits, it is not estimated post-implementation.

### C7.2 Later SOIs

The later SOI (2010–13) included the following indicator: ‘Investment performance measures: New and improved infrastructure for state highways and local roads: % of projects reviewed post-implementation that have an assessment profile within approved construction thresholds’ (NZTA 2010c).

However, the current SOI (2012–15) does not contain any specific targets or indicators with respect to post implementation reviews. Value for money is mentioned frequently but no specific indicators of this are contained in the SOI.

To check on the value for money being obtained, in the absence of any specific advice in the SOI, it appears there is a continuing need for PIRs to inform monitoring activity against performance measures and targets.

<sup>31</sup> Excluding PIRs which assumed that ‘after benefits’ were identical to ‘before benefit forecasts’.

### C7.3 BCR targets

The limitations associated with the former SOI performance indicator and target, particularly the absence of a cost target and/or value for money target, means that (for working purposes), the Investment Monitoring Unit reviews the performance of projects against the informal targets shown in table C.5.

**Table C.5 Informal performance targets**

Performance monitoring 'working' performance measure target	2009/10	2010/11	2011/12
Post-implementation reviews (% of sample size) (realisation of 90% of BCR or a BCR>4: Yes/No)	>90%	>90%	>90%

However, there are inherent problems in using ratio-based targets. In particular it is not always immediately clear why a ratio may not have met a certain criteria. For example, is this due to a benefit forecasting or cost estimation issue or is it a combination. The above working target is also project based, rather than being based on a cumulative total BCR, and this creates further problems of achievability and relevance as discussed in C7.4.2 below.

It has been estimated elsewhere (Flyvbjerg et al 2002) that the average cost over-run on major road projects internationally is around 20% on average. From the available PIRs undertaken (2001–10), overall cumulative costs in New Zealand have been found to be around 14% higher than estimated (NZTA 2010a). However, the international estimate is based primarily on major projects, whereas the PIR figure is based on much smaller projects.

Some difficulties in the BCR working target can be illustrated as follows:

- On the basis of project performance where there was no bias in cost estimation and benefit forecasting (and a normal distribution of benefits and costs), 50% of projects could be expected to achieve (or better) their forecast BCR.
- However in practice, actual costs are usually higher than forecast and benefits are on average lower than forecast. This creates the likelihood that only a minority of projects will meet or better their BCR in practice. It should be noted that such an overall finding cannot automatically be taken in isolation as an indicator of particularly poor performance.
- From the PIR database 2001-2009, the current performance, in terms of the proportion of projects that 'achieve or better' their BCR is approximately 38% (NZTA 2010a). This is broadly consistent with published performance in the UK (Highways Agency 2009).

In order to address value for money, the overall cumulative cost performance of projects could be used in conjunction with their overall cumulative benefit performance, to calculate an overall cumulative BCR performance for programme assessment purposes.

To summarise:

- The SOI 2009–12 (NZTA 2009) target required 90% of PIR sampled projects to achieve at least their stated benefits. This would have been more appropriate if the performance indicator had been 'overall cumulative benefits', rather than being based on a percentage of projects.
- Later SOIs have been more strategic in nature and the current SOI (2012-15) does not contain any specific indicators or targets with respect to BCRs.
- The use of 'overall cumulative cost' performance indicators and tests of the accuracy or otherwise of BCRs are needed at the more detailed level to enable overall 'value for money' to be assessed.

- For working purposes therefore, the IMU has adopted a cost-benefit ratio target as follows: 90% of projects are expected to either i) achieve or better 90% of their forecast BCR, or ii) to achieve a BCR of over 4.
- Analysis of PIRs undertaken indicates that the proportions of projects within a  $\pm 20\%$  accuracy range are as follows: benefits 56%, costs 75%, BCRs 66%.

## C7.4 Development of future indicators and targets

### C7.4.1 Discussion

The choice of future performance indicators and associated targets is very important in designing the PIR process, analysing overall programme performance and in undertaking individual reviews. When thinking about targets the following aspects are likely to be relevant:

- Targets have to be well thought through, as what may look instantly appealing, may be very poor in practice.
- Targets are most likely to be effective if they are well understood and command widespread support.
- Targets can be irrelevant or even perverse, but if well constructed, they can be very useful in generating positive behaviour change.
- Ambitious 'stretch' or 'aspirational' targets have their uses, but in the case of PIRs, such an approach is not likely to be effective.
- For PIRs, there is a need to be realistic about current performance, how this can be incrementally improved and to find effective ways forward.

### C7.4.2 Matrix approach

The concept of a performance indicator and target 'matrix' is potentially useful for both 'strategic' (SOI type) applications and also for 'working level' reporting and analysis purposes. This is because a single indicator or target cannot comprehensively describe project performance.

Future PIR headline targets could usefully include references to the 'overall cumulative' achievement of benefits and costs. To complement this, and to allow project performance to be monitored against targets, some changes to PIR methodology also need to be made to ensure that all benefits are considered, rather than only those over a certain threshold.

In addition to monitoring the overall cumulative performance of projects, it is also important to continue to monitor the distribution of individual project performance and especially to identify outliers and reasons for cost estimates or benefit forecasts that are well outside expected norms. This could be included within a matrix approach, as one type of 'level of service' criteria.

A performance indicator and target matrix type approach could include 'value for money' and 'level of service' aspects, as follows:

- Value for money could be established by using the headline benefit and cost indicators to derive an overall cumulative BCR for the overall sample and for any other samples of project types.
- Level of service criteria could be used to identify the incidence of 'outliers' in project performance terms, by referring to the proportions of project actual outcomes falling below defined lower estimated/forecast bands (of say): benefits <80%, costs >120% and BCRs <60%.

An illustration of a possible approach to developing a PIR performance indicator matrix and associated targets is suggested in table C.6.

**Table C.6 Potential performance targets**

Performance indicator:	Possible targets		
	20011/12	2012/13	2013/14
Cumulative overall actual benefits (/) forecast benefits	>90%	>95%	>100%
Cumulative overall actual costs (/) estimated costs	<110%	<105%	<100%
Cumulative overall predicted BCR (-) actual BCR	<+0.5	<+0.25	>or=0
Proportion of projects with benefits $\pm 20\%$ of forecast	60%	65%	70%
Proportion of projects with costs $\pm 20\%$ of estimated	80%	85%	90%
Proportion of projects with BCRs $\pm 20\%$ of predicted	70%	75%	80%

**C7.4.3 Recommendations**

Adjust PIR indicators and target measures as follows:

- Introduce ‘headline’ PIR indicators and targets to measure against ‘overall cumulative benefits’ rather than being based on a percentage of projects and add an equivalent overall ‘cost achievement target’.
- Develop a ‘matrix’ based working level approach to indicator and target analysis, covering the concepts of ‘value for money’ and ‘level of service’.

## C8 Processes

### C8.1 Current processes

The PIR process is undertaken in response to NZTA functions outlined in legislation and referred to briefly and very generally in the PPFM.

The detailed specification of PIRs is contained in guidance notes and an associated worksheet (NZTA 2008a).

The PIR process is not sufficiently integrated with or supported by other important NZTA processes, such as Transport Investment Online, EEM and the PPFM.

The PIR process is not currently ‘open’ and little information on it is ever published or transmitted to the wider transport sector.

### C8.2 Potential changes to processes

In the future it would be helpful to strengthen the role of PIRs to require any project applying for funding from the NLTF to maintain and make available all material that has been relied on for project development, justification and funding approval.

In particular, this would mean that data and documents were recorded at key stages of the project lifecycle to allow pre and post-implementation aspects to be compared.

**C8.2.1 Recommendations**

Introduce a requirement (in PPFM or equivalent manual) for documents to be maintained and post-implementation data to be obtained for PIR purposes:

- Apply this requirement throughout the project lifecycle (including post completion for a defined period) to ensure that data and documents are available in an appropriate form for reviewers, when required.

- Ensure this requirement does not involve significant additional effort or cost on the part of submitters, as most of the documents and data required are already produced, the main problem being that information is often not conveniently available.
- Ensure this requirement is limited to particular aspects relied on for funding justification and approval.
- Develop and introduce the automated recording of documents and data using Transport Investment Online, say, through its enhanced entry and reporting facilities. If done well this would improve information quality and reduced compliance costs.

It would also be helpful for PIR information and document requirements to be included and integrated into the following NZTA processes and systems:

- Transport Investment Online
- PPFM (for example: remove the PPFM reference to a '50:50 split' between state highway and local authority projects).
- EEM (volumes 1 and 2)
- HNO manuals (including PFR/SAR requirements)
- PROMAN (a project management system developed by Transit NZ).

References to PIRs could also be usefully made in the following NZTA processes and systems:

- safety audit requirements
- other technical audit procedures
- post-approval reviews
- procurement procedures, including post-implementation review requirements in tendering
- lessons learned/construction management reviews.

There also appears to be good potential to refer, include and integrate PIR requirements with existing AO procedures, especially when compliance, risk and/or handover assessments are undertaken on projects.

Adopting a more open approach to publishing and transmitting PIR information to the wider transport sector would also represent a positive step.

### **C8.2.2 Response to findings**

Following completion of the PIR review work (September 2010), NZTA has been pursuing a number of the review recommendations and has commented as follows. (NZTA Investment Monitoring Unit, pers comm March 2012):

*We have no official response to the recommendations of the PIR. However, we have been working on:*

- *modifications to Transport Investment Online, so that we can capture targets and feedback on all projects/packages going forward*
- *bringing delivery of PIRs in-house, both to save money and as an aid to up-skilling NZTA staff in their assessments of projects*
- *more of a focus on what the findings of PIRs mean to NZTA and how we can learn from these.*

*We have yet to revisit our sampling methodology. This was attempted this year, but we had no budget to complete PIRs for large projects. There will be a greater focus on our sampling for the 2012/13 year, as well as a review of the methodology being applied to the PIRs.*

The NZTA has also now undertaken a PIR for a large PT project, the Auckland northern busway (April 2012).

### **C8.2.3 Roads of national significance (RoNS)**

The review of PIRs and the case studies considered in this research deal with much smaller-scale projects and all pre-date the RoNS. As a result this research is generally silent on RoNS related issues.

The RoNS projects are currently subject to separate considerations to establish and enhanced (ePIR) process and monitoring framework. In this respect there has been liaison between this research project and the RoNS ePIR advisor, which has identified some relevant points as follows:

- The PIR review and the case studies undertaken have been highly dependent on the availability of comparative pre- and post-information data. In practice, required data is often partial or incomplete and this means that confidence in the findings emerging from the current research is limited.
- With one exception, the RoNS do not have 'historic data limitation' constraints and a more comprehensive pre- and post-implementation assessment framework and associated data monitoring process needs to be developed for the RoNS.

There are also lessons that the RoNS ePIR considerations can usefully take from the findings of this research, especially the following:

- Good project record keeping is essential and there is a need for a formal (probably contractual) requirement to be introduced to ensure that appropriate and accessible records are maintained into the future.
- Post-implementation surveys and associated analysis are needed and the cost of this should be included within project cost approvals.

## Appendix D: New Zealand case studies

### D1 Introduction

#### D1.1 Purpose

This appendix was prepared by Don Wignall, as sub-consultant to Ian Wallis Associates on this research project. This paper relates primarily to chapter 7 of the main report.

The impact of recent road projects in New Zealand has been reviewed through a series of case studies.

Two principal themes were explored in the case studies, namely:

- 1 Comparison between actual post-implementation conditions, and the do-minimum (or do nothing) scenario in terms of the forecast/expected conditions that would have occurred in the absence of the project.
- 2 The accuracy or otherwise of forecast conditions and associated analysis.

#### D1.2 Case study selection

Five case studies were chosen to reflect a range of project types, within the cost range \$30m to \$360m, as follows:

- Auckland northern motorway extension (Alpurt B2)
- Auckland southern motorway ramp signalling (ASMRS)
- Auckland northern busway (NB)
- Tauranga harbour link
- Wellington inner city bypass (WICB).

#### D1.3 Qualifications

The case studies were dependent on the availability of the pre-implementation monitoring, analysis, forecasting and assessment information held by the implementation and operational agencies and their willingness to commit resources to release it.

There is no requirement to maintain or to provide information and the only universal data available for all road projects, for both pre- and post-implementation conditions are: traffic counts, crash statistics and cost information. All other information either may or may not be available, depending on the particular project concerned.

In two cases (NB and WICB) post-implementation model tests have helped inform the assessment of post-implementation conditions.

The factors examined for each case study were mainly selected on the basis of data availability and relevance of particular factors to the project. An alternative to this approach would have been to produce a comprehensive assessment table common to all projects examined, but this was not possible as quantified data was not available to fully populate such tables.

While it is often possible to say that measureable changes in prevailing conditions have occurred following the implementation of a project, it is much more difficult to attribute the actual cause of such changes. To determine causation, a series of detailed checks would be necessary, including a comprehensive look at



changes in background conditions and other (non-project) interventions over the period involved. Whether or not this is possible in any particular case is largely dependent on the scope and quality of post-implementation monitoring and analysis undertaken by the project owners.

## D2 Methodology

### D2.1 Approach

The case studies used a structured approach to identify the impacts of road projects, through obtaining and comparing information relating to:

- actual base year conditions
- actual post-implementation conditions
- forecast conditions do-minimum (ie in the absence of implementation)
- forecast conditions post-implementation.

If comprehensive information concerning base year conditions, actual post-implementation conditions and forecast conditions (with and without implementation) is fully available, then it is likely that the impact of projects can be accurately determined.

The nature of the information sought under each of the above categories can be described in more detail as follows.

### D2.2 Actual base year conditions

Quantified description of pre-implementation conditions (ie covering all factors used in project evaluation, assessment or other justification) of relevance to the funding decision. This may consist of either or both of the following information on which:

- the 'decision to proceed in principle' was taken, or
- the 'main construction funding decision' was taken.

Network conditions could have been measured through network monitoring, on the basis of a validated base year traffic or transport model, supported by traffic counts, travel time, other survey data, land use data and growth trends.

### D2.3 Actual post-implementation conditions

Quantified monitoring and survey-based information on post-implementation 'actual' network conditions (ie all factors used in project evaluation, assessment or other justification) is required in order to:

- test the actual changes in costs and conditions over the period between the base year and the post-implementation year
- compare actual changes with forecast changes in costs and conditions.

If forecast assumptions have changed substantially or if the project is very large and complex, post-implementation monitoring is likely to require modelled forecasts to be re-run post-implementation to allow a meaningful comparison between actual and forecast conditions.

## D2.4 Forecast conditions: do-minimum (no implementation)

In New Zealand it is often the case that fixed demand matrices and fixed land use assumptions are used for both the do-something and the do-minimum (or do-nothing) scenarios. While this may be appropriate in some cases, for large road projects it is often more appropriate to consider what associated developments, growth or network changes would have been likely to occur or not occur in the absence of implementation.

