Demonstrating the benefit of network operations activities
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An important note for the reader

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Abbreviations and acronyms

AADT	annual average daily traffic
Austroads	Association of Australian and NZ road transport and traffic agencies
BCR	benefit-cost ratio
CAS	Crash Analysis System
CBA	cost-benefit analysis
CDB	central business district
CTM	Christchurch Transportation Model
EEM	*Economic evaluation manual* (NZ Transport Agency)
GIS	geographic information system
GPS	global positioning system
HOT	high-occupancy toll (lane)
HCV	heavy commercial vehicle
IAF	*Investment assessment framework* (NZ Transport Agency)
IBC	indicative business case
ITS	intelligent transport systems
LOS	level of service
PT	public transport
PIR	post-implementation review
RCA	road controlling authority
RIAWS	Rural Intersection Advanced Warning System
Safe system	internationally recognised system to reduce death and serious injury crashes
SCATS	Sydney Coordinated Adaptive Traffic System
SCOOT	Split Cycle Offset Optimisation Technique
SoI	*Statement of intent (NZ Transport Agency)*
TMC	traffic management controller
TMS	traffic management system
TOC	transport operations centre
VMS	variable message signs
VOC	vehicle operating cost
VPD	vehicles per day
VPH	vehicles per hour

Contents

Executive summary

Core research scope

This research project addressed the economic evaluation of operations activities with a particular focus on the suitability of economic evaluation procedures and the development of a framework to carry out economic assessment of operations activities. These activities relate to the day-to-day management and operation of the transport system – including real-time management and operation systems, the management of planned and unplanned events, provision of traveller information, and the collection and utilisation of business intelligence. The purpose of this project was to investigate and establish economic evaluation principles and techniques for the evaluation of these activities.

The initial phase of the project involved clarifying the scope of the research, identifying operations activities in the context of this project, carrying out an international literature review into the practices and approaches to economic assessment of operations, and establishing core economic principles and processes for assessment of the benefits of operations activities. The second phase included the development of the economic framework and application of this framework to three case studies.

Overview

Operations activities are playing an increasingly important role in the delivery, management and optimisation of our transport systems. In the New Zealand context, these activities are largely covered by the regional transport operations centres (TOCs) for urban areas for all modes of travel. The TOCs and their activities were determined to be a reasonable proxy for the scope of this research and, generally, there is a focus towards urban operations covering the whole network and all travel modes.

Historically, assessments of the economic benefits of operations activities have not been carried out extensively. In more recent years, some appraisals have been carried out but these have been largely limited to specific examples (eg signal optimisation and motorway intelligent transport system management techniques) that are of somewhat limited scope. In comparison, economic appraisal of 'typical' transport schemes (infrastructure, public transport, etc) follows well-developed and documented procedures and analysis techniques.

International review

A review of New Zealand and overseas literature, research, examples and practices identified the following key points in relation to the economic appraisal of operations activities:

- There is an overwhelming use of standard cost-benefit analysis (CBA) procedures, deriving a benefit-cost ratio (BCR), for the evaluation of economic benefits of operations activities.
- Economic procedures adopted cover essentially the same types of project benefits as are included in the NZ Transport Agency's *Economic evaluation manual* (EEM) (predominantly used for evaluating infrastructure projects).
- There is a tendency for economic evaluations to be relatively light (eg not covering alternative options and not assessing the full range of economic measures), and focused on the short-term lifespan of the activity.
- There is a tendency for the types of schemes evaluated, particularly signal optimisation projects, to demonstrate relatively low costs and high economic benefits (resulting in high BCR estimates).

Key considerations

Assessment environment

A trend identified from the international review and examples from New Zealand is a tendency for the economic benefits of operations activities to be analysed using a post-implementation evaluation process. Typically this involves carrying out on-street data measurements before the activity is implemented and repeating the data collection exercise following the activity to establish the benefits. This differs from the more common transport scheme economic assessment focused on a pre-implementation appraisal, where the benefits of the scheme are commonly forecast either through desktop analysis or often with the use of transport modelling.

The NZ Transport Agency business case approach to assessments supports the need to consider operations activities within the suite of potential solutions and treatments – potentially to extend the lifespan of existing or planned infrastructure. This approach places emphasis on assessing operations within a pre-implementation appraisal framework.

The agencies which carry out operations activities, such as the regional TOCs, typically work in an 'agile' environment which focuses on immediate on-street changes and (perceived) low-cost approaches. This tends to favour quick turnaround of analyses, which may be limited compared with fuller scheme assessments, using post-implementation evaluation processes with on-road data collection approaches.

Key economic assessment considerations

The economic framework for operations activities has been developed to be flexible and practical in its application. The procedures are adaptable to both pre-implementation approaches, including the application of transport models, and post-implementation approaches utilising on-road traffic data collection methods. Consideration of on-road data techniques and transport modelling approaches plays an important part in the assessment of the economics of operations activities. Considerations relating to these aspects have been documented within the main body of the research report (specifically chapter 1) and referenced within the framework.

Aside from the decisions around using a pre-implementation (eg modelling) or post-implementation (before and after measured data), there are three key considerations relating to the economic appraisal of operations activities:

- The definition of the 'do minimum' scenario: This is often as straightforward as reflecting a 'do nothing' situation. However it may involve careful consideration of the scenario without the intervention (eg when incident management or traveller information systems are implemented and in assessing optimisation strategies) and the specification of a 'base level' of operational upkeep.
- The lifespan of the activity: The length of the activity lifespan needs to consider the type of activity and typically the lifespan and evaluation period will be significantly shorter than the standard economic scheme appraisal length (eg for traffic management activities, incidents and planned events if the lifespan is the length of the event). For optimisation this may be the length of time over which it is anticipated that activity will continue to deliver benefits. For traveller information this requires case-by-case consideration.
- Fully assessing the costs of the operations scheme: Including both external costs (consultancy contracts, equipment etc) and allowance for the operating agencies' internal resources (staff time, running costs, software etc).