This type of approach requires more realistic modelling with compatible demand and supply assumptions, allowing the effect of network changes to be estimated using variable demand matrices and associated variations in land use assumptions.

## D2.5 Forecast conditions: post-implementation

Quantified forecasts describing future network conditions (ie all factors used in project evaluation, assessment or other justification) of relevance to the funding decision.

Forecasts of the do-something scenario and forecasts for the do-minimum scenario are of particular interest. Other scenarios may also have been produced, including do nothing, business as usual or a range of do-something scenarios, all of which are potentially useful for post-implementation comparison with actual conditions.

All scenarios need to be tested with compatible growth, land use or price assumptions, as these may vary between scenarios. For example, a do-minimum network may not be compatible with major growth or land use change assumptions.

In any particular case, a number of post-implementation future years could have been forecast, depending on the nature of the project, issues involved and basis of the funding decision. These future years could include:

- +1 year post opening to predict short-term impacts
- +5 year post opening to allow comparison with safety statistics to be made
- +10 year post opening to capture substantive economic benefits (given the high discount rate, currently 8%)
- +15 years post opening if an operational level of service or design flow range has been defined for a particular year
- +30 years post opening to the end of the economic evaluation period.

The method of forecasting could be based on a traffic/transport model, or could be based on other techniques. Where specific forecasts for future years have not been undertaken, interpolation or projection techniques may be required.

Most forecasts are likely to be based on standard assumptions, but where there are significant uncertainties, for example with respect to the timing of network improvements, growth, demand, land use or price assumptions, then sensitivity testing of forecasts is required.

### D2.5.1 Safety

Safety data was obtained from the NZTA CAS system for the periods shown in table D.1.

**Table D.1 Crash analysis system periods**

Project	Before			After		
	Start	End	Years	Start	End	Years
Alpur B2	1/01/2004	31/12/2008	5.00	1/01/2009	31/03/2011	2.25
Auckland southern motorway ramp signalling	1/01/2001	31/12/1005	5.00	1/01/2007	31/04/2011	4.33
Northern busway	1/01/2001	31/12/1005	5.00	1/01/2007	31/12/2010	5.00
Tauranga Harbour link	1/04/2001	31/03/2006	5.00	1/01/2010	31/12/2010	1.25
Wellington inner city bypass	1/03/2002	28/02/2007	5.00	1/03/2007	30/04/2011	4.17

The social cost of road crashes varies by region and by time period. These costs are influenced by the number of fatalities and injuries per crash (some regions have higher numbers of casualties per crash) and the accuracy of reporting rates.

Additionally an unpublished estimate is used when calculating non-injury/property damage only costs. The total number of open road non-injury crashes and the total number of urban non-injury crashes are estimated from the actual numbers reported.

## D2.6 Discussion

The quality and amount of information available is partly dependent on the scale and nature of the project concerned, although comprehensive information on base year, forecasting and monitoring is rarely available for historical projects in New Zealand. This is typically due to the partial nature of information produced for assessment purposes and partly due to the absence of any formal project requirement to undertake post-implementation monitoring and to maintain accessible documentation in the post-implementation period.

For the case studies, observed conditions shortly after project implementation have been compared with observed conditions prior to implementation.

Depending on the project concerned, these pre- and post-situations are generally between two and six years apart. However, this varies depending on the type of project and data set being used. For example, in terms of road crash records, five years pre-implementation and five years post-implementation data has been analysed whenever possible.

Ideally, our assessments would allow for any 'underlying' changes (ie not related to the project itself) in this two to six year period. For example, sub-regional, regional and national road safety social cost trends have been used to compare to equivalent localised (ie within the probable area of influence of projects) pre- and post-implementation changes in background trends.

We have commented on the information used in each case, and on the robustness of the resulting findings.

We have not attempted to calculate updated estimates of project BCR performance in any detail, as this would have involved re-forecasting exercises in the light of changes since the pre-evaluation. However, we have undertaken an outline assessment on the probability or otherwise of the pre-forecast BCR being achieved or otherwise.

The primary focus of the case studies has been on shorter-term project impacts, and comparing these with the pre-implementation situation and/or the shorter-term future do-minimum forecast scenario.

## D3 Auckland northern motorway extension: Alpurū B2

Auckland northern motorway extension: Alpurū B2, opened January 2009 as a new four-lane tolled motorway.

### D3.1 Project description

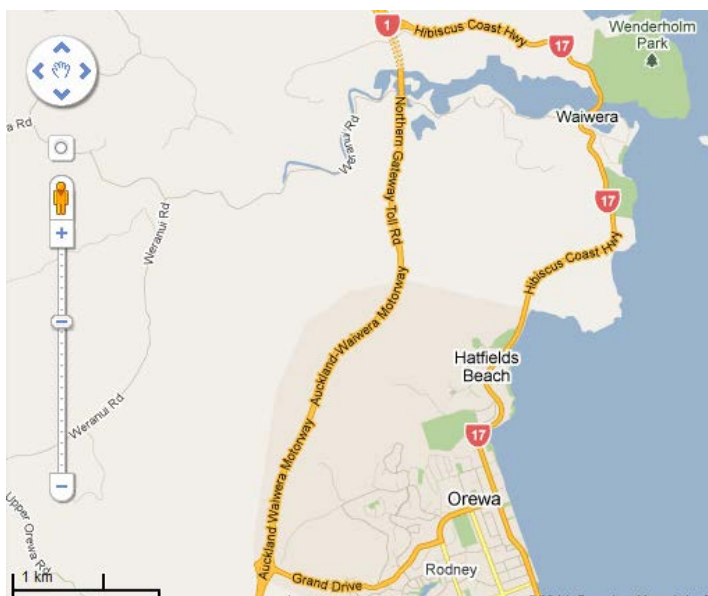
This is the latest project in a longstanding intention to provide a motorway standard link between Auckland and Northland.

The aims of the project (Transfund NZ 2004) were to:

- develop an alternative route to the existing state highway that bypasses Orewa and reduce congestion in Orewa and Silverdale at peak periods and holiday weekends
- improve the strategic route between Auckland and Northland
- improve the traffic safety characteristics of the present route and reduce the current high crash rate.

The location of the project is shown in figure D.1.

**Figure D.1 Alpurū B2 toll road (SH1)**



The alignment of this project was through rolling and environmentally sensitive countryside between Silverdale and Puhoi.

The new road is shorter (by 5km) than the former state highway route via Orewa and has been designed to a much higher standard.

The project was developed as a 7.5km dual carriageway electronic collection toll road and opened in January 2009.

### D3.2 Project costs and funding

In terms of capital costs, in 2004 the pre-construction estimate was \$341m (MoT 2006), but this was reported to have increased by \$17m to a new estimated outturn cost of \$358m by the following year (MoT 2006; Transit NZ 2004).

The funding and financing of the project was for an 'up front grant' to be awarded of \$180m which was approved from the National Land Transport Fund (NLTF) in 2004 (Transfund NZ 2004). A borrowing requirement to fund the residual capital construction related costs of the project of \$260m (interest \$101m and construction \$159m) was approved by the Treasury in 2004.

An operational subsidy from the NLTF (of \$84.8m) was also approved in 2004, over the period 2009–25 with an NPV of \$25.2m for evaluation purposes (Transit NZ 2004).

Post-implementation outturn costs relating to the upfront grant are available, but no detailed information on the overall construction costs or operational subsidy outturn costs has been identified.

### **D3.3 Method (modelling, forecasting and evaluation techniques)**

Analysis and model forecasting techniques were developed considerably over the project planning period (1995–2004) as follows:

- unconstrained network analysis (Coughlan 1995)
- more realistic bottle-neck modelling used for the economic evaluation and funding application (Beca 2004)
- more accurate SATURN modelling used to forecast future traffic volumes and travel times for the business case (Hyder Consulting 2004a; 2004b; 2005).

Diversion analysis was carried out, based on local market surveys, to estimate usage of the toll road under various pricing scenarios (Beca 2004).

Default crash rates for different volumes and compositions of traffic using different types of road were applied to estimate future road safety social costs (NZTA 2011).

### **D3.4 Actual base year conditions (ie pre-implementation or ex ante)**

Recorded traffic volumes were taken from NZTA count data (NZTA 2010b). Volumes in the corridor are a third busier in the highest month (December) than the lowest month (June) (Beca 2010)

Pre-implementation travel time surveys were undertaken in November and December 2008 (Beca 2010).

Pre-implementation road safety social cost was estimated from an interrogation of the NZTA CAS system for the five years 2004–08. This identified the social cost of road crashes as being substantial, at \$15.5M pa.

### **D3.5 Actual post-implementation conditions (or ex post)**

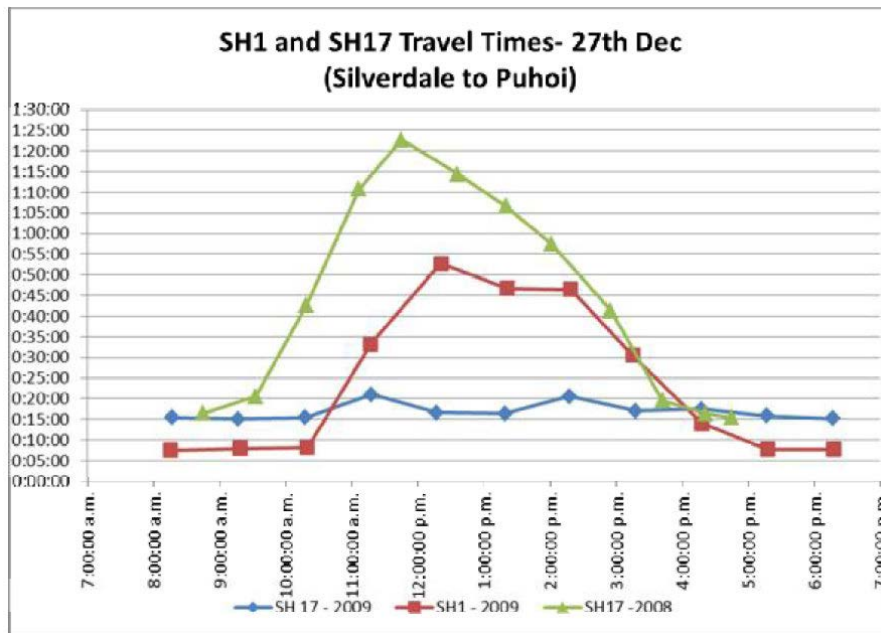
The actual implemented toll for cars was \$2.00 and for commercial vehicles \$4.00 (2009\$) (Beca 2010).

Recorded traffic volumes are available from NZTA count data. Initial post-implementation traffic volumes using SH17 were 4500 ADT from SCATS data (Beca 2010).

Travel time surveys found large travel time savings for toll road users and smaller time savings for those continuing to use the untolled alternative SH17 route (Beca 2010).

In seasonal peak conditions, substantial delays are still experienced by toll road users, due to SH1 capacity constraints to the north. Surveys conducted before and after implementation, indicate that, in the northbound direction, seasonal congestion is now lesser in scale but congested seasonal conditions have now transferred to the new toll road, with travel times on the SH17 remaining relatively constant through the day and around 30 minutes quicker than using SH1 during the busiest 11am–3pm travel period. During this period travel on the toll road can take 45 to 50 minutes, compared with travel times in seasonal conditions between 15 and 20 minutes along the alternative SH17, as shown below in figure D.2 below (Beca 2010).

**Figure D.2 Comparison of toll road and alternative route travel times**



The CAS interrogation indicated a reduction in the social cost of road crashes in the early post-implementation period (NZTA 2011).

Environmental and amenity conditions do not appear to have been monitored, perhaps because this was viewed as a mitigation issue.

### D3.6 Forecast conditions do-minimum (no implementation)

Traffic volumes in the absence of the project were expected to grow steadily over the evaluation period (Beca 2010).

The decrease in the social cost of road safety in the project's area of influence may be due entirely to the implementation of the project, although background safety trends at the sub-regional, regional and national levels indicate that background social costs and casualties were falling by a similar or greater rate than those associated with the changes within the project area of influence during the same period.

### D3.7 Forecast conditions post-implementation

A number of forecasts were developed in the project planning stage (2004/5) as follows:

- linear future traffic growth rate using the toll road of 3.7% pa between 2008 and 2031 (Beca 2010)
- continued peak/seasonal delays on the toll road due to lack of SH1 capacity to the north (Beca 2010)
- toll \$1.80 for cars (2004\$) (Beca 2004)
- a total volume of traffic on SH1 and SH17 of 21,000 AADT (Beca 2010).

### D3.8 Key performance statistics

Key performance statistics for the Alpur B2 project are shown in table D.2.

**Table D.2 Key performance statistics – base, actual and forecast conditions**

	Base	Actual	Forecast DM	Forecast DS	% Difference (Actual vs base or DM)
Costs	\$341m total <sup>(b)</sup> Inc. \$180m (grant) with an additional \$84.8m (operating subsidy) <sup>(c)</sup>	\$358m total <sup>(b)</sup> Inc. \$191.13m grant + unknown other capital costs or operating subsidy) <sup>(c)</sup>			5% increase over base
Alpur B2 volume AADT <sup>(a)</sup>	N/A	13,100 (11% CV)		14,000 (15% CV)	7% AADT (4% CV) less than DM
SH17 volume AADT <sup>(a)</sup>	17,700	7000(s)		4500	60% AADT less than DM
SH17 diversion <sup>(a)</sup>	N/A	26%		33%	
Alpur B2 travel time <sup>(a)</sup> non seasonal	N/A	6.5–8 min	16–17 min	7–10 min	56% less than DM
SH17 travel time <sup>(a)</sup> non-seasonal	16–17 min	16 min			3% less than DM
Alpur B2 seasonal travel time <sup>(a)</sup>	N/A	45 –50 min			N/A
SH17 seasonal travel time <sup>(a)</sup>	50 min – 1 hr 20 min	15–20 min			70% less than base
Alpur B2 revenue (AECOM 2010)	N/A	\$11.34m (2010)		\$11.36m (2010)	N/A
Safety annual social cost (CAS)	\$15.5m	\$14.3m		Forecast difference \$4.6 m (2003 prices) Alpur B2 economic evaluation <sup>(e)</sup> later evaluation indicates a lower forecast of 3.1 m	7.7% less than base (or \$1.2m pa)
Road safety – casualties (fatal, serious, minor, total) (CAS)	2004–08 (5 years) casualties: 8f/s, 41m, 49t (CAS)	2009 (Jan)–11 (Apr) (2.25 years) casualties: 8f/s, 38m, 46t (CAS)			7% less than base
BCR <sup>(e)</sup>		BCR 1.6		BCR 1.8	9% less than forecast

Notes: Toll revenue quoted above excludes transaction costs and GST.

(a) Beca (2010); (b) NZTA (2010b); (c) Opus 2004; (d) AECOM 2010; (e) Beca (2004).

### D3.9 Summary of project impacts

Despite the extensive literature available for this project, the scope of reported information on a consistent and quantified basis is relatively limited. Consequently it has proved difficult to develop a clear and comprehensive summary of the base, predicted and actual effects of the project.

There are only limited references to safety or to environmental impacts (such as air quality and noise) in the documentation available.

However, the identified project impacts are summarised in table D.3, with associated commentary as follows.

#### **D3.9.1 Costs**

The outturn cost of the project in terms of the upfront 'grant' was similar to that anticipated at construction approval stage. The residual capital cost and associated finance, repayment and subsidy performance is not known.

#### **D3.9.2 Traffic**

##### *New/improved roads:*

- **Volumes:** Toll road volumes are similar but slightly lower in early monitoring compared with predictions. The diversion rate to non-tolled roads was lower than forecast. Commercial vehicle forecasts appear to differ significantly from actual (see table D.2). Traffic volumes on SH17 are significantly lower than predicted.
- **Induced traffic effects:** It is possible that the introduction of the toll road may have had both an induced traffic impact, due to the substantial increase in north/south capacity, which for example, may have released additional local trip making at Orewa/Hatfield's Beach, and a suppressed traffic impact due to the effect of tolling. Overall, however, the project does not appear to have resulted in any significant amount of induced travel in the corridor (although this may occur in the longer term).
- **Travel times and speeds:** Travel times are similar to predicted, with significantly reduced times on the toll road during non-seasonal conditions. During seasonal peaks, travel times are much longer on the toll road than the alternative SH17 route, by around 30 minutes during the mid-day travel period, but these times are still lower than pre-implementation conditions. The effect of delays to travel due to manual payment use (and whether the scale of this is as expected) is not recorded in post-implementation monitoring information.
- **Reliability:** No direct information available, but the reductions in travel times in seasonal peak periods relative to the prior situation suggests that travel time reliability will also have improved.
- **Revenue:** Despite lower than anticipated overall traffic volumes and proportion of HCVs, actual revenues are similar to those forecast. The reasons for this are not known, but may be due to differences between estimated and actual transaction cost performance.

##### *Effect on other/local roads*

- Smaller time savings have been recorded for those continuing to use the original route.
- This is unknown (a traffic-only project model was used) and no quantified monitoring of modal demands is available.
- The PT mode share for movements in the corridor would be very small, and unlikely to have been significantly affected.
- It can be inferred that any effects are likely to have been small as there has been some improvement in the relative attractiveness of car-based travel but some improvements in conditions for walking and cycling have occurred due to lower traffic use of the original route through Orewa.



### D3.9.3 Safety effects

In the area of project influence, the social cost of road safety has fallen in the early post-implementation monitoring period similar to background sub-regional trends but less than regional or national trends, as shown in table D.3.

**Table D.3 Project and background safety trends**

Alpurt B2		Pre-annual average	Post-annual average	% Change
Project	Fatal and serious	8	7.6	-6%
	Total	49.2	45.8	-7%
	Social cost \$m pa	15.5	14.3	-8%
Sub-regional state highways (rural north and urban north NZTA zones)	Fatal and serious	36	34	-6%
	Total casualties	257	243	-5%
	Social cost \$m pa	67.7	61.8	-9%
Regional state highways (Auckland)	Fatal and serious	104	101	-3%
	Total casualties	902	844	-6%
	Social cost \$m pa	234.7	200.2	-15%
National state highways	Fatal and serious	1227	1052	-14%
	Total casualties	5672	5120	-10%
	Social cost \$m pa	1936.30	1682.10	-13%

Further analysis has been undertaken of the section of SH1 (now SH17) north of Orewa (see figure D.3) bypassed by the completion of Alpurt B2 toll road in January 2009.

**Figure D.3 Location of Alpurt B2 toll road and bypassed road (SH17) through Orewa**



The results from the post implementation review (Beca 2010) and associated analysis (NZTA 2011) using CAS are shown in table D.4.

**Table D.4 Comparison of social costs before and after implementation**

	2008	2009	% Change
Traffic volume (AADT)	17,700	7000	-60%
	<b>2004-08</b> (5 years)	<b>2009-11</b> (2 years 9 months)	<b>% Change</b>
Crashes (pa)	44	15	-65%
Casualties (pa)	24	16	-35%
Social cost (pa)	\$4.5m	\$4.3m	-4%

Although the above summary represents a relatively early post-implementation safety analysis, it indicates that the large fall in traffic, on a largely untreated bypassed route, resulted in a broadly equivalent fall in the number of crashes.

The table also indicates that reduction in the annual rate of casualties was much smaller and that the overall social cost has only reduced marginally, in the absence of suitable treatment and management measures. It is also worth noting that the pre-implementation forecast traffic volumes on the bypassed SH1 were 4500, a predicted fall of 75%, rather than the 60% reduction recorded.

#### **D3.9.4 Effect on other modes**

- These are unknown as traffic-only project models were used and limited quantified monitoring of modal demands has been undertaken
- It can be inferred, however, that for long distance travel, the improvement in the relative attractiveness of car travel is likely to have reduced demand for other modes.

In terms of local movements, the reduction in traffic volumes through Orewa is likely to have encouraged some additional local walk and cycle trips.

#### **D3.9.5 Local environmental effects**

No specific information available but the fall in traffic levels on the bypassed road (now SH17) of 60% is likely to have had significant noise and air quality benefits in localised areas, such as Orewa.

#### **D3.9.6 Global environmental effects**

Greenhouse gas emissions and VOCs are likely to have fallen as a result of the shorter routing and reduced congestion. Some counter-effects may also have occurred due to higher speeds of traffic using the toll road. However, no quantification of these effects has been attempted.

#### **D3.9.7 Overall economic performance**

- The original BCR for the project was 1.8: and the overall benefit split was: standard travel time 68%, congested travel time 16%; reliability 2%; VOC 7%, safety 7%, CO<sub>2</sub> 0.3% (Beca 2004).
- Using immediate post-implementation data, it is possible that some factoring down of benefits may be justified to reflect the lower forecast volumes experiencing improved travel times.
- Looking at an evaluation review of the project (Wallis 2005, table D1.2) the increased capital outturn cost further erodes the economic justification for tolling the route.

## D3.10 Conclusions

- The improvement in model forecast techniques over the project planning period resulted in the predicted traffic volumes and travel times on the toll road being close to actual. This was despite the slight variation in toll setting, and meant that the Alpur B total traffic forecasts for the toll road were found to be fairly robust. Predictions of diverted trip proportions and volumes on bypassed roads proved less accurate. This may be due to less detail being developed for bypassed roads and the primary focus for the modelling work being the forecasting of revenues. It may also be because the model was limited in spatial scope.
- The project has resulted in significantly reduced travel times for users of the toll road and slight reductions in travel time for those continuing to use the alternative route via Orewa. These were similar to the predicted changes in travel time.
- The actual diversion of traffic from the toll road was slightly less than predicted.
- The actual use of the toll road by vehicles is slightly less than predicted.
- The actual use of the alternative route via Orewa for through movements is substantially less than predicted.
- The toll road appears to have had a limited impact on the on-going seasonal peak delay issue with continuing long delays on the network.
- There has been a reduction in the social cost of crashes as a result of the project, but these are substantially less than had been forecast.
- Environmental effects (air quality, noise, GHGs and severance effects) are likely to be broadly consistent with changes in traffic conditions, meaning that the redistribution of traffic is likely to have resulted in reductions in negative traffic-related effects on the bypassed SH17 through Orewa.
- Increased capital costs, lower than anticipated volumes, lower traffic growth rates and lower safety benefits (if these materialise over the life of the project) would all suggest that the 'actual' BCR is likely to be lower than the forecast BCR, on which the funding decision was made.
- The project represents a significant intervention in the regional network, reducing travel times substantially for the majority of through traffic. However, major delays remain during seasonal peak periods and, although the scale of the problem has reduced, the seasonal congestion has now been transferred from the old route to the new toll road.

A summary of effects is given in table D.5.

**Table D.5 Impact summary table – ALPUR B2**

Aspect	Impacts relative to base/do minimum forecasts	Impacts relative to project forecasts
1 Capital costs	\$358m capital costs plus an operational subsidy of \$84.8m (NZTA 2010b). Approx. 50% of capital cost to be funded through up-front grant (originally \$180m) with the remainder to be funded through borrowings – repaid (through toll charges) over 15 years.	c.\$17m (5%) estimated increase – although detailed cost impacts are not clear.
2 Traffic volumes	Little change in overall traffic volumes in corridor ('new' and 'old' road combined). Traffic on old road reduced by c.60%.	Total corridor volume of 17,600, compared with modelled forecast of 21,000. Split between the two routes at 26% of traffic remaining on former route was also lower than the 33% forecast. .

Aspect	Impacts relative to base/do minimum forecasts	Impacts relative to project forecasts
3 Travel times	<p>In non-seasonal AM and PM peak periods, 'though' traffic on new route saves 8-10 minutes (new route is 5km shorter).</p> <p>In highly congested seasonal periods for northbound travel, the new route is substantially slower than the old route, by around 30 minutes for mid-day travel, but still around 30 minutes quicker than in the prior situation. For northbound travel the Orewa 'bottleneck' has now moved further north and congestion transferred from the old route to the new toll road.</p>	<p>Non-seasonal AM and PM peak time savings similar to forecasts.</p> <p>Time savings during seasonal peak conditions were not specifically forecast.</p>
4 Safety	<p>Best evidence to date (based on 2 years 'after' data) indicates an accident cost reduction of c.\$1.2M pa (c.8%) on the two routes combined.</p> <p>Because of increased fatalities the reductions in social cost as a result of the project appear consistent with changes in background network conditions.</p>	<p>Forecast accident cost reduction was c.\$4.6M pa, or about 30% of the total annual social cost. The early indications to date are that this is not being achieved.</p>
5 Operating costs and global environmental impacts	<p>VOC savings are expected to accrue, given i) the shorter route, ii) the lack of substantial induced traffic; and iii) the improved traffic flow conditions (but partly offset by higher than optimum speeds).</p> <p>Consequently, some GHG reduction should have been achieved.</p>	<p>Forecasts were for VOC savings to account for some 8% of total benefits.</p> <p>Given that traffic volumes and travel times are approximately as predicted (apart from in seasonal peak conditions), it is expected that the forecast VOC savings will have been realised.</p>
6 Local environmental effects	<p>The new route diverts traffic away from Orewa township and other developments alongside the old road. Hence some benefits are anticipated along the old road in terms of reduced noise, improved air quality and enhanced local amenity. No post-implementation environmental monitoring surveys appear to have been undertaken.</p> <p>The new route runs through areas of environmentally sensitive countryside between Silverdale and Puhoi. The route design was intended to mitigate adverse environmental effects.</p>	<p>The probability is that the forecast improvement in environmental effects has largely been achieved, as these were largely related to changes in traffic conditions along the old route.</p>
7 Overall economic performance	<p>The project produced significant travel time benefits and associated vehicle operating cost benefit.</p> <p>Earlier work (Wallis 2005) indicates that the project benefits would have been significantly higher if it had been implemented as a non-tolled route (with an NPV increase of c.\$50M).</p>	<p>It appears that the project will largely have achieved its estimated benefits (for the early years) in terms of travel time/ reliability and VOC, but not have achieved significant safety benefits.</p> <p>The shortfall in safety benefits is likely to reduce total benefits by c.5%</p> <p>Capital costs were c.5% higher than the pre-construction estimates (given the method of funding, the effective increase in public expenditure may be greater than this percentage).</p> <p>These figures indicate, based on evidence to date, that the BCR likely to be achieved would reduce the forecast of 1.8 by 9% to around 1.6</p>

## D4 Auckland southern motorway ramp signalling

Auckland southern motorway ramp signalling (ASMRS) has been operational since 2006 and consists of ramp signalisation and priority lane traffic management systems.

### D4.1 Description

The aim of the project was to: 'Actively influence traffic patterns and manage corridor traffic conditions, using flow monitoring and control systems together with the delivery of traveller information, to optimise the operation of the motorway and its supporting arterials' Land Transport NZ (2005).

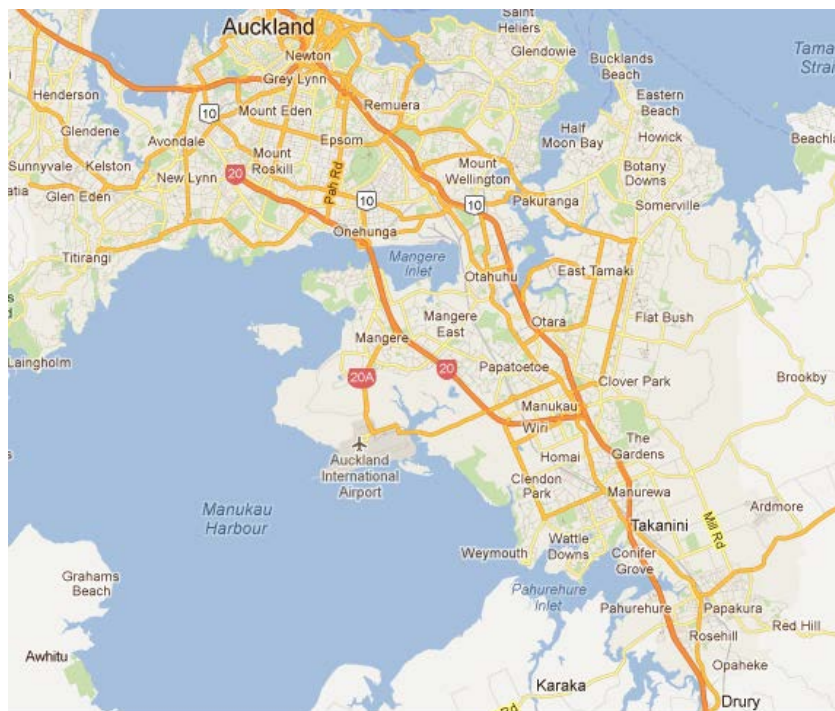
The project involved:

- installing ramp signalling at all northbound and southbound on-ramps (32 in total) between central Auckland and Drury
- priority access for freight or HOVs at four of the ramps (Grafton St southbound trucks only, Takanini northbound buses only, south eastern arterial northbound and Mount Wellington northbound 2+HOVs, trucks, taxis and M/C).

It should be noted that the southern motorway project was the largest element of a wider initiative, which also introduced ramp signals on the northern and north western motorways.

The location of the project is shown in figure D.4.

**Figure D.4 Southern motorway location (SH1)**



### D4.2 Project costs

The overall costs of the project were determined as part of the procurement process adopted, which was for the delivery of all three motorway ramp signalling systems rather than just for the southern motorway part of it.

The estimated cost of the southern motorway element of the overall project was \$30.8m (Land Transport NZ 2005) in 2005 with the actual outturn recorded at \$27.5m.

### D4.3 Method (modelling, forecasting and evaluation techniques)

Assignment and micro-simulation models were used to determine if and where motorway traffic might divert, especially on local arterials, as a result of the ramp signal operation (Land Transport NZ 2005).