Conclusions and recommendations

The background research investigation reached a number of conclusions which form the basis of the development of the economic assessment framework. The key conclusions from this project were:

- Key outcomes established through this project form principles which underpin the transport economic value of day-to-day TOC and journey manager work.
- This research project and economic framework provides a practical tool for business case assessments where solutions may, and should often, consider operations treatments to extend the lifespan of existing infrastructure and potentially delay more costly capital expenditure.
- The economic framework for evaluating the benefits of operations activities is practical, flexible and not onerous to apply and therefore fits with the agile TOC approach.
- The operations economic framework fits within the overall NZ Transport Agency assessment framework, and notably can be included within business case assessments.
- A key consideration in assessing the benefits of operations is the assessment approach adopted, notably whether pre-implementation appraisal or post-implementation evaluation is carried out. The framework is applicable to both approaches.
- Social CBA is an appropriate framework for assessing the economic benefits of operations activities, with the main ranking criterion being the BCR.
- The economic impacts that are relevant to operations are all covered by the EEM.
- It is appropriate to adopt the EEM procedures and parameters for the economic evaluation of operations activities (unless there are good reasons to the contrary in any particular case).

An economic evaluation framework was developed and applied to three case studies. The case studies tested the practical application of the framework, sensitivities, and formed the material for completing the research report. The development and application of the framework to the case studies identified the following key outcomes from the research project:

- Definition of the do minimum and development of option costs are key components of economic assessment of operations.
- Considering and evaluating the lifespan of the activity is often a critical aspect of an operations economic assessment.
- Before and after data measurement can be an effective technique for measuring the benefits of operations activities. This needs to be balanced against the risk of this approach and the robustness of measurements from the data collection system.
- Microsimulation transport modelling is an effective mechanism for evaluating the economic benefits of the majority of operations activities, either alongside on-street data measurement or as a stand-alone approach. This needs to consider the added-value and potential risk reduction of this approach.
- It is relatively straightforward to include operations activities within the suite of potential solutions to identify problems and to assess the economic returns of these options within NZ Transport Agency policy and economic evaluation frameworks.
- Generally operations activities are highly cost-effective transport treatments.

The research project identified the following recommendations for further investigation and research (further details are provided in section 8.3):

- Consideration and exploration into the optimal funding strategy for generalised operations activities, systems and tools relative to small-scale capital works (eg minor efficiency projects).
- Further research into the suitability of alternative transport modelling approaches to measuring economic benefits of operations against real-world measurements (refer section 4.2.2 and appendix C).
- Further research into the suitability of on-street data collection systems for establishing robust travel time measurements (refer case study 1, section 6.2.3 and appendix B).
- Review of areas of the New Zealand network where incident management systems may offer benefits to travellers (refer case study 1, section 6.2.5).
- Wider application of economic assessment of (generalised) TOC activities may identify efficiencies and wider economic gains. Potentially more generic ‘strategies’ could be developed and applied across wider areas based on case studies of highly cost-effective activities.
- Testing the economic framework against pedestrian and public transport (PT) operations projects. PT or pedestrian case study examples were not identified by the research Steering Group or TOC staff, but can easily be assessed from application of the framework using the appropriate pedestrian/PT economic parameters.
- Risk assessment of modelling compared with before/after on-street data measurement approaches.

Abstract

The benefits and processes for evaluating economic outcomes of ‘standard’ transport interventions are well recognised – infrastructure improvements, intersection treatments, public transport schemes, safety improvements etc.

Operations activities such as network optimisation, ITS system operation, traffic management, events, traveller information, ‘soft’ measures etc, are generally accepted to be beneficial. Compared with other interventions, these activities generally require significantly lower investment and therefore industry practices and views are that any benefits are likely to return high value-for-money outcomes.

Historically there has been limited requirement in New Zealand to carry out in-depth economic assessments of operations activities. The methodologies and approaches for carrying out benefit appraisal of operations activities are not well established.

In line with the NZ Transport Agency better business case approach, operations activities need to be considered as part of the potential lifecycle of transport solutions and evaluated alongside, or as part of, the main investment solution options. Parties involved in the implementation of operations, such as the transport operations centres, also have a need to consider the economic impacts, benefits and balances as part of their day-to-day tasks and processes.

The key purpose of this research was to identify economic approaches, evaluation methodologies, comparison with ‘standard’ interventions, and develop a feasible framework for the economic assessment of these activities.

1 Introduction

1.1 Economic evaluation of transport activities

Practices for assessing the economic benefits of transport interventions have been established over the last 50+ years. This is particularly true for infrastructure projects, such as road widening, public transport (PT) schemes and safety improvements. In the current transport planning environment, these practices have also been applied relatively widely to investigate returns on the installation and year-on-year existence of ‘soft’ transport management and operations systems, ie intelligent transport systems (ITS). Internationally a reasonable amount of literature exists and a number of economic studies have been undertaken in this area examining the benefits of ITS, for example, the benefits of installing and operating a managed motorway system along a motorway corridor. An assessment of this kind takes the form of a comparison of a ‘do minimum’ (without the ITS scheme or with a lower level of ITS infrastructure/ management) compared with a ‘do something’ (with the fuller ITS scheme).