A series of key performance indicators (KPI) were established through meetings with local authorities to adopt post-implementation performance targets (see D4.6 and D4.7 below). These included a specific goal of improving travel times along the motorway corridor while also ensuring no increase in travel times across the corridor.

Each local authority nominated the arterial routes crossing the motorway that they wanted included in the KPI measures. Some territorial local authorities nominated a representative set; others nominated all of their arterials crossing the motorway interchanges. For the most part, all key interchanges were included. Auckland Council commissioned specific before studies that would be used as a base comparison if and where needed. The NZTA made and archived video footage of each arterial approach.

As part of the overall performance measurement, the NZTA also commissioned a specific study of travel speeds, delays and journey times on Khyber Pass Road, being one of the key arterials crossing (beneath) the southern motorway and whose south-facing on-ramp was included in the early phase of commissioning (Land Transport NZ 2007).

### D4.4 Actual base year conditions

Safety: 226 peak period injury crashes per year, 897 peak-period non-injury crashes per year (Land Transport NZ 2005).

Reliability: range from -10% to +85% of average travel time (Land Transport NZ 2005).

Volume throughput: 1268 to 1913 vph per lane (Land Transport NZ 2005) for eight sites.

Average car occupancy: 1.27 (Land Transport NZ 2005).

Average on-ramp queues: AM peak 112m, PM peak 293m. (Land Transport NZ 2005).

The social cost of road crashes on the relevant section of SH1 was substantial at \$70m pa.

### D4.5 Actual post-implementation conditions

Reported effects of project implementation (pers comm project manager, Sept 2010) were as follows:

*Individual on-ramps carrying more traffic on to the motorway compared to the same period before the ramp signals were commissioned, and with no adverse effects on other arterial traffic. Mostly, and with the motorway carrying more throughput than before, the effects on arterials have been beneficial... ARTIS software as used for the Khyber Pass studies show the minute by minute travel times and delays for travel in both directions along Khyber Pass Road passing through the interchange. Comparing the before and after results it is apparent that commissioning the ramp signals has brought no adverse effect at all. By contrast, and through periods of the day, there has been some tangible improvement in local arterial travel times and reduced delay.*

Extensive monitoring of the ramp performance was undertaken (pers comm project manager, July 2011): (Transit NZ 2007b; NZTA 2010)

*Through the initial six months as individual sites were completed, operators and the partner Councils were provided with weekly and then monthly reports listing the key operating performance measures that was progressively expanded as more sites were commissioned and brought on line. Then, as public acceptance grew and as operating experience increased and the available range and amount of data expanded exponentially, new methods of real-time analysis were introduced in place of the original static measures in order to provide a better and more complete account of travel conditions and the manner in which the installed system and operators were performing in real-time. These are in the form of the widely used MTV (Motorway Traffic Viewer) diagrams which enable a much improved and more descriptive minute-by-minute account of the overall operating performance. A simplified version of these reports has most recently now also been included as part of the information available to the public on the NZTA Traffic Website.*

Specific effects can be described as follows:

- Safety: SH1 injury crashes have reduced since 2005 by 11.5% (on the basis of a four-year post-implementation average) (NZTA 2011).
- Reliability: at some specific locations the period of congestion has reduced, although this is not a consistent pattern (GHD 2010).
- Average corridor travel times: results are mixed, SH1 southbound PM peak speeds reduce, SH1 northbound PM peak speeds increase (GHD 2010).
- Volume throughput: change in throughput volumes (vph per lane), Newmarket Viaduct southbound +6% Victoria Park Northbound +4% (GHD 2010).
- Very little change in average peak hour ramp person movement (GHD 2010).
- No large travel time savings for priority vehicles at bypass lanes were recorded (GHD 2010).
- Average queuing on ramp queues: some detailed data is available but not summary averages (Transit NZ 2007b; NZTA (2010).
- Local road conditions, overall impacts in quantified summary terms are not available, although the project manager stated that increased on-ramp and motorway flows during peak periods enabled improved arterial conditions (pers comm July 2010).
- Before and after monitoring at Khyber Pass Road also indicates little change in localised travel time conditions as a result of the introduction of ramp signals (Land Transport NZ 2007).

The original performance targets have not been updated as was originally envisaged (Land Transport NZ 2005). Rather, operating experience resulted in the view being taken by the project manager that the static measures used in the original KPIs needed to be replaced with continuous measures enabling a much more dynamic account of current travel conditions measured and reported in real-time (pers comm July 2010).

#### **D4.6 Forecast conditions do-minimum (no implementation)**

Background traffic volumes in the absence of the project were expected to grow steadily over the evaluation period.

Background regional and national safety trends indicate a substantial reduction in social costs between the pre and post-implementation periods (see table D.4).

## D4.7 Forecast conditions post-implementation.

Comprehensive target-based forecasts were proposed; most of these appear to have been based on modelling and other analysis.

Table D.4 lists specific performance targets for safety, reliability, average corridor travel time Improvement, volume throughput, average car occupancy, travel time savings for priority vehicles at bypass lanes and average on ramp queues (Land Transport NZ 2005).

The forecast BCR was 5.3 (Land Transport NZ 2005).

The BCR net present cost (NPC) cost of \$33.1m was composed of 63% discounted capital (\$20.9m) and 37% operational/maintenance (\$12.2m) costs.

The discounted net present benefit (NPB) (\$174.3m) split was as follows: standard travel time (39%), congested travel time (15%), reliability travel time (37%), VOC (-0.7%), CO<sub>2</sub> (-0.1%), safety (10%).

## D4.8 Key performance statistics

Key performance statistics for the ASMRS project are shown in table D.6.

**Table D.6 Key performance statistics – base, actual and forecast conditions**

	Base	Actual	Forecast DM	Forecast DS (targets)	% Difference (actual vs base or DM)
Costs	\$30.8m <sup>(a)</sup>	\$27.5m (NZTA actual)			11% less than base
SH1 AADT	111,586 <sup>(b)</sup>	115,387 <sup>(b)</sup>			3.8% more than base (2006 to 2010)
SH1 volume (throughput capacity)	1268 to 1913 vph per lane for eight sites <sup>(a)</sup>			+5% in through-put volumes (vph per lane) <sup>(a)</sup>	
SH1 reliability	-10% to +85% of average travel time <sup>(a)</sup>			-5% to +40% of average travel time <sup>(a)</sup>	
On-ramp car occupancy	1.27 <sup>(a)</sup>			1.33 <sup>(a)</sup>	
On-ramp queues	AM peak 112m, PM peak 293m <sup>(a)</sup>			AM peak/PM peak no change over base conditions <sup>(a)</sup>	
SH1 safety: annual social cost	\$70.0m p.a. (2001–05)	\$56.7m pa (2007–11)		Approximately \$1.6m in social cost reduction per annum was forecast due to ramp metering (SAR)	19% less than base
Road safety: casualties (fatal, serious, minor, total)	Casualties: (5 years) 21f/s, 258m, 279t pa (CAS)	Casualties: (4.25 years) 18f/s, 249m, 267t pa (CAS)			4% (total casualties) less than base
Road safety: non-injury crashes.	Crashes: (5 years) 894 pa (CAS)	Crashes: (4.25 years) 760 pa (CAS)			15% less than base
BCR		BCR 5.9		BCR 5.3 <sup>(c)</sup>	12% over forecast

Notes: <sup>(a)</sup>Land Transport NZ (2005); <sup>(b)</sup>NZTA (2010a); <sup>(c)</sup>Transit NZ (2005b).



## D4.9 Summary of project impacts

For a relatively small capital investment, a relatively large amount of sophisticated analysis, forecasting and monitoring has been undertaken for this project. The nature of the project also means that monitoring of operational performance is a complex and difficult task.

From the available information, the conclusions drawn on the project impacts are summarised in table D.5, with further comments as follows:

### D4.9.1 Costs

- The outturn costs for the southern motorway at \$27.5m are \$3.3m (11%) less than anticipated.

### D4.9.2 Traffic

#### *New/improved roads:*

- **Volumes:** There is evidence at a number of ramps and sections of the motorway itself that throughput has increased post-implementation during the periods of ramp operation.
- **Induced traffic effects:** It is not clear if induced traffic effects have occurred but this is probably unlikely due to the relatively marginal nature of the time savings involved as a proportion of total origin-destination travel times.
- **Travel times and speeds:** Travel times are likely to have reduced slightly and speeds on the shoulder of the peaks appear to have increased as a result of ramp signalling implementation.
- **Reliability:** This is likely to have also improved marginally as a result of ramp signalling.
- **Vehicle occupancy:** There is little evidence for any significant changes in car occupancy and the pre-evaluation target forecasts of an increase from 1.27 to 1.33 do not appear to have been achieved. However, occupancy changes are not critical to the achievement of overall benefits, as the occupancy issue only arises at the priority lane ramps, of which there are only four out of a total 32 of signalised ramps.

#### *Effect on other/local roads*

- The effects on other potentially affected local roads are not known, but do not appear to be significant, on the basis of the post-implementation studies undertaken.

### D4.9.3 Effect on other modes

- This is unknown as traffic-only project models were used, and only limited quantified monitoring of modal demands has been undertaken (for example to check occupancy ratios).
- It can be inferred, however, that any effects on other modes are likely to have been small as a result of the improvements for car-based travel and the effect of priority access measures, because these effects will have been limited in comparison with overall travel times.

### D4.9.4 Safety effects

- Post-implementation trends indicate that social cost, casualties and crashes have all reduced very substantially in the post-implementation period (by \$13.3m pa). To what extent this can be attributed to the effect of ramp signalling (forecast safety cost reduction \$1.6m pa) is not known. It can be inferred that the scale of social cost reduction (19%) is reasonably consistent with the sub-regional and regional trends over the same period and so may not be primarily project related.

- It should also be noted that the area of influence of the project is very large and there are likely to have been a number of interventions and changes in network conditions over the pre- and post-implementation review period. Project area changes should be compared with changes in background sub-regional, regional and national trends which also show social costs falling over the same period, as shown in table D.7.

**Table D.7 Project and background safety trends**

ASMRS		Pre-annual average	Post-annual average	% Change
Project	Fatal and serious	-14%	-14%	-14%
	Total	-4%	-4%	-4%
	Social cost \$m pa.	-19%	-19%	-19%
Sub-regional state highways (urban north and rural north NZTA zones)	Fatal and serious	43	25	-41%
	Total casualties	426	409	-4%
	Social cost \$m pa.	105.2	83	-21%
Regional state highways (Auckland region)	Fatal and serious	115	85	-26%
	Total casualties	860	762	-11%
	Social cost \$m pa.	237.3	179.5	-24%
National state highways	Fatal and serious	1286	1051	-18%
	Total casualties	5459	5134	-6%
	Social cost \$m pa.	1984.90	1762.30	-11%

#### D4.9.5 VOC and environmental effects

- VOC, greenhouse gas emission and local environmental effects are likely to have been small but probably negative, due to the stop-start effects of the ramp signals.

#### **D4.9.6 Monitoring information**

The project manager explained (pers comm July 2011) that:

*...on-going operating experience has resulted in the realisation that the static measures used in the original KPIs needed to be replaced with continuous measures enabling a much more dynamic account of current travel conditions measured and reported in real-time. ...this is probably one of the most important benefits of the project and which now both enables and drives the entire operational focus now being applied for the first time by the Auckland Joint Traffic Operations Centre across the entire network. ...the project not only achieved its principal goal of providing the means of actively managing travel patterns across the principal network using techniques that were new to NZ and seen as adverse and threatening, but with an outcome that has achieved a wide level of public acceptance. These understandable concerns largely shaped the original KPI's which were as you have seen largely static in nature principally because that was the way in which traffic measurements had always been done prior to that date...What emerged however was a realisation that traffic management on this scale is a far more dynamic matter with controls varying on a minute by minute basis (in fact the system measures performance and updates its settings every 20 seconds), so requiring means of tracking and reporting performance on a continuous basis – as you are aware, that is how it is now being applied through motorway travel viewer (MTV) diagrams which are recorded on a 24/7 basis for all motorways, and most recently are now available to the public online and in real-time and can even be read on your smart phone amongst all of the other live traffic data.*

#### **D4.9.7 Overall economic performance**

It is probable that the forecast BCR has been achieved or bettered, on the assumption that overall travel time benefits (91% of total benefits) and safety benefits (10%) are similar or better than forecast.

However, to confirm this some overall summary data, for example obtained through a structured sample of sites and time periods, is required rather than the sort of ad hoc information currently available.

It should also be noted that the original BCR was based on an expected capital cost estimate of \$23m (Transit NZ 2005c), ie less than the actual outturn of \$27.5m.

#### **D4.10 Conclusions**

The stakeholder involvement, modelling, analysis and technical monitoring of this project are of a very high quality and are very detailed. A number of post-implementation reviews have been undertaken into specific aspects and at particular locations. In this respect, the project represents good practice in the field of the quality of technical analysis undertaken.

The SAR and supporting material contained pre-implementation monitoring data and associated analysis that defined the performance indicators and targets. This preparatory work indicated that the targets were likely to be achievable and were to be monitored post-implementation.

From the results available, it appears that the effect of the ramp signalling is positive in overall terms. Some effects appear to be significantly positive, as in the case of crash reduction and increased throughput capacity. There seem to be few if any identified negative effects, but in many cases (such as raising car occupancies) the effects of ramp signalling, taken in isolation, appear to be either neutral or marginal.

One of the problems in interpreting results is the difficulty in filtering out the variation in before and after conditions for other reasons, for example, due to seasonal changes (in the case of traffic flow) or due to other initiatives, for example, in the case of safety.

No summary information has been produced in the form of the target performance indicators envisaged at the start of the process and as promised at the time of construction funding (Land Transport NZ 2005). These performance indicators are not, by themselves, sufficiently specific to allow measurement against. In other words they are in outline and required more detailed definition, for example, to explain which periods, ramps, vehicle types, links are being addressed and how seasonality and other factors need to be accounted for and sampled.

The techniques employed in monitoring and reporting on motorway performance that emerged from this project are very useful, however the ability to look at detailed data 'snapshots' dynamically, does not replace the need for aggregated summary information. It is regrettable that better monitoring has not been undertaken on this project as, unlike many other projects, even now it would be very easy to test the effect of the ramp signals either working or not working over representative periods.

The priority initiatives do not seem to have significantly affected behaviour or occupancies, perhaps not surprisingly as these do not represent significant time savings in the context of overall journey times.

The overall costs of the project were fixed as part of the procurement method adopted which was for the delivery of all three motorway ramp signalling systems rather than just for the southern motorway element. Approved funding for the southern motorway was \$30.8m; with a lower outturn cost at \$27.5m.

BCR of 5.3 is likely to have been achieved or bettered given the absence of negative effects and the available evidence of improvements in travel time and safety.

A summary table of project impacts is provided below in table D.8.

**Table D.8 Impact summary table – Auckland southern motorway ramp signalling**

Aspect	Impacts relative to base/do-minimum' forecasts	Impacts relative to project forecasts
1 Capital costs	\$27.5m outturn cost Part of a wider fixed cost contract for Auckland motorway ramp signalling. Funded at a FAR of 100% as a state highway project.	\$3.3m less than pre-construction estimate of \$30.8m.
2 Traffic volumes	Improved ramp and motorway throughput recorded at studied locations.	Thought to be similar or better than target performance indicator forecasts but definitive summary information is not available.
3 Travel times	Marginal improvements on ramps and motorway at study locations. Not significant deterioration in local road conditions at studied locations.	Thought to be similar or better than target performance indicator forecasts but definitive summary information is not available.
4 Safety	The social cost of crashes has reduced very substantially (by an average of \$13.3m pa, or 19%). The total number of casualties have decreased marginally (from 279 pa to 272 pa) post-implementation. Non-injury crashes have decreased more substantially from 894 pa to 760 pa.	It is not possible to attribute all of the major reduction in social cost to ramp metering implementation without more detailed investigation. Safety improvements are generally consistent with target performance indicator forecasts.

Aspect	Impacts relative to base/do-minimum' forecasts	Impacts relative to project forecasts
5 Operating costs and environmental impacts	Marginal VOC, GHG and other environmental effects likely to be slightly negative due to increased stop-start conditions on entry ramps.	Detailed forecasts not available to confirm whether or not negative effects due to ramp signals are counteracted by improvements in motorway operations.
6 Overall economic performance	<p>The main benefits from the project arise from time savings to main line traffic in the peak and 'peak shoulder' periods.</p> <p>Other benefits include: time savings for ramp traffic and merge related safety benefits.</p>	<p>The BCR is likely to have been achieved or bettered due to the outturn cost increase (compared with the original evaluation) more than outweighed by the outturn benefits being greater than expected.</p> <p>The main forecast benefit is for time savings (91%) and the available evidence indicates that time savings are likely to have been achieved.</p> <p>It is possible that the forecast safety benefits of \$1.6m (10%) may have been underestimated</p>

## D5 Auckland northern busway

Auckland northern busway (NB), operational since January 2008, consists of a segregated busway and supporting services and facilities.

### D5.1 Scheme description

The project aims were to:

- increase accessibility to public transport
- provide an alternative mode of transport between the North Shore and Auckland City
- reduce travel times of HOVs and bus users along SH1
- increase person carrying capacity of harbour bridge
- minimise adverse environmental effects of private motor vehicle use
- enhance activity in city centres by improving accessibility and capacity (Transit NZ 2004).

The location of the project is shown in figure D.6.

**Figure D.6 Northern busway location (SH1)**



The original project concept was developed by the Auckland Regional Council in the early 1980s in response to the level of congestion and difficulties experienced by bus services in peak periods.

Bus use of the shoulder on the northern motorway dates back at least to the early 1990's. The shoulder speed limit was 50km/h and its use was normally limited to peak use only. In practice, the sections of shoulder available for bus use changed over time and the bus lane was not continual, requiring bus merging manoeuvres with motorway traffic. Even so (reportedly) the use of the shoulder was found to have improved bus travel times to some extent.

Concepts for a dedicated busway were investigated in detail between 1988 and 1992 and a scheme assessment report (SAR) was produced by Works Consultancy Services for a preferred option, which was for a dedicated busway at a cost of approximately \$35m. The project was then modified after a series of meetings chaired by Transfund NZ, resulting in the 1997 proposal to allow HOVs to use the busway.

Following work by consultant MRC for North Shore City Council (NSCC) in 1998 the project was modified to increase the scale of construction required for the busway and the development of associated stations and facilities, resulting in a capital cost requirement of \$130M.

The project was designed with the potential for later conversion to rail and a number of other aspects of the project improving access for pedestrians, cyclists and heavy vehicles were also incorporated into the final design.

As defined<sup>32</sup> in the latest evaluation (Beca 2004) the project comprised:

- a dedicated busway from Constellation to Onewa, potentially available to high occupancy vehicle (HOV) traffic. This operates as a two-way, two lane facility between Constellation and Akoranga stations (6.2km) and one-way, one lane facility (2.5km) between Akoranga and south of Onewa Road interchange
- improvements at Onewa Interchange to permit dedicated busway operation
- associated basic stations, park/kiss and ride facilities at Akoranga, Westlake, Sunnynook, Constellation and Albany
- extension of the existing HOV lane along Onewa Road
- provision of bus-only ramps from SH1 to the Albany station.

The northern busway (NB) project was previously referred to as the 'North Shore busway'. The busway and associated works and service changes were implemented over the period between July 2005 (commencement of new services) and February 2008 (busway opening). Subsequent park and ride extensions were added in 2009. Service frequencies have also been continuously reviewed since 2005, in response to demand.

## D5.2 Scheme costs

The scope of the project for the final evaluation (Beca 2004) prior to funding approval was constrained to certain works in the NSCC area, namely the busway itself at \$162.2m, extension of Onewa Road HOV lane \$6.0m, basic station (civil) costs \$28.9m, property \$17.5m giving a total capital cost for evaluation purposes of \$214.6m (Beca 2004) as shown in table D.9.

**Table D.9 Capital costs**

	Evaluation costing (2004)	Approval cost (2005)	Outturn cost (2008)
Busway	\$162.2m	\$180m	\$190.5m
Total station cost	<i>Not included</i>	<i>Not funded by NLTF</i>	<i>(\$85m)</i>
'Basic' stations	\$28.9m	<i>Not funded by NLTF</i>	<i>N/A</i>
Property	\$17.5m	\$30m <i>(unspecified)</i>	\$30m <i>(assumed)</i>
HOV lane	\$6m		
Total	\$214.6m	\$210m	\$220.5m

The above costs also exclude any increases in road capacity on SH1 for general traffic, for example, improvements to the Onewa interchange (open June 2008), major improvements to the Esmonde interchange (open May 2007), other local road works required in NSCC and works to the south of the Harbour Bridge, all of which were evaluated separately.

The funding approval cost for the project was \$210m (total) of which \$180m was for the busway construction cost (2004); the actual outturn cost was \$190.5m (NZTA Transport Investment Online).

The construction of the five busway stations was funded by the NSCC (\$35 million) and ARTA (\$50 million, \$40 million of which was granted by the now disbanded regional funding agency Infrastructure Auckland).

<sup>32</sup> Scope definition remains an issue in interpreting this project as NLTP funding approval was essentially for busway only construction.

### D5.3 Method (modelling, forecasting and evaluation techniques)

Pre-implementation analysis was undertaken using a mixture of different models, including ART2, APT, SATURN project model and the NSCC TRACKS model. The two procedures used for NB evaluation were the Transfund NZ (1997) *Project evaluation manual* (PEM) and the Transfund NZ (1997) *Alternatives to roading manual* (ATR). Transfund NZ (1996) *Programming and funding manual* (PFM) was also relevant to the final funding decision.

This was a complex project requiring joint funding and management approaches, between Transit NZ, Transfund NZ, NSCC, Auckland Regional Council, ARTA, Infrastructure Auckland and Transpower. The funding policy during the main period of project specification and evaluation (1999 to 2003) required certain thresholds to be reached for BCRs and efficiency ratios. Roothing and ATR projects were in competition with each other on the basis of their respective 'ratios'. A range of evaluation techniques were therefore considered for the NB project, including a full evaluation of the whole project under the ATR procedures.

The final NB project evaluation effectively treated the proposal as a 'road' based on the PEM procedures, although the actual funding of the project was divided between a number of parties. The busway ended up being funded as a state highway (at 100%) and the stations were funded out of local/regional funds with no contribution from the NLTF. Bus operational subsidy costs were shared between the regional council and Transfund NZ, although no economic evaluation of NB-related service changes appears to have been undertaken.

Legislative complexity in interpreting the Transit Act at the time meant that the treatment of the evaluation for the NB was particularly contentious. However, at the actual time of the construction funding of the NB, the Land Transport Management Act (LTMA) had been enacted allowing a more broadly based transport funding decision to be taken (in December 2003 and February 2004) and this allowed the Transfund NZ Board more discretion in project funding decisions.

Post-implementation monitoring of journey time surveys, volume counts and patronage surveys were undertaken post implementation by ARTA and AT.

Some post-implementation model tests using ART3 have also been undertaken (Auckland Transport 2011).

### D5.4 Actual base year conditions

2005 traffic volumes on SH1 were over 7000 vehicles per hour (one-way southbound) over the Harbour Bridge in the AM peak period.

Travel times were relatively slow for general traffic between Albany and the CBD due to the presence of stop-start driving conditions (Auckland Transport 2011).

ARTA staff involved at the time report that the introduction of limited bus priority measures through hard shoulder use immediately prior to the construction of the busway had a small but positive impact on bus travel times.

The social cost of road crashes on the relevant section of SH1 is substantial at \$8.6m pa (CAS data).

### D5.5 Actual post-implementation conditions

The travel times for buses (35min) from Albany to the CBD were slightly higher than for cars (34min 30s) prior to the introduction of the busway in 2005.



By 2009, bus travel times had reduced by 36% to 23min 20s whilst car travel times had increased by 5% to 36min 24s. Over the same period, busway southbound patronage increased by 46% during the AM peak period.

Post-implementation traffic volumes remained high, but monitoring indicates that southbound AM peak period traffic volumes fell in absolute terms by around 2% over the period 2005 to 2009 (Auckland Transport 2011).

A slight change in car occupancy was also recorded over the same period from 1.21 to 1.28, although this was not as a result of any planned HOV initiatives none of which had been implemented as at June 2011.

It appears doubtful that following the increased frequency of bus operations any significant amount of HOV use of the existing busway is feasible without significant further investment (Auckland Transport 2011).

There has been a post-implementation reduction in the social cost of road crashes of \$0.6m per annum. This is the average annual difference between five-year pre- and post-implementation periods (ie either side of the commencement of busway implementation) and hence will include periods, post-2005, where off-line construction was taking place (CAS data).

In terms of the potential impact on the BCR, costs have exceeded earlier assumptions, bus patronage is greater than previously forecast, and an absolute reduction in SH1 traffic demand has been recorded together with a small deterioration in car travel times due to unrelated road works (Auckland Transport 2011).

As a result, applying the original evaluation methods produces an actual outturn BCR of 1.3, a slight increase on the original evaluation BCR of 1.2.

## D5.6 Forecast do-minimum conditions (no implementation)

Modelling was undertaken using project SATURN modelling by Beca for Transit NZ, the North Shore Tracks model by Gabites Porter for NSCC, the APT model by ARC/ARTA for bus and patronage forecasts and the use of ART 2 (ARC) for mode split estimates.

Documented details of this modelling or other detailed information (on projected volumes and travel times 'without the busway') have not been maintained and are not therefore available.

More recent (retrospective) testing was undertaken for a current post-implementation review being conducted for the NZTA, to estimate conditions with and without the busway in 2011, using the Auckland Council ART3 model (Transport Futures 2012).

Background traffic volumes in the absence of the project were forecast to grow steadily over the evaluation period.

In the absence of the busway, the project evaluation assumed that no reduction in casualties or serious / fatal casualties would have occurred.

## D5.7 Forecast post-implementation conditions

The forecast benefits for the busway elements of the scheme (excluding HOV use) were: existing PT users 22%, new PT users (diverted from car) 17%, new PT users (other) 11%, decongestion 41%, safety 2%, VOC 7%, CO<sub>2</sub> 0.3%, resulting in a BCR of 1.2 (Beca 2004).

With HOV use the BCR rose to 1.7, as a result of increased travel time savings and despite a marginal increase in estimated cost. The benefit split for this scenario was: travel time savings, for PT and traffic (81%), vehicle operating costs (15%) safety (3%) and Co2 (1%) (Beca 2004). The HOV proposal was forecast to both give benefits to the HOVs themselves and lead to decongestion for general traffic.

Forecast safety benefits at \$0.5m pa are very close to the actual reduction in social costs recorded on the CAS system (Beca 2004).

## D5.8 Performance statistics

Key performance statistics for the NB project are shown in table D.10.

**Table D.10 Key performance statistics – base, actual and forecast conditions**

	Base	Actual	Forecast DM	Forecast DS	% Difference (Actual vs base/DM)
Costs	Total project cost used for evaluation \$214.6m <sup>(a)</sup>	Total outturn cost \$220.5m (see D5.2)			<i>Total costs</i> 5% more than base.
Pre-bus patronage (ALL) 2002–05	2002 AM S/B: 4782 <sup>(b)</sup>	2005 AM S/B: 5249 <sup>(b)</sup>			9.8% more than base (approx. 3% pa)
Post-bus patronage (ALL) 2005–10	2006 AM S/B: 5249 <sup>(b)</sup>	2010 AM S/B: 7508 <sup>(b)</sup>			43% more than base (approx. 7.5% pa)
Post-bus patronage (busway services) 2006–10	2006 AM S/B: 2614 <sup>(b)</sup>	2010 AM S/B: 4142 <sup>(b)</sup>			58.5% more than base (approx. 9.5% pa)
Post-bus patronage (non-busway services) 2006–10	2005 AM S/B: 2656 <sup>(b)</sup>	2010 AM S/B: 3035 <sup>(b)</sup>			29.5% more than base (approx. 5% pa)
Vehicle demand	2005 AADT: 166,130 <sup>(c)</sup>	2009 AADT: 158,102 <sup>(c)</sup>			4.8% less than base (2005 to 2010)
Vehicle demand	2005 AM S/B: 14,729 <sup>(c)</sup>	2009 AM S/B: 14,482 <sup>(c)</sup>			1.7% less than base
Car passengers	2005 AM S/B: 17,822 <sup>(c)</sup>	2009 AM S/B: 18,537 <sup>(c)</sup>			4% more than base
Bus mode split	2005 AM S/B: 22.2%	2009 AM S/B: 28.7%			6.5% more than base
Car transfer		2007 AM S/B Previous mode car 26% all bus passengers, 43% Northern Express. <sup>(d)</sup>			
Bus travel time	2005 AM S/B: 35.0 min <sup>(c)</sup>	2009 AM S/B: 22.3 min <sup>(c)</sup>			36% less than base
Car travel time	2005 AM S/B: 34m 30s <sup>(c)</sup>	2009 AM S/B: 36m 24s <sup>(c)</sup>			6% more than base

	Base	Actual	Forecast DM	Forecast DS	% Difference (Actual vs base/DM)
SH1 speeds	22.6 km/h <sup>(b)</sup>	19.8 km/h <sup>(b)</sup>			12% more than base
Road safety: average annual social cost	2001–05 \$18.0M pa (CAS)	2006–10 \$17.4M pa (CAS)			3% less than base (CAS)
Road safety: casualties (fatal, serious, minor, total)	2001–05 (5 years) casualties: 5f/s, 71m, 76t (CAS)	2006–10 (5 years) casualties: 3f/s, 79m, 82t (CAS)			8% (total casualties) more than base
BCR		BCR 1.3		2004 BCR 1.2 (up to 1.7 with +2 HOVs) <sup>(a)</sup>	12% more than forecast

Note: the AM peak period referred to in the above table is 7am to 9am on Mon-Fri working days, ie excluding holidays.