The focus of this research was economic consideration of operations activities, separate to the core assessments of ‘standard’ transport interventions as described above. In the searches completed and in the authors’ experience, little literature is available documenting economic considerations of the ‘operational’ activity itself and carrying this out in practice does not appear to be widespread. In the ITS example noted above, evaluating the benefits of the ‘operation’ of the system would focus on the day-to-day management, monitoring, and optimisation of the ITS managed motorway system. In this situation, it is difficult to clearly identify a ‘do minimum’ and ‘scheme’ so as to measure economic returns. A generalised view within the industry is that these operations activities have a relatively low cost (potentially operator staffing, software and hardware updates and minor running costs) compared with ‘standard’ transport intervention scheme costs. The general understanding follows that the benefit to the transport system from the operational upkeep is sufficient to significantly outweigh the low cost input. For example, VicRoads (2014) notes:

> *VicRoads documentation shows that international transport research studies confirm that traffic signal timing modifications arising from traffic signal reviews are estimated to have a benefit-cost ratio of up to 21:1. Despite this, VicRoads does not conduct such cost-benefit analysis as a matter of course and has not calculated the economic costs and benefits of its route review program.*

In other recent example, the United States Department of Transport (USDOT) published a review of a number of cost-benefit studies carried out in America annually of ITS installations and pilot studies. Some selected findings highlighted by ITS International (2015) note benefits of traffic signal retiming and synchronization projects with benefit-cost ratios (BCR) in the order of 50 – 60:1, and as high as 175:1.

Because of this tendency for the benefits of operations activities to be large relative to their costs, or the belief that this is the case, to date it appears little effort has been placed in measuring these benefits and as a result there is limited literature and background information around these considerations worldwide. This point applies more directly to the activities carried out by the transport operations centres (TOCs) in isolation. Operations or optimisation associated with a new investment project should generally be evaluated within the benefit stream of the main investment, but assessment of this aspect has also historically been weak. This issue is effectively the ‘gap’ in understanding and the style of assessment that this research focused on.

1.2 Overarching system framework

1.2.1 Transport outcomes

The NZ Transport Agency's (the Transport Agency's) (2014a) *Statement of intent* (SoI) sets out an approach and course of action that will contribute to the delivery of transport objectives and wider transport vision. The desired outcomes from the New Zealand transport sector are listed as:

- Effective: moves people and freight where they need to go in a timely manner
- Efficient: delivers the right infrastructure and services to the right level at the best cost
- Safe and responsible: reduces the harm from transport
- Resilient: meets the future needs and endures shock.

The state highway network contributes to the desired goals and outcomes outlined in the SoI, and the draft *State highway activity management plan 2015–2018* (SHAMP) (NZ Transport Agency 2014a) provides more focus and refinement around operations activities. The plan classifies operations activities into the following areas:

- Manage: operating one reliable network across all transport modes
- Inform: providing accurate and timely transport information.
- Optimise: optimising the efficiency and effectiveness of the network
- Monitor: monitoring real-time network performance.

These four areas effectively classify the type and style of projects which fit within the operations activity umbrella and form the context of this research project.

1.2.2 Performance measures

The outcomes noted above are generally defined against performance measures which in turn include economic evaluation components. The SoI includes notes on a number of performance measures which are relevant to this research. Examples include speed/flow/capacity measures, crash and injury reductions, 'standard' measures of reliability, efficiency and environmental impacts. Some specific performance measures which are common across the New Zealand regional TOCs can be categorised as follows:

- Customer focus: complaints, journey reliability, customer satisfaction measures
- One network: journey time reliability (similar to above)
- Safety: death and serious injury crashes, response time to reduce safety risk, secondary incident reductions
- Operational excellence: network availability for all modes, productivity
- Value for money: cost of an event and event planning/mitigation, operational costs of TOCs
- Network optimisation: network utilisation, number of people on the network, utilisation by mode, journey time reliability
- External collaboration: response and recovery times to unplanned events (from the start until return to normal flow).

Section 1.3 discusses the possible benefits (performance measures with economic evaluation components) that may be identified from each TOC team area.

1.2.3 Evaluation framework and business case approach

The Transport Agency currently uses a business case approach to guide the planning, investment and project development processes. This approach links the transport strategy to outcomes and defines problems and their consequences before identifying solutions.

An economic evaluation to establish the economic efficiency of an activity (following the *Economic evaluation manual* (EEM) procedures), typically assessed by the BCR, is a core factor in Transport Agency funding allocation process and a critical component of the business case approach. An 'economic framework' for operations activities will fit within the EEM procedures and therefore align with this economic efficiency component of a business case assessment.

1.3 Operation benefits

Measuring the benefits of the operations activities (described in more detail in chapter 2) can be focused into three areas which form teams as per the structure of some regional TOCs:

- Real-time operations: Operation and optimisation of ITS, notably the Sydney Coordinated Adaptive Traffic System (SCATS) traffic signal system and ramp signalling systems. Includes all modes, tends to focus on private and freight vehicle traffic movement but also includes PT priority, optimisation and pre-emption, signalised and general pedestrian and cycle infrastructure etc.
- Traveller information: Informing and influencing travel behaviour across all travel modes.
- Traffic management: Management of the network impacts of TM activities balanced against safety and efficiency (the cost of works delivery to the road controlling authority (RCA)).

These areas effectively form the scope and direction of this research project, with a focus on the whole urban network and flexibility to apply the principles to rural locations.

A fourth area noted in the SHAMP, network monitoring and collection of network intelligence, is covered by each of the three teams to varying degrees, eg the real-time operations team monitors the network in real time and collects data on the daily ITS operation, the traveller information team collects and makes use of network intelligence data, and the traffic management team monitors traffic management activity on the network and makes use of network intelligence data in the assessment of traffic management impacts.