<sup>(a)</sup>Beca 2004; <sup>(b)</sup>Auckland Council 2006–10; <sup>(c)</sup>Auckland Council (2011); <sup>(d)</sup>ARTA 2007.

## D5.9 Summary of scheme impacts

This project has been subject to extensive modelling, forecasting, evaluation and monitoring, although only a limited amount of relevant archive material has been located. This is partly due to pre-implementation efforts being directed towards fulfilling the funding requirements at the time, which were largely BCR driven, rather than recording forecasts that could be used for project review purposes.

From the material available, comments on particular aspects are provided below:

### D5.9.1 Costs

- Component costs are described in table D.9 above.
- The overall outturn costs were very similar to earlier estimates used for evaluation and funding approval, although the scope of works covered by these costs changed during the planning and implementation period.

### D5.9.2 Traffic

*New/improved roads:*

- **Volumes:** The implementation of the busway and associated station and service changes has been accompanied by a reduction in traffic volumes on the parallel state highway similar in scale to that originally predicted. This means that traffic delays have stabilised to some extent and have not grown at the rate expected to occur without the busway.
- **Induced travel effects:** There is no evidence of substantial induced traffic effects, although it is possible that the effect of retimed and rerouted commuter traffic could have lead to recorded reductions in peak traffic volumes being slightly less than anticipated.
- **Travel times/speeds:** Travel times for buses are lower (and speeds higher) than would have been the case in the absence of the busway. On the basis of a small bi-annual moving observer sample, general traffic travel times on SH1 appear to have continued to increase (in absolute terms) in the post-implementation period. The reasons for this seem likely to include temporary delays south of the Harbour Bridge as a result of the Victoria Park and Newmarket Viaduct projects and works on SH1 itself to provide additional lane merge capacity.

- **Reliability:** Although detailed information is not available, it is likely that there has been little improvement in road traffic reliability in the post-implementation period and it may well have worsened in keeping with increased travel times for general traffic. In contrast, bus reliability has significantly improved in keeping with the significant reduction in bus travel times experienced.

#### *Effect on other/local roads*

- The effects on other/local roads are likely to have been small but positive, due to the removal of some traffic demand due to mode shift.

#### **D5.9.3 Effect on other modes**

- There has been a significant reduction in PT travel times, improved reliability and increased service frequency, leading to substantial growth in overall post-implementation bus patronage (7.5% pa) compared with pre-implementation bus patronage growth rates (3% pa)
- The growth in post-implementation busway services has been 9.5% pa compared with 5% pa growth in post-implementation non-busway services.
- There has been an increase in the number of people (+13.4%) using the busway to access the CBD as a result of PT and car passenger growth (4).

The change in morning peak southbound mode share is shown in table D.11.

**Table D.11 Harbour Bridge mode share**

SH1 S/B AM peak only	Prior 2005 <sup>(a)</sup>	Actual 2009 <sup>(a)</sup>
Cars	14,749	14,482
Car pass	3093	4055
<i>Total car users</i>	<i>17,822</i>	<i>18,537</i>
PT users	5096	7444
Busway PT mode share	22.2%	28.7%

(a) ARTA 2006

- If Onewa services are included, the total PT patronage in the peak two hours inbound over the harbour bridge and the vehicle mode split increases to 9143 which takes the overall PT mode share to 33.1%. This is consistent with the target range of the Auckland Regional Land Transport Strategy and the Auckland Transport Plan of 28% to 38% for 2001 to 2016 respectively.
- In the Beca 2004 evaluation it was assumed that bus patronage (and associated benefits) would grow by 36% between 2001 and 2011. In fact the growth has been much higher than that at 81% (source: CBD cordon-based ARTA analysis).

#### **D5.9.4 Safety effects**

Road safety related social costs derived from the CAS system, with five years pre-introduction of the Northern Expresss (NEX) services 2001–05 and five years post-implementation data 2006–10, for the SH1 and associated junctions between Albany and the Harbour Bridge, were found to have reduced in absolute terms. A detailed comparison of project safety impacts and background changes in social cost is shown in table D.12.

Table D.12 Project and background safety trends

Northern busway		Pre-annual average	Post-annual average	% Change
Project	Fatal and serious	-37%	-37%	-37%
	Total	8%	8%	8%
	Social cost \$m pa	-3%	-3%	-3%
Sub-regional state highways (urban central and urban north NZTA zones)	Fatal and serious	43	32	-24%
	Total casualties	475	470	-1%
	Social cost \$m pa	118.1	104.1	-12%
Regional state highways (Auckland region)	Fatal and serious	115	100	-13%
	Total casualties	860	870	1%
	Social cost \$m pa	237.3	216.4	-9%
National state highways	Fatal and serious	1,286	1,151	-10%
	Total casualties	5,459	5,514	1%
	Social cost \$m pa	1,984.90	1,833.10	-8%

The following points can be drawn from the trends described:

- A small reduction in the social cost of crashes on SH1 is indicated in early localised safety monitoring (CAS before and after analysis) as a result of project implementation.
- Forecast annual project related benefits at \$0.5m were similar to actual savings of \$0.6m.
- It should be noted that there are likely to have been a number of interventions and changes in corridor conditions over the pre and post-implementation review period.
  - Comparison of project area change in social cost with regional and sub-regional changes in social cost (over the same period) indicates that potential safety benefits may not have been fully realised in the implementation of the project.
  - The CAS assessment shows an 8% increase in casualties but a reduced number of serious casualties and fatalities between pre- and post-implementation.

#### D5.9.5 Local and global environmental effects

- Not known, but VOC, GHG emissions and local environmental changes are likely to be minor as these are probably dependent on changes in traffic conditions, which have been relatively small.

#### D5.9.6 Overall economic performance

- Despite a small change in outturn cost for the busway itself, the forecast BCR of 1.2 is likely to have been bettered (to a BCR of 1.3) due to the actual performance of the project in patronage and traffic reduction terms.
- The higher forecast BCR from the original evaluation for the implementation of HOV initiatives (1.7) is unlikely to be realised.
- If current procedures (using the EEM) were applied to the project this would result in a higher BCR range than the originally estimated range of 1.2. The increase in the corridor travel capacity to access the CBD **may** have resulted in increased economic activity and employment effects (such as agglomeration) that are additional to the transport-based economic evaluation undertaken.

A summary table of effects is included below in table D.13.

**Table D.13 Impact summary – northern busway**

Aspect	Impacts relative to base/do-minimum forecasts	Impacts relative to scheme forecasts
1 Capital costs	\$220.5m outturn construction cost Part of a package of measures to provide bus stations, park and ride facilities and introduce service changes. The busway-only element of the project was funded at a FAR of 100% as a state highway project.	c.5% (\$10.5m) more than pre-construction estimate of \$210m.
2 Travel demand	Bus patronage demand has grown substantially by 46%. This is greater than would have been anticipated in the absence of the busway. Traffic demand in terms of vehicle volumes has fallen by 2% post-implementation (between 2005 and 2009) and there has been an increase in car occupancies (from 1.2 to 1.3).	Actual changes in bus patronage and traffic demand are similar to forecast.
3 Travel times	Significant 36% reduction in bus travel times. Slight 6% increase in road travel times.	Forecast reduction in travel times.
4 Safety	The social cost of crashes has reduced (by an average of \$0.6m pa). The total number of casualties have increased slightly (from 76 pa to 82 pa) post-implementation with a reduction in crash severity.	Safety improvements are generally consistent with forecasts.
5 Vehicle operating costs and environmental impacts	Marginal VOC, GHG and other environmental effects likely to be small due to changes in general traffic conditions also being small.	Generally consistent with forecasts
6 Overall economic performance	The BCR has been achieved due to the outturn cost increase (compared with the original evaluation) being balanced by the bus user benefits being greater than expected.	The main forecast benefit is for time savings (77%) made up by a combination of traffic reduction and bus user benefits. From the evidence available it appears the traffic benefits are similar to forecast and the bus user benefits are greater than expected.

## D5.10 Conclusions

- The project has achieved its aims of significantly increasing PT patronage and mode share.
- The project has contributed to an increased number of people (+13.4%) accessing the CBD by a combination of PT and private vehicles, during the AM peak period.
- The early evaluation for this project was problematic, partly because economic evaluation procedures at the time had not been fully designed for application to major PT projects. Consequently, for funding evaluation purposes at the time it was necessary to adopt a number of non-standard approaches and assumptions.
- The original forecast BCR of 1.2 is likely to have been achieved in terms of the evaluation method employed at the time of funding approval. This because costs have remained close to the funding approval estimates, and forecast PT benefits (in the early post-implementation period) have been

achieved resulting in a revised outturn BCR, using the original PEM/ATR methodology for PIR purposes, of 1.3.

- The position concerning travel time benefits to general traffic is less clear, as traffic volumes have reduced in absolute terms, but travel times in the immediate post-implementation period appear to have increased slightly, due to the effect of unrelated road works.

## D6 Tauranga Harbour link

Tauranga Harbour Link, operational since January 2010, consists of a cross harbour bridge duplication and associated approach works.

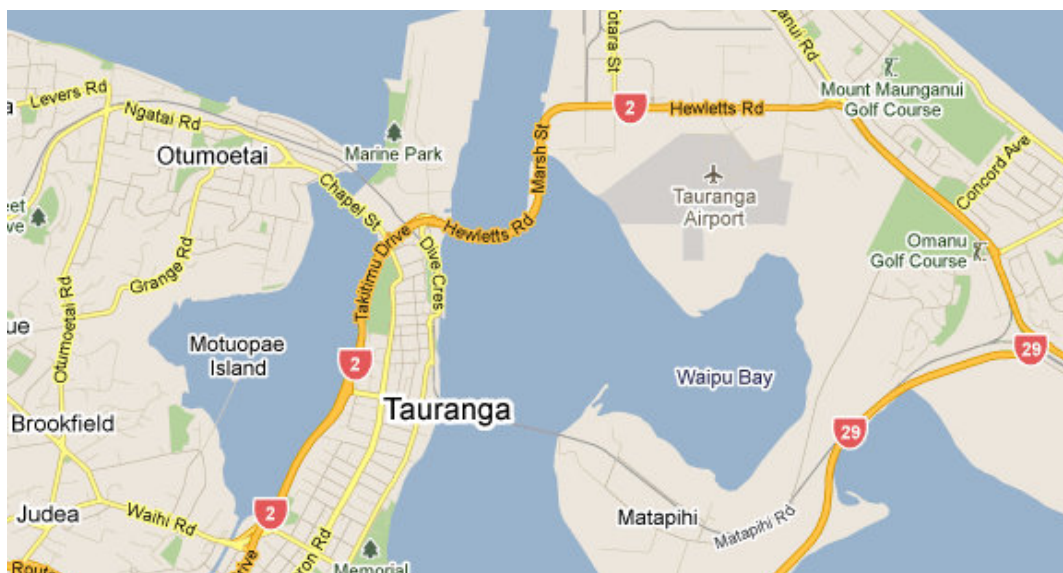
### D6.1 Description

The original Tauranga Harbour Bridge was opened in 1988 and included a \$1 toll for its use. Over the next 13 years, the daily traffic flow on the bridge increased from 10,000 vehicles per day (vpd) to 27,500 vpd because of the continued strong residential development across the harbour from the city centre. The effect of removing the toll (in 2001) over the original harbour crossing was to increase demand substantially and to increase travel times. The daily flows on the Harbour Bridge increased by 26% from 27,600 vpd to 34,900 vpd during a 14-week post-removal period. After an initial reduction, the flows on the parallel alternative route (Maungatapu Bridge) returned to their pre-toll-removal level of 20,100 vpd within the 14-week period (ie a change of 0%). The proposal to duplicate the crossing emerged from the pressure placed on the route following toll removal (10).

The duplication of the harbour bridge was preceded by Hewlett's Road flyover, the Hewlett's link and implemented with the grade separation of Chapel Street. The duplication was planned as a tolled crossing but was implemented in non-tolled form and resulted in a doubling of the capacity of the original crossing by providing a new two-lane road over Tauranga Harbour and associated connections.

The location of the project is shown in figure D.6.

**Figure D.6 Harbour link project location (SH2)**



The duplication project aims were to provide more efficient and quicker access between Tauranga and Mount Maunganui, reduce congestion on the existing harbour bridge and Hewlett's Rd and the traffic

bottleneck at Chapel Street for through traffic. The harbour link was constructed in two stages, namely: the four-laning of Hewlett's Rd on the Mount Maunganui side of the harbour, completed in September 2007, and the bridge duplication, which took place between July 2007 and January 2010 (14).

## **D6.2 Project costs**

The Harbour Link project comprised the bridge duplication, the four-laning of Hewlett's Road, the Hewlett's Road flyover and the grade-separation of Chapel Street.

The estimated cost at the time of funding approval was \$254.7m (from NZTA's Transport Investment Online).

The pre-implementation evaluation assumed a cost of \$232.8m (Beca 2006).

The outturn cost was much lower than anticipated at \$168.9m (from NZTA's Transport Investment Online). This is probably due to a combination of an over-estimation of costs and the effect of competitive tendering at a time of economic downturn.

## **D6.3 Method (modelling, forecasting and evaluation techniques)**

Pre-implementation techniques included the use of TRIPS/Voyager Traffic Modelling to predict traffic volumes, travel times and vehicle operating costs.

Post-implementation monitoring included traffic volume counts and travel time surveys.

## **D6.4 Actual base year conditions**

Harbour bridge traffic volumes were 36,500 vehicles per day. (NZTA 2010a) The alternative (round harbour) route (now SH29) was used by some traffic in preference to the harbour bridge.

Cross harbour travel delays were experienced in busy periods (Beca 2005).

The social costs of crashes was \$3.9m pa (CAS data).

## **D6.5 Actual post-implementation conditions**

Cross harbour traffic volumes have increased broadly in line with expected growth (NZTA 2010b).

Cross harbour travel times have reduced substantially (Beca 2010).

Alternative (round harbour) route changes in volume and travel time as a result of the harbour link project implementation are not substantial (Beca 2010; NZTA 2010b).

Early indications are of a substantial reduction in social cost (CAS data).

The outturn cost is much lower than anticipated at \$168.9m (from NZTA's Transport Investment Online).

The outturn BCR is likely to be significantly greater than the pre-implementation forecast BCR, due to the additional safety benefit and cost reduction factors.

An earlier study considered the justification for tolling the road compared with construction in an untolled form (Wallis 2005). The substantial reduction in outturn costs would not have been sufficient to adjust the findings of the study, namely that a toll road could not be economically justified.

## **D6.6 Forecast conditions do-minimum (no implementation)**

Background traffic volumes in the absence of the project were expected to grow steadily over the evaluation period.



The background regional and national trends in safety terms (either side of project implementation) were for an increase in total casualties, but reductions in serious casualties and fatalities over the period.

## D6.7 Forecast conditions post-implementation

Forecasts and associated evaluations were produced for scenarios with and without tolling (Beca 2006; 2005).

The forecast benefit split without tolling was as follows: travel time (74%), congestion (11%), reliability (7%), VOC (7%), walking/cycling (0.5%), CO<sub>2</sub> (0.5%) (Beca 2006).

## D6.8 Key performance statistics

Key performance statistics for the harbour link project are shown in table D.14.

**Table D.14 Key performance statistics – base, actual and forecast conditions**

	Base	Actual	Forecast DM	Forecast DS	% Difference (Actual vs base/DM)
Costs	\$254.7m <sup>(a)</sup> The evaluation assumed a cost of \$232.8m <sup>(b)</sup>	\$168.9m <sup>(a)</sup>			33.7% (\$85.8m) less than base.
Combined cross-harbour volume (AADT) <sup>(d)</sup>	(2006) 36,508 <sup>(c)</sup>	(2010) 38,716 <sup>(c)</sup>			6% more than base (2006 to 2010)
Harbour Bridge speeds <sup>(c)</sup>	AM (W/B) 45.2 km/h PM (E/B) 41.6 km/h	AM (W/B) 55.5 km/h PM (E/B) 47.0 km/h			AM 23% (10.3km/h) higher than base PM 13% and 5.4km/h
Harbour Bridge travel times <sup>(c)</sup>	12min 11s	9min 22s			2min 49s (23%) time saving (average of peak and inter-peak times) compared with base
Alternative route (SH29) speeds <sup>(c)</sup>	AM 70km/h PM 75km/h	AM 71km/h PM 76km/h			AM 1.4% (1km/h) higher than base PM 1.3% (1km/h)
Road safety: annual social cost (CAS)	\$19.59m (5 years) \$3.92m pa	\$2.63m (1.25 years) \$2.1m pa		No benefits included in forecast.	46% (\$1.82m pa) less than base
Road safety: casualties (fatal, serious, minor, total) (CAS)	2002-2006 (5 years) casualties: 2f/s, 10m, 12t pa (CAS)	2010 (Feb)-2011 (Apr) (1.25 years) casualties: 0f, 1f/s, 10m, 11t pa (CAS)			5% total casualties less than base
BCR <sup>(b)</sup>	N/A	BCR 4.2		BCR 2.9 untolled (2006 est. <sup>(b)</sup> ) BCR >1.1 tolled (2005 estimate <sup>(e)</sup> )	42% increase over forecast

<sup>(a)</sup>Transport Investment Online (NZTA); <sup>(b)</sup>Beca 2006; <sup>(c)</sup>Beca 2010; <sup>(d)</sup>NZTA 2010a; <sup>(e)</sup>Beca 2005.

## D6.9 Summary of project impacts

There are only limited references to safety and environmental impacts (such as air quality and noise) in the project documentation.

However, from the available information, the conclusions drawn on the project impacts are summarised in table D.14, with further comments as follows.

### D6.9.1 Costs

- Outturn costs were one-third lower than the approved construction funding cost.

### D6.9.2 Traffic

#### *New/improved roads:*

- **Volumes:** Post-implementation traffic volumes are slightly higher than pre-implementation volumes. This increase was lower than expected, probably due to the economic downturn since 2008 and because of other improvements undertaken on the alternative route to the harbour link.
- **Induced traffic effects:** No significant induced traffic effects appear to have occurred in the immediate post-implementation period.
- **Travel times/speeds:** The reduction in travel times and increase in speeds appear to be consistent with forecasts.
- **Reliability:** This is likely to have improved on the harbour crossing and immediate approaches as a result of increased capacity and associated reduction in delays on these parts of the network.

#### *Effect on other/local roads*

- Some improvements in conditions on the alternative round harbour route have been recorded.

### D6.9.3 Effect on other modes

- This is unknown, as a 'traffic-only' project model was used. However, it could be inferred that the effect on other modes will have been negative due to the improvement in the relative attractiveness of car-based travel.
- It is likely that there has been some encouragement of cycling due to the dedicated facility provided on the new bridge.
- Overall, however, the effects are likely to be small due to the low mode share of non-car modes in the area.

### D6.9.4 Safety effects

- Early indications are that social costs and associated casualties on the harbour link have substantially reduced post-implementation. This is likely to be the greatest area of safety impact, as changes in volumes and speeds on the alternative route have been relatively small.
- Background sub-regional, regional and national trends also show reductions in fatalities/serious casualties and social cost over the same period, although these are proportionately smaller than background safety trends within the primary area of influence of the project as shown in table D.15

**Table D.15 Project and background safety trends**

Tauranga Harbour link		Pre-annual average	Post-annual average	% Change
Project	Fatal and serious	1.8	0.8	-56%
	Total	11.8	11.2	-5%
	Social cost \$M pa	3.9	2.1	-46%
Sub-regional state highways (Tauranga and Western Bay of Plenty)	Fatal and serious	48	42	-12%
	Total casualties	162	166	3%
	Social cost \$M pa	96.6	72.1	-25%
Regional state highways (Bay of Plenty region)	Fatal and serious	116	98	-15%
	Total casualties	404	374	-7%
	Social cost \$M pa	205.7	172.3	-16%
National state highways	Fatal and serious	1289	997	-23%
	Total casualties	5511	4951	-10%
	Social cost \$m pa	1981.1	1606.3	-19%

- The immediate post-implementation data indicates a similar level of overall annual casualties (at 98% of pre-implementation levels) but a reduced number of serious casualties and fatalities, with a consequent reduction in overall social cost.

#### **D6.9.5 VOC, global and local environmental effects**

- VOC, greenhouse gases and local environmental effects such as air pollution and noise impacts have not been monitored or assessed, but are likely to be small due to the relatively marginal effect of the project on overall traffic volumes.

#### **D6.9.6 Overall economic performance**

- It seems likely that the pre-construction forecast of a 2.9 BCR can be revised upwards by around 50% as the benefits appear to have been achieved or bettered and the outturn cost is substantially below the original estimate.
- However, the lowering of outturn costs would still not have been sufficient to justify the introduction of the project as a tolled road in economic terms (Wallis 2005).

### **D6.10 Conclusions**

- The project did not lead to a substantial increase in immediate post-implementation traffic volumes.
- The aims of reducing travel time and delivering VOC savings appears to have been achieved.
- A reduction in road safety social cost is indicated in early post-implementation safety monitoring.
- Outturn costs are substantially less than forecast and largely as a result of this, the actual outturn BCR is likely to be significantly higher than forecast.

A summary of effects is given in table D.16.

**Table D.16 Impact summary table – harbour link**

Aspect	Impacts relative to base/do-minimum' forecasts	Impacts relative to project forecasts
1 Capital costs	\$254.7M (2005) Funded at a FAR of 100% as a state highway project.	Outturn costs \$85.8m (33.7%) less than pre-construction estimate.
2 Traffic volumes	Little change in immediate post-implementation period with a combined cross-harbour increase of 6% over a four-year period (2006 to 2010)	Forecasts thought to be similar to immediate post-implementation volumes.
3 Travel times/speeds	Significant increases in peak direction travel speeds (+10km/h AM and +5km/h PM).	Forecast speeds thought to be similar to forecasts.
4 Safety	Early indications are that social costs may be reduced due to reduced severities.	No social cost benefits were forecast.
5 Operating costs and environmental impacts	VOC, GHGs and local environmental effects are all likely to have been reduced as a result of the more efficient operating conditions post-implementation.	VOC savings and CO2 reductions forecast are thought to be similar to forecasts.
6 Overall economic performance	It is likely that the original evaluation underestimated the BCR and that an outturn BCR approximately 40% higher than forecast would be justified.	Earlier work (Wallis 2005) indicates that the reduction in project costs would not have been sufficient in economic terms to warrant the implementation of the project as a tolled road (as the NPV remains heavily negative).

## D7 Wellington inner city bypass (WICB)

Wellington inner city bypass (WCIB), operational since February 2007, involves the rationalisation and improvement of state highway routes between the Terrace Tunnel and Basin Reserve.

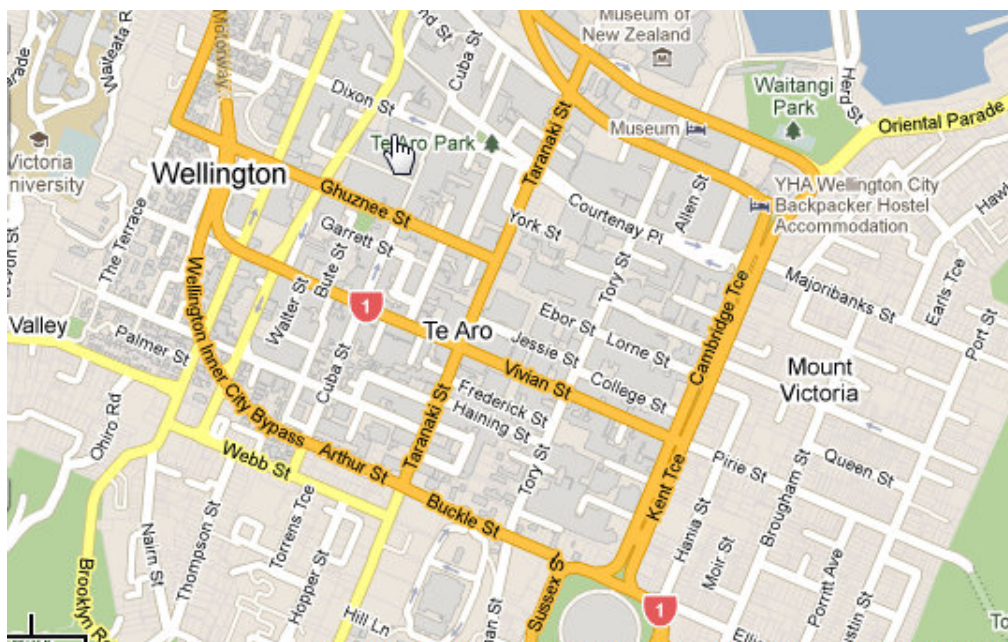
### D7.1 Description

The project aims were as follows:

*The Wellington Inner City Bypass (the Bypass) will provide a less congested, safer, and more efficient route between the Terrace Tunnel and the Basin Reserve. The Bypass is a one-way, two-lane road, at ground level, with dedicated turning lanes and a 50 km/h speed limit. It will separate cross-city and central business district traffic and provide a safe route for pedestrians and cyclists. (Opus 2008)*

This project involved the rationalisation of SH1 traffic in central Wellington, including revised traffic management arrangements to straighten the south bound movement and a short section of new two-lane northbound highway connecting the Basin Reserve with the Terrace Tunnel.

The location of the project is shown in figure D.7.

**Figure D.7 WCIB project location (SH1)**

The effect of the project was to shorten the distances travelled by SH1 traffic through the city between the Terrace Tunnel and Basin Reserve. Summed over both directions the state highway has been shortened by 410m from 3320m to 2820m.

The project was implemented between August 2005 and February 2007.

## D7.2 Project costs

The pre-implementation cost estimate used at the time of funding approval was \$38.9m (from NZTA's Transport Investment Online).

The cost used for the calculation of the earlier economic evaluation which calculated the BCR for funding application purposes was substantially lower than the funding approval figure (Opus 2000a; 2000b)

The outturn cost for the project was \$42.84m (from NZTA's Transport Investment Online).

## D7.3 Method (modelling, forecasting and evaluation techniques)

Pre-implementation 2001-based SATURN traffic modelling was later updated using 2006 demand matrices from the Wellington Transport Strategy Model (WTSM). The SATURN model extended north to Johnsonville and Petone, while covering much of the Wellington city road network in simulation. The demands from the SATURN model were also used for the WICB Paramics model, which was developed for the detail design and signal optimisation of SCATS for the project and associated local roads.

Post-implementation traffic modelling was undertaken using the Wellington SATURN model.

Post-implementation reviews made use of area-wide traffic (SCATS) and crash records (CAS) data.

Post-implementation travel time surveys were undertaken using moving car observer methods for the modelled time periods AM, IP and PM (Opus 2008b).

## D7.4 Actual base year conditions

Conditions on the network were congested in peak periods and travel speeds on the local network were particularly slow at peak times (Opus 2008a).

The crash record of this part of the network was also problematic in terms of the proportion of pedestrian and cyclist casualties (CAS data).

## D7.5 Actual post-implementation conditions

The scope of the analysis post-implementation evaluation available includes:

- the quantified review of changes in traffic volume, travel time, crashes, noise and ground water
- qualitative discussion of other aspects such as pedestrian, cycling and PT facilities.

Aspects not specifically monitored or estimated post-implementation include air quality, emissions and the impact on development.

Peak flows on the state highway remain similar to base conditions and there is no clear evidence of induced traffic (Opus 2008a; 2008b)

Travel speeds have improved marginally on the local network and also more substantially on SH1 (Opus 2008b).

The social cost of road crashes and the number of casualties on SH1 have both increased post-implementation (CAS data).

## D7.6 Forecast conditions do-minimum (no implementation)

Background traffic volumes in the absence of the project were expected to grow steadily over the evaluation period.

The background regional trend in road safety (either side of project implementation) indicates a slight increase in total casualties. Serious casualties and fatalities at the regional and national level remained stable in absolute terms over this period.

The adjusted SATURN model (Opus 2008b) which was rebased (to reflect 2006 conditions), was used in 2008 to produce 'retrospective' forecasts of do-minimum conditions (Opus 2000a). These were similar to the original 2001 based modelled forecasts.

Other more detailed information is not available.

## D7.7 Forecast conditions post-implementation

The adjusted SATURN model predicted two-way time-savings of around 1m 30s for state highway traffic during the AM and PM peak hours (Opus 2008a).

The forecast benefit split was standard travel time benefits (73.5%), congested travel time (19.8%), vehicle operating costs (distance) (-1.5%), vehicle operating costs (idling) (6.1%), accident costs (1.0%), CO<sub>2</sub> (0.1%) (Opus 2000a).

## D7.8 Key performance statistics

Key performance statistics for the WICB project are shown in table D.17.