The initial phase of the research project covers following stages:

- Outline clearly the scope of the research, ie classify and identify operations activities.
- Carry out a literature review of economic evaluation processes of operations activities.
- Identify key considerations in the methodologies and techniques for measuring benefits of operations.
- Summarise and draw conclusions on appropriate economic procedures for operations.
- Provide a recommendation on the approach to develop an economic framework for operations activities

The second phase of the research includes the development of a framework for the economic evaluation of operations activities based on the findings from the initial phase and application of the framework to case studies.

1.4 Report structure

Chapter 2 of this report identifies the scope of the research project. Its focus is to identify what are considered operations activities in the context of this research project.

Chapter 3 summarises the literature review carried out, which focussed on the approaches and application of economic evaluation processes in assessing the economic benefits of operations projects.

Chapter 4 discusses pre-implementation appraisal and post-implementation evaluation methodologies in the context of operations activities.

Chapter 5 presents the framework for assessing the economic benefits of operations activities.

Chapter 6 summarises the application of the framework to the three case studies.

Chapter 7 presents a summary of the conclusions and key findings and recommendations for further investigation and consideration.

Chapter 8 contains a bibliography listing documents consulted in the course of the research.

Various appendices (as listed on the contents page) include further information and detail on the literature review, information on data collection systems and methods, and further technical detail and examples, including the application of transport models.

2 Scope of research

2.1 Knowledge gap and key issue

As described in section 1.1, economic evaluation techniques for 'standard' transport interventions are well established and understood. Knowledge and understanding around the measurement of benefits of operations activities is less established, in the light of the common view that that these activities offer very high value-for-money return. This is largely generated from assessment of ITS installations and optimisation projects.

This points to the need to clearly identify for this project what are considered operations activities, what is within the scope of the research and what is outside of the scope of this project. Two general alternatives can be identified:

- TOC activities, eg in the example described in section 1.1 of evaluating the benefits of 'with' and 'without' an ITS managed motorway scheme, this would not be considered a TOC operations activity. The TOC operational aspect of the managed motorway scheme would include the shorter-term maintenance, operation and optimisation of the ITS system.
- Operations associated with new investment options, eg in the same managed motorway example, if the installation of the ITS scheme was being considered as a separate new scheme, it would be evaluated using some of the specific operations principles and procedures identified in this research, but generally evaluated following standard New Zealand scheme evaluation processes. It may also be considered as being an aspect of a larger project (ie if the managed motorway scheme was included as part of a new motorway project), and the same principles apply.

Describing operations activities and further clarifying the scope of this research is expanded below.

2.2 Network application and coverage

Considering the activities carried out by the various regional TOCs is a clear way to identify the scope and focus of this research project, as described further below. The TOCs are generally partnerships between the various regional RCAs and transport operators (eg PT operators). Their activities cover the complete regional transport network and therefore this research has a similar wide-ranging scope, ie it is not limited to state highways, to particular routes or road hierarchy elements, and covers a range of transport system user modes where applicable.

2.3 Description of New Zealand operations activities

2.3.1 Overview

The definition of network operations provided by the Transport Agency to seed this research is as follows:

> *Network operations in this context refers to the day to day operational activities managed by the traffic operations centres and network maintenance contractors, and the 'soft'*

engineering solutions to manage, monitor, and optimise the road asset, and inform customers[1].

The above statement excludes maintenance of the road network and the draft SHAMP provides more refinement around this. It identifies the four main areas of operations activities as:

- network monitoring: collection of network intelligence
- traveller information: communication of network intelligence
- management of events: control and response to events on the network
- network optimisation: maximising the value of the state highways and our services to customers.

These four areas define the core scope of this research project. Further information is provided below.

2.3.2 Transport operations centres

The various regional TOCs, Christchurch, Wellington, Tauranga and Auckland, currently manage all of the components described above to some degree (the structures and organisation of the geographic TOCs varies slightly). The TOCs are generally structured into three teams:

- Real-time operations monitor the network and are responsible for the management and optimisation of ITS systems.
- Traveller information provides information and communications to the wider public and stakeholders.
- Traffic management supervises, manages and approves traffic management activities on the network.

Each of the TOC teams' practices to some degree covers the four main operations activities areas as identified in the draft SHAMP. Table 2.1 provides an indication of how these practices correspond and their crossover with the operations activities areas.

Table 2.1 Mapping of TOC team practices to SHAMP areas of operations activities

TOC team	Network monitoring	Traveller information	Management of events	Network optimisation
Real-time operations	Monitor network performance in real time (eg through ITS such as signal control systems, vehicle/traveller detection)	Provide information to the traveller information team on current network performance	Work with traffic management team on systems and prioritisations for planned and unplanned events	Carry out optimisation of systems
Traveller information	Provide travellers with information on current network conditions (eg through variable message signs (VMS), web, apps, media)	Provide travellers with current, historical, and future travel information	Provide communications to the travellers around events	(currently no significant actions, but could expand in the future to advise on optimising travel)
Traffic management	Consider current and recurrent network conditions in appraisal of planned traffic management impacts	Provide traveller information team with information on planned events	Balance impacts of roadworks against delivery efficiency and safety considerations, consider 'whole of network' influence	(as per management of events)

[1] The NZ Transport Agency subsequently clarified that maintenance of the roading system infrastructure was outside the scope of this project.

2.3.3 Project types

It is important that this research has a realistic practical application. One requirement is that applying the framework to evaluate the benefits of operations activities is not so onerous as to significantly outweigh the resources involved in carrying out the operations activity itself. For example, if a straightforward optimisation activity requires 20 hours of staff time to implement and has some degree of clear well-established benefits without any significant trade-offs to other transport system users, it would be unreasonable to expect an economic evaluation to be carried out taking 80 hours of staff time simply to quantify the potential magnitude of benefits.

The following list of the more common 'project' types that each of the TOC teams carry out as part of the day-to-day practices has been developed to provide some reference to practical activities for this research.

2.3.3.1 Real- time operations

- ITS optimisation projects, eg SCATS signal optimisation, ramp signalling system operation
- incident management, eg alteration to ITS systems to prioritise routes
- ITS network operation and management systems, eg speed management, automated safe systems
- ITS network enforcement and management tools, eg weigh in motion, tolling
- linkage to the traveller information team to provide travel information about typical and real-time network conditions
- network measurement and system equipment servicing, upgrades, installation of new systems etc.

2.3.3.2 Traffic management

- Evaluate and manage planned events on an individual project basis – balancing traffic impacts, safety, and project delivery efficiency, eg from roadworks, public events, and other activities with traffic management requirements.
- Evaluate, plan and manage overall network operation across all planned projects – balancing impact, safety and delivery efficiency.

2.3.3.3 Traveller information and journey management

- Provide on-line, app-based and roadside notification traveller information, eg website mapping, travel time information, warnings, network status information and updates.
- Prepare communications and strategies for planned and unplanned events.
- Prepare press releases and public notices.

2.4 Carrying out assessments

Generally the day-to-day tasks involved in the above operations activities require relatively modest resource; little significant capital expenditure and relatively short periods of staff time (hours/days rather than weeks/months). Other aspects (not day-to-day) of TOC activities do involve more significant assets and potentially require greater consideration, eg refurbishment of region-wide ITS systems.

Developing a practical assessment framework will need to consider the balance between the resource requirements of carrying out the operations activity against the resource requirements of applying the framework to estimate the benefits of the activity. For example, it is unlikely to be desirable for operations staff to spend a substantial proportion of time carrying out evaluations of their activities as this would impact on their time available to carry out the operations activities themselves and the overall effectiveness of these activities. Consultants may be used to carry out this work which could alleviate this issue, however this should be balanced against the cost of carrying out the activity (and the potential benefits it could produce), any delays and restricted effectiveness of the activity, and the consultants' level of experience and knowledge of the activity.

However, this is not a definitive statement. It may be the case that the comparative magnitude and potential range of benefits of differing operations activities is not well established. Although this may be a resource-intensive undertaking, a reasonably comprehensive and robust evaluation of benefits may enable the relative returns from investment in different activity areas to be identified. Increasing or rebalancing investment across activity areas may in turn lead to greater transport system benefits (and in turn, a benefit of carrying out the evaluation process itself). An evaluation of this nature could consider the whole mix of activities and the effects across the wider transport network. A process such as this may be undertaken as periodic 'strategic review' across operations activities, eg annually or similar, rather than undertaking comprehensive evaluation for all individual projects.

2.5 Summary, practicality and flexibility

In summary, the activities carried out by the TOCs provide a clear indication of the scope of operations activities and the focus of this research project is around this work area. The goal of the research was to develop a framework for the assessment of the benefits of these activities which can be applied flexibly across the core operations activities. This extends to activities outside of the TOC remits, which could include:

- assessment of operational components, eg IT and ITS measures, on new infrastructure projects
- operations activities carried out by other network contractors
- operations activities in rural locations (although the focus is mainly on urban areas).

As noted in the section above, there are benefits and disbenefits in any requirement to evaluate the benefit of operations activities; a key benefit is the possibility of identifying the most beneficial activities and rebalancing resource to achieve greater value for money, and a key disbenefit is the potential lost time spent carrying out the operations activity itself. Coming out of these considerations is the overriding need to develop a flexible framework, so that it can be applied:

- in a straightforward manner with low resource implications in order to evaluate the benefits of a task
- as a more comprehensive assessment across activity areas
- using a range of assessment approaches (on-road data, a desktop approach, and/or transport models).

3 Literature review

3.1 Background

The material reviewed through this project has been diverse, from high-level information on Transport Agency policy and strategy, detailed information on the development of TOC key performance indicators and specific New Zealand TOC operations projects and examples, through to international transport operations examples and literature. The specific literature review process summarised in this chapter focuses on the findings from our review of international literature and practice on assessment of 'network operations' type projects and extracts the pertinent points from previously completed and relevant Transport Agency research. The focus of the review is on the assessment methods, principles and techniques commonly used in establishing the benefits of 'operations activities'.

The objectives and scope for the literature review follow directly from the overall purpose of the project, as set out in the project request for proposals, ie:

- 'What international approaches exist to understand and estimate the benefits of investment in day-to-day operational activities . . . and how can these be applied in New Zealand?'

Within this overall purpose, based on preliminary review and discussions, we identified the following more specific aspects for investigation in the literature review:

- Assessment approaches adopted internationally to assess operations activities – including the use of cost-benefit analysis (CBA), multi-criteria analysis, cost-effectiveness analysis and other alternatives.
- Relative emphasis on pre-implementation and post-implementation assessments.
- Types of operational schemes amenable to economic assessment, and issues in the specification of the 'base case' and 'option case' for such schemes.
- Principal benefit components for typical operations schemes and the basis for their estimation.
- Types of data sources for input to economic assessments, including the roles for model-based approaches.
- Issues in cost estimation for operations-type schemes.

The outcomes and findings from this review have been used (in the remainder of this report) to inform and develop a general New Zealand approach to evaluating the benefits of operations activities.