**Table D.17 Key performance statistics – base, actual and forecast conditions**

	Base	Actual	Forecast DM	Forecast DS	% Difference ( <i>actual vs base/DM</i> )
Costs <sup>(a)</sup>	\$38.9m (May 2004)	\$42.84m			10.1% higher than base
SH1 peak volume <sup>(b)</sup>	AM 3162 veh/h (2005) PM 3319 veh/h (2005) Total 6481 veh/h (2005)	AM 3376 veh/h (2008) PM 3112 veh/h (2008) Total 6488 veh/h (2008)		Peak hr volumes not expected to change due to existing constraints on entry/exit to the project. Background AADT growth of around +1% pa was forecast.	AM 7% higher than base. PM 6% lower than base. Overall 0.1% increase compared to base.
SH1 daily volume <sup>(b)</sup>	Terrace Tunnel two-way AADT 42,960 (2005)	Terrace Tunnel two-way AADT 45,364 (2007)		Indicates an increase in daily traffic over and above expected growth of 3% of 2.6% <sup>(b)</sup> .	5.6% higher than base (2005 to 2007).
Local road volumes <sup>(b)</sup>	Ghuznee AM 1536 veh/h (2005) Ghuznee PM 1553 veh/h (2005) Taranaki AM 1467 veh/h (2005) Taranaki PM 1486 veh/h (2005)	Ghuznee AM 475 veh/h (2008) Ghuznee PM 623 veh/h (2008) Taranaki AM 1464 veh/h (2008) Taranaki PM 1514 veh/h (2008)		Only 2008 modelled estimates available but not available in equivalent locations.	Ghuznee AM 69% less than base. Ghuznee PM 60% less than base. Taranaki AM 0% no change. Taranaki PM 2% more than base.
SH1 travel times <sup>(c)</sup>	AM 8m 52s (2005) IP 7m 56s (2005) PM 12m 17s (2005)	AM 6m 31s (2008) = -2m 21s change IP 6m 6s (2008) = -1m 5s change PM 9m 8s (2008) = -3m 9s change		Modelling forecasts (run in 2008) estimated savings for SH1 users of 1m 56s AM peak, 1m 9s IP and 1m 32s PM peak <sup>(b)</sup> .	AM 27% (2m 21s) less than base. IP 14% (1m 5s) less than base. PM 26% (3m 9s) less than base.
SH1 speeds <sup>(c)</sup>	AM 21.9km/h (2005) IP 24.4km/h (2005) PM 15.8km/h (2005)	AM 26.0km/h (2008) IP 27.7km/h (2008) PM 18.5km/h (2008)			AM 19% more than base. IP 14% more than base. PM 17% more than base.
Local road travel times <sup>(c)</sup>	AM 18m 48s (2005) IP 17m 36s (2005) PM 23m 12s (2005)	AM 19m 29s (2008) IP 16m 54s (2008) PM 24m 27s (2008)			AM 4% (41s) more than base. IP 4% (40s) more than base. PM 5% (1m 15s) more than base.
Local road speeds <sup>(c)</sup>	AM 11.9km/h (2005) IP 12.8km/h (2005) PM 9.7km/h (2005)	AM 11.5km/h (2008) IP 13.3km/h (2008) PM 9.2km/h (2008)			AM 3% less than base. IP 4% more than base. PM 5% less than base.
SH1 safety: annual social cost	Social cost \$23.9m for 5 full years (2002 to 2006).	Social cost \$26.5m for 4 yrs 2 months (Apr 2007 to Mar		\$1.02m NPV (equivalent to a small annual reduction in social cost of approx.	33% (\$1.6m pa) more than base.

	Base	Actual	Forecast DM	Forecast DS	% Difference ( <i>actual vs base/DM</i> )
(CAS)	Annual average \$4.8m	2011). Annual average \$6.4m		-\$0.1m)	
Road safety: casualties (fatal, serious, minor, total) (CAS)	2001–05 (5 years) casualties: 3f/s, 14m, 17t (CAS)	2007 (Mar) to 2011 (Apr) (4.17 years) casualties: 4f/s, 24m, 28t (CAS)			64% total casualties more than base.
BCR		BCR 3.1		BCR 3.7 <sup>(d)</sup>	20% below forecast

(a) Transport Investment Online (NZTA); (b) Opus 2008a; (c) Opus 2008b; (d) Transport Investment Online NZTA).

## D7.9 Summary of project impacts

The pre-implementation analysis and post-implementation evaluation of this project have been quite extensive, probably reflecting the amount of public interest and associated scrutiny involved immediately pre and post-implementation.

From the available material, the conclusions drawn on the project impacts are summarised in table D.16, with further comments as follows.

### D7.9.1 Costs

- Outturn costs were 10% higher than the approved construction funding cost (from NZTA's Transport Investment Online), and much higher than the estimated costs in the 2000 SAR (Opus 2000a; 2000b). It is difficult to compare the 2000 SAR cost (\$25.1m) and construction funding approval cost of \$38.9m as the SAR cost was discounted back to an earlier year.

### D7.9.2 Traffic

#### *New/improved roads:*

- **Volumes:** Post-implementation peak traffic volumes are similar to pre-implementation volumes in overall terms. Non-peak traffic growth on SH1 has been slightly greater than forecast meaning an additional growth in SH AADT of 2.6% over and above expected growth of 3% over the period 2004 to 2007 (Opus 2008a). There have also been substantial changes in the distribution of traffic within the central area as a result of project implementation.
- **Induced traffic effects:** Overall traffic volumes within the network have increased as a result of background traffic growth. Some localised increases over and above background growth appear to have occurred as a result of the project, but this is likely to be due to re-routing rather than any significant induced traffic impact. This is to be expected given the relatively small scale nature of the project (in overall network terms) and the peak period constraints on approaches to and links within the central area.
- **Travel times/speeds:** Post-implementation travel time savings on SH1 have been achieved and these are similar to forecasts. The reason we cannot be more specific is that detailed tabulated forecasts are not provided in the project literature. Peak period traffic disbenefits to non-SH1 traffic have been



identified. Actual congestion relief was estimated, from the post construction 'remodelling' undertaken, as being lower than original SAR modelled forecasts.

- **Reliability:** This is likely to have improved for SH1 users.

#### *Effect on other/local roads*

- On the local network there has been an increase in peak period travel times and associated speeds remain low. It is not clear how much of this effect is due to the introduction of new traffic management and road construction and how much might be due to the reallocation of signal timings in favour of SH1 traffic.

#### **D7.9.3 Effect on other modes**

- This is unknown as a 'traffic-only' project model was used, and no quantified monitoring of modal demands is available, but it can be inferred that any effects will have been small. This is because there have been some improvement in the relative attractiveness of car-based travel but this is countered to some extent by improvements in bus routing and walking/cycling facilities, introduced as part of the project implementation.

#### **D7.9.4 Safety effects**

- Social costs and the total number of casualties on the sections of state highway affected by the project have increased substantially post-implementation. It is possible that the increased social cost may be due to increased speeds on the existing road network, as a result of the project. However, there could be other contributory factors and further investigation of this issue is recommended.
- The background regional trend, either side of project implementation, showed a substantial reduction (-25%) in social cost over the same period, see table D.17.
- The effect of the project on road safety social costs was forecast to result in a benefit of approx. 0.1m pa, but in fact (after 4.5 years) an annual disbenefit of -1.6m has been recorded.

Project, sub-regional, regional and national safety trends are shown in table D.18.

**Table D.18 Project and background safety trends**

Wellington city inner bypass		Pre-annual average	Post-annual average	% Change
<b>Project</b>	Fatal and serious	2.8	3.6	29%
	Total casualties	17	27.8	64%
	Social cost \$M pa	4.8	6.4	33%
Sub-regional state highways (Wellington city)	Fatal and serious	15	18	18%
	Total casualties	120	153	28%
	Social cost \$M pa	176.9	144.2	-18%
Regional state highways (Wellington region)	Fatal and serious	83	59	-29%
	Total casualties	391	405	3%
	Social cost \$M pa	140	105	-25%
National state highways	Fatal and serious	1289	1150	-11%
	Total casualties	5623	5612	0%
	Social cost \$M pa	1988.80	1749.60	-12%

#### **D7.9.5 Local and global environmental effects**

- The effects of the project on VOC, GHG and air pollution have not been specifically monitored, but impacts are likely to be small due to the relatively marginal effect on traffic volumes and speeds.
- Noise effects have been studied immediately pre- and post-implementation and their effects found to be relatively small scale with a mixture of increases and decreases due to changes in the distribution of traffic.
- Ground water effects of construction were also studied pre- and post-implementation and found to be relatively minor.

#### **D7.9.6 Overall economic performance**

- This is difficult to establish as the basis of the 2004 calculations are not available. However, on the basis of the earlier SAR calculations, it seems likely that the forecast BCR of 3.7 may not have been achieved and the actual BCR figure may be around 20% less than forecast, as a result of cost and safety adjustments (although it should be emphasised that a detailed economic re-evaluation of the project has not been undertaken).

The rationale for this is as follows:

- Costs increased by 10% between the construction funding approval and the post construction outturn cost, ie the original NPC of \$25.12m is assumed to have increased by 10% to \$27.63m.
- The proportional increase in benefits is assumed to be identical to the change in costs the period to assume that the estimated BCR of 3.9 is maintained up to the time of construction funding. The total forecast benefits were \$97.8m (Opus 2000a; 2000b). The social cost NPC changes from +1.02m forecast to -\$15.9m actual. A small (5%) increase in travel time and associated VOC benefits to \$100.5m has been assumed. This means that the total net benefit NPB is 85.6m.
- This produces a BCR of 3.1. The difference between forecast and outturn BCRs is therefore 0.8 or-20%.

#### **D7.10 Conclusions**

- The project has achieved the expected overall travel time savings due to the reduction in peak travel times and associated increased speeds on SH1.
- In contrast, travel conditions on the local road network have marginally worsened, although significant traffic flow redistribution has occurred.
- The implementation of the project may have contributed to recorded increases in social costs of road crashes and in an increased number of casualties.
- The pre-implementation BCR was 3.8. It appears that, in view of the project cost increases and the significant increase in safety-related social costs, the post-implementation outturn BCR is likely to be lower than forecast by around 20%.

Project-related impacts are summarised below in table D.19.

**Table D.19 Impact summary table – Wellington inner city bypass**

Aspect	Impacts relative to base/do-minimum forecasts	Impacts relative to project forecasts
1 Capital costs	The estimated cost was \$38.9m. Funded at a FAR of 100% as a state highway project.	The outturn cost was \$42.8m which was 10% higher than the pre-implementation funding approval estimate.
2 Traffic volumes	Post-implementation peak traffic volumes on SH1 are virtually identical to pre-implementation volumes in overall terms (0.1% growth over a three-year period). In contrast, daily traffic has grown by 5.6%. Large redistribution effects on the local road network, with flows reduced on Ghuznee Street by 64.5%.	Forecasts were similar to immediate post-implementation volumes on both SH1 and the local network.
3 Travel times/speeds	Reductions in SH1 peak travel times by 2 to 3 minutes and associated increases in peak period speeds of between 3 and 4km/h. Inter-peak travel times on SH1 have reduced by around a minute and speeds increased by 3km/h. An increase in local road peak travel times by around a minute with associated reductions in speeds.	SH travel time savings and increases in speeds on SH1 were similar to forecast for the AM and inter-peak. Actual PM SH peak travel time reduction was greater than forecast. Forecasts indicated no worsening of local road conditions.
4 Safety	Social costs on SH1 have increased by a third (\$1.6m) to a level of \$6.4m pa post-implementation. This could be related to the increase in speeds on an existing road network. The number of casualties on SH1 has increased by 64%.	A small annual reduction in social cost of \$0.1m pa was forecast.
5 Operating costs and environmental impacts	In overall terms, VOC, GHGs and local environmental effects have only changed marginally as a result of the project. Environmental effects will be significant in localised areas, for example along Ghuznee Street (positive) and Karo Drive (negative).	Actual changes in VOC, CO <sub>2</sub> and noise are similar to that forecast.
6 Overall economic performance	It is likely that the original evaluation overestimated the BCR and that a recalculated outturn BCR would be reduced by around 20%.	The suggested outturn BCR is mainly due to increases in capital costs and higher post-implementation social costs of road crashes.

## Appendix E: Glossary

Abbreviation	Term
AADT	annual average daily traffic
ALPURT B2	Auckland northern motorway extension
AO	approved organisation (for NZTA funding)
Appraisal	broad assessment of project effects, including cost benefit analysis, usually undertaken (internationally) pre-implementation
ARTA	Auckland Regional Transport Authority (now Auckland Transport)
ASMRS	Auckland southern motorway ramp signalling
BCR	Benefit-cost ratio
BOTE	back of the envelope (modelling)
BTRE	Bureau of Transport and Regional Economics (Canberra, Australia)
CAS	crash analysis system (MoT)
CBA	cost-benefit analysis or appraisal
CGE	computable general equilibrium
DfT	Department for Transport (UK) from 2002 to date
DoT	Department of Transport (UK) from 1981-1997
EA	Environmental assessment
EEM V1/V2	<i>Economic evaluation manual volume 1/volume 2</i> (NZTA)
ePIR	enhanced post-implementation review (see also PIR)
Evaluation	Narrow assessment of project effects, including cost benefit analysis usually undertaken (internationally) post-implementation.
FAR	Financial assistance rate
FTM	fixed trip matrix
FYRR	First year rate of return
GHG	greenhouse gases
GPS	<i>Government policy statement on land transport funding 2012/13 – 2021/22</i>
HCV	heavy commercial vehicle
HNO	Highway Network Operations unit (of NZTA)
HOV	high occupancy vehicle
HIA	health impact assessment
IO	input-output
KPI	key performance indicator
LNMS	local network management schemes
LTMAA	Land Transport Management Amendment Act 2008
LUTI	land use transport interaction
MSC	marginal social costs
NATA	New approach to appraisal (UK DfT)
NB	Northern Busway (Auckland)
N/B	northbound
NLTF	National Land Transport Fund
NLTP	National Land Transport Programme
NPB	net present benefit

NPC	net present cost
NPV	net present value
NSCC	North Shore City Council
NZTA	New Zealand Transport Agency
OD	origin–destination
PCA/PCR	post construction audit/review
PE	post-evaluation
PFR	Project feasibility report
PIR	post-implementation review (see also ePIR)
PKT	person kilometres travelled
PMU/IMU	Performance Monitoring Unit/Investment Monitoring Unit (NZTA)
POPE	post-opening project evaluation
PPFM	Planning Programming and Funding Manual (NZTA)
Pre-implementation	before the commencement of project construction (ex-ante)
Post-implementation	after opening of project (ex post)
PROMAN	project management system, developed by Transit NZ
PT	public transport
RMA	Resource Management Act 1991
RoNS	roads of national significance
SAR	scheme assessment report
S/B	southbound
SCGE	spatial computable general equilibrium
SH	state highway
SIA	social impact assessment
SOI	NZTA <i>Statement of intent</i>
TDM	travel demand management
TRB	Transportation Research Board
TTI	Texas Transportation Institute
VDM	variable demand model
VKT	vehicle kilometres travelled
VMT	vehicle miles travelled
VOC	vehicle operating cost
vpd	vehicles per day
VTM	variable trip matrix
WEBS	wider economic benefits
WICB	Wellington inner city bypass
wrt	with respect to
WTP	willingness to pay