3.2 Relevant New Zealand research

3.2.1 Research projects reviewed

Four previous Transport Agency research reports (undertaken over the last 15 years), which appeared to have some relevance to this project, were identified and reviewed. These were:

- Raine et al (2014) Literature review of the costs and benefits of traveller information projects. RR 548.
- Chang et al (2013) Customers' requirements of multimodal travel information systems. RR 540.
- James, R (2006) Intelligent transport systems: What contributes best to the NZTS objectives? RR 302.
- Dalziell et al (1999) Risk assessment methods in road network evaluation. RR 148.

Our review provides an overview of each of these research reports and gives specific comments on aspects most relevant to this project. The full review is given in appendix A, section A2.

We also note a further Transport Agency research report, which has recently been published: Tomecki et al (2016) 'Considering a cost-benefit analysis framework for intelligent transport systems' RR 584. This project focuses on evaluation methods, principally CBA, for ITS projects. We have discussed the two strands of research with the research owner for this project and note that although they are complementary, there is no anticipated direct implication of each project on the other. We understand the ITS project is focused on identifying actual or potential benefits of various ITS schemes and the very detailed economic considerations such as the value of time, whereas this project is focused on a higher level more generic framework approach.

3.2.2 Key outcomes and considerations

We found the extent of information in these previous New Zealand research reports directly relevant and helpful for our current project was quite limited.

Probably the most useful previous material is that given in James (2006). This provides information on the benefits and costs of ITS-based projects implemented internationally, arranged under a detailed set of project categories. However, we note that this report is now nine years old and that: (i) technologies and costs for ITS applications will have changed substantially since then; and (ii) methods for estimation of benefits will also have improved, to a large extent related to recent technology developments.

3.3 International literature review – overview of scope

3.3.1 Scope of review task

The international review focused on assessments of 24 'network operations' and related scheme types undertaken and reported internationally over recent years. A summary of each scheme and its evaluation is given in tabular form in appendix A, table A.1. For each scheme examined, this appendix provides information in summary form on the following aspects:

- scheme category
- reference title and date
- scheme title, responsible agency and state/country
- benefit framework used in assessment
- BCR estimate (where available)
- benefit components included
- evaluation results by benefit and cost components
- notes on evaluation data sources and methods
- basis for definition of 'base case'
- basis for cost estimates

3.3.2 Scheme categories

The schemes reviewed were divided into four main categories (as used elsewhere, such as within the Transport Agency (2014b) SHAMP) with the following number of examples in each category:

- network monitoring 1
- real-time operations 15
- travel information 4
- temporary traffic management 4.

3.3.3 Countries covered

The schemes reviewed are mostly in developed countries, with half of them (12) being in the USA. Other countries represented are Australia (2), various EU/EC countries (UK 3, Finland 1, Netherlands 1, Germany 1, Spain 1, EC joint 1), Colombia 1 and Qatar 1.

3.4 International review – assessment

3.4.1 Assessment approaches

The approach used in about half the schemes is (social) CBA, with the discounted benefits and discounted costs providing the BCR. Further information on the formulation and application of the BCR is given throughout this chapter.

In some other cases, where the costs (or cost differences between base case and option case) are relatively insignificant, the emphasis has been on estimating net annual benefits.

In other cases, where the benefit differences between the base case and option case are insignificant (eg where the project is concerned with alternative ways to provide a given level of service), the emphasis has been on minimising the (public sector) costs involved (ie a financial analysis). Examples encountered include methods to minimise the costs associated with temporary road works on existing routes and methods to minimise the costs of operating and maintaining traffic signals.

None of the schemes reviewed appear to use multi-criteria analysis[2] in any formal sense, although it is possible such multi-criteria analysis trade-offs have been made at the political level in taking decisions on preferred schemes. Appendix A1 notes the evaluation approach adopted for each international example.

3.4.2 Assessment parameters

Most of the literature reviewed has not been explicit on the discount rate used in either social CBA or financial analyses (the authors note that this information may be available from detailed scheme evaluation reports if required).

The length of the evaluation period is discussed for some schemes. The general approach is to use an evaluation period corresponding to the expected (economic) life of the main assets involved. For example, for signal retiming schemes, normal practice in the USA is to adopt a life of three years, on the basis that

[2] Multi-criteria analysis is a system of evaluation where options are given a score on each of multiple criteria, and then weightings are applied to each criterion to derive the weighted sums of scores for each option: the 'preferred' option is then the one that has the best score. Typically, the weightings selected are politically driven rather than having a firm foundation in economics.

signal re-timings should generally be reviewed after such a period. Details of practice adopted for each scheme reviewed are given in appendix A1.

For the evaluation of transport schemes in general, in order to select the preferred option we would expect several options to be considered and evaluated in comparative terms for each scheme. For most of the schemes examined, the articles reviewed make little or no reference to alternative options (apart from the preferred option and the base case). We would expect that more than one option would warrant serious consideration for at least some of the schemes and some forms of operation activities. However this situation may well be typical of the developing area of operations activities. Reasons for not assessing alternative options could include:

- An operations system is implemented and it is believed that estimation of benefits can only be carried out post-implementation, or thought is only given to this sometime after installation.
- There are very few (if any) realistic alternative options. For example, potentially there is no reasonable alternative to carrying out regular optimisation processes/programme of network signal management systems such as SCATS and changing from SCATS to an alternative system such as split cycle offset optimisation technique (SCOOT) would be extremely unlikely. However, where there are potential alternatives (eg alternative optimisation approaches or signal management strategies) these should be evaluated.
- Some operations activities are effectively so 'new' and different to traditional transport engineering (eg the provision of traveller information systems) that there is no comparable technique to achieve similar outcomes. Therefore the question is more about financial viability (is it worth it) rather than economic evaluation of options.

Traffic management is an exception to the generalised points above. In many cases it should be straightforward to consider alternative traffic management schemes and carry out an evaluation of these options.

3.4.3 Pre- and post-implementation assessment

Of the 24 schemes reviewed, the evaluations for 21 of them were undertaken after the scheme was implemented in the transport system. They were based on data collected both before and after scheme implementation, and estimated the benefit and cost differences between the 'before' situation and the 'after' situation.

For the other three schemes, pre-implementation forecast assessments (appraisals) were undertaken. All three schemes related to optimisation of traffic signal timings at intersections on arterial routes. In each case a transport model was developed and calibrated for the intersections concerned based on the current methodologies used for signal settings. Then these methodologies were varied (to use more adaptive algorithms) and the model re-run to estimate the resulting travel times.

In New Zealand, as in many other countries, for larger (and more costly) infrastructure projects, most assessment effort is incurred in appraisal at the pre-implementation stage (this is the focus of the EEM procedures). Often there is no or minimal post-implementation evaluation. This is typically not the case for 'operations activities' – these are typically cheaper than infrastructure projects and may be regarded as 'no brainers'. There may also be no realistic alternatives or a desire not to be confronted with objective analysis, and there may be perceptions that pre-implementation appraisal is difficult for certain schemes. The result of these considerations is that the primary focus for operations activities internationally is on post-evaluation (as indicated by the numbers above).

3.4.4 Types of data sources

For the 21 schemes subject to post-implementation evaluation, travel times were measured for both the 'before' and 'after' situations, and the differences translated into economic benefit terms (using standard values of time). Somewhat surprisingly to the researchers, there was only limited description in the literature reviewed on the techniques used to measure the 'before' and 'after' situation outcomes (eg data systems and collection techniques, any use of models) – further information may be contained in more detailed project reports and appendices.

In addition to time savings, other benefit components assessed were vehicle operating cost (principally fuel) savings, crash savings, local emission/health benefits and global emission benefits. Generally (in the material reviewed), the detailed methodologies for estimating these various savings were not set out. The researchers assume they generally used standard relationships between vehicle time savings (and numbers of stops made) and fuel consumption, crash costs, CO_2 emissions, etc. Some relationships of these types are given in the EEM. It was notable that very few assessments included estimation of any travel time reliability benefits (refer section 3.5.3 following).

In most cases, evaluations undertaken were confined to changes in peak period traffic conditions. In the USA cases, the 'peak periods' usually comprised the AM and PM commuter peaks plus a lunchtime peak; in other countries, the 'peak periods' were usually confined to the two commuter peaks.

3.4.5 Issues in defining the base case

For the three pre-implementation appraisals of traffic signal settings, the prime data source was the signal-setting model (SCOOT, SCATS, VA etc), which was calibrated to the 'before' signal settings at some or all of the intersections being studied. All of these projects used micro-simulation traffic models.

For the pre-implementation appraisals, in all cases the base case for assessment was the situation of the transport system immediately before the scheme implementation. This was then compared with the situation after implementation, to derive costs and benefits. Typically the base/before situation was measured in the 12 months immediately before scheme implementation, while the after situation was measured between a few months and a few years after implementation.

For the three schemes involving pre-implementation modelling of alternative algorithms for traffic signal settings, the current signal settings may not reflect any available algorithms. In such a situation, one useful approach in defining the base case is that used in the SCATS evaluation (refer table A.1, scheme 14). This scheme assessed the benefits of the SCATS 'Masterlink' (fully adaptive) system over a less sophisticated semi-fixed time system, which was represented by the SCATS 'Fallback' system. Modelling of the two SCATS alternative systems was undertaken, with the difference in travel times etc being taken to reflect the benefits of the fully adaptive system.

3.4.6 Cost estimation issues

The principal measure used by the Transport Agency for assessing the economic merits of any transport scheme is the BCR from a national perspective. This is the ratio of the present value of national economic benefits to the present value of national economic costs. The costs represent any costs to the Transport Agency and approved organisations (and to any service provider, where relevant). The benefits represent any national economic benefits (which may be positive or negative) to transport system users and to other 'external' affected parties. The main points to note here are that costs, in the BCR denominator, are those costs incurred by government agencies; whereas benefits (positive or negative), in the BCR numerator, are those items affecting transport system users and external parties. These guidelines should be applied to network operations projects in just the same way as to roading construction projects. Further details are given in the EEM, chapter 2.

Defining the costs of the 24 schemes (ie the discounted cost differences between the base case and the option case) seemed to be reasonably straightforward in most cases, based on the papers reviewed. The main point the researchers noted was a tendency to under-estimate the true costs of schemes by agencies, typically including external costs directly related to the scheme (eg for a consultancy contract) but making no allowance for the (incremental) costs of their own resources (eg staff time, software and hardware maintenance and purchase, utility costs).

3.5 International evaluation results – summary and commentary

3.5.1 Overall economic performance

For those schemes for which BCR results are provided, in almost all cases the estimates are at least 4.0, with some more than 10.0. No attempt has been made (by the researchers) to verify the quality and realism of the results given, nor to 'standardise' them across all the schemes examined. The range of BCRs is provided in appendix A1.

3.5.2 Key benefit components

In almost all cases where a comprehensive benefit assessment has been undertaken, the following are the main components incorporated:

- travel time savings
- vehicle operating cost (fuel) savings
- crash savings (but not included in many cases)
- local emissions/health impacts (pm10, nox, hc)
- global emissions (GHG=CO2e).

In terms of the relative contribution of these components to overall benefits, the travel time savings component is dominant in almost all cases, accounting typically for 80%–90% of total net benefits. A related measure quoted in many evaluations is the change in the number of stops involved (at signalised intersections), which in turn impacts on other benefit components.

Typically vehicle operating cost (VOC) (principally fuel) savings is the second largest benefit component, accounting for in the order of 10%–20% of total benefits. There seems to be little recognition of VOC benefits apart from fuel savings.

In many cases, crash savings are mentioned, but appear not to have been quantified. Where they are specifically evaluated, they comprise up to 30% of total benefits.

Where local emissions have been assessed, the contribution of any changes to total benefits is usually small, less than 10% of total benefits.

Changes in global emissions (GHG) appear (surprisingly) not to be mentioned in most cases (particularly in the USA studies). Where global emissions impacts have been assessed, their contribution to total benefits appears to be no more than about 5%. It may be that in some cases GHG benefits have been included with the fuel cost savings, but there is no clear evidence of this.

The researchers have not attempted to examine the unit benefit parameters (eg unit values of time) used in estimating the various benefit components. This would be a much more detailed undertaking and of very limited value given that the EEM specifies the unit values to be used in New Zealand evaluations.

3.5.3 Travel time reliability and values of time

Relative to best practice, the researchers (and peer reviewers) are surprised to note very little mention and no estimates of any benefits associated with changes in the reliability (variability) of travel times. For many of the scheme types reviewed, involving reduction of peak period congestion, we would expect that a significant component of benefits would be related to improvements in reliability, associated with reduced levels of congestion. To the extent that these factors have been ignored, typically the benefits quoted will have been understated. We suggest this aspect ought to be given more serious consideration in the context of the economic evaluation of New Zealand network operations projects.

This aspect may again be related to the style of evaluations carried out around operations activities. Often there is limited or no requirement to assess alternative options and establish a preferred option and therefore any assessment may be focused on financial viability. If the activity is economically viable from a straight-forward travel time saving calculation, there may be no real benefit in carrying out a more thorough and comprehensive evaluation of other benefit component streams. Furthermore in some circumstances where the operations activity has very low costs, it may not be worthwhile to carry out comprehensive economic evaluations of such activities.

The researchers have seen no discussion, for any of the schemes reviewed, about how values of time might need to be varied in different circumstances. It is surmised that single ‘standard’ values have been used in all cases. This may be sufficient for most schemes (assuming the values applied are appropriate), but is potentially misleading for projects that involve differential pricing. For example, for the USA project involving conversion of a high-occupancy vehicle lane to a high-occupancy toll (HOT) lane, it would be expected that those motorists who switch to the HOT lane (with payment of a fee) would tend to have substantially higher values of time than those who remain in the ‘free’ lanes. This should be reflected in the economic evaluation of such schemes, but there is no sign this has been done. This is worth noting and may be worth revisiting for any New Zealand evaluations of projects involving differential pricing (eg toll roads, cordon pricing); however, it is not a key issue for the current research as such projects are not classified as operations activities.

3.5.4 General outcome and conclusion

The findings described in the section above support the use of ‘standard’ economic evaluation techniques for the evaluation of economic benefits of operations activities. This indicates that typical New Zealand transport economic principles and approaches involving application of the EEM can also be applied in evaluating the benefits of operations activities on the New Zealand transport network.

3.6 Summary of literature review findings and implications

The international literature review (and, to a lesser extent, the review of previous relevant New Zealand research) has proved useful in the development of our approach to the subsequent study tasks. The most relevant and useful findings from the literature review may be summarised as follows:

- Internationally (based on the available literature), economic assessment of operations activities is relatively common at the post-implementation (evaluation) stage, but relatively rare at the pre-implementation (appraisal) stage. This may be contrasted with the situation in New Zealand, and many other countries, for larger (more costly) infrastructure schemes. In New Zealand, pre-implementation appraisal is required for all such schemes, whereas post-implementation evaluation of such schemes is the exception rather than the norm.

- For the international assessment studies reviewed, the benefit categories covered (usually in post implementation evaluations) are essentially the same as the benefit categories covered in the EEM (for application in pre-implementation appraisals). Our conclusion from this is that the current EEM benefit categories and associated unit values will (generally) be appropriate for assessing operations activities (at either pre-implementation or post-implementation stages).
- The literature review confirms for us that the greatest area of difficulty in assessing operations activities is likely to be in quantifying impacts on traffic operational conditions (eg travel time and reliability changes) rather than in translating these impacts into economic terms. This aspect is discussed in later sections of this report.
- We note what appear to be two specific areas of deficiency in assessment scope and methodology from the international case studies examined:
  - In most cases, no estimates of travel time reliability changes have been made, although such changes are likely to be one of the major economic benefits of many operations-type schemes.
  - In no cases does it appear that differential values of time have been adopted for different market segments (even where these would clearly be appropriate, such as for HOT lane schemes).
- In terms of the life of schemes adopted for economic assessment purposes, we note that most of the international cases adopt economic lives tied to the effective scheme life (eg in the case of traffic signal settings, which are typically recalibrated every (say) three years, an economic life of three years is adopted for evaluation purposes). We recommend this approach should also be adopted for New Zealand evaluations.

4 Operations assessment approaches

4.1 Background

4.1.1 Assessment approaches

To establish the benefits of operations activities requires some form of assessment. A range of assessment approaches are possible, and these generally fit into two broad categories as described below. This chapter describes some of the key considerations in selecting these assessment categories for assessing the benefits of operations activities.

4.1.1.1 Pre- implementation appraisals

The evaluation of many transport interventions will involve a pre-implementation appraisal, ie an assessment prior to the implementation of the project. This will include analyses at certain stages of the assessment process, for example option comparisons, economic analysis at specific stages etc. Pre-implementation appraisals usually focus on quantification of the 'with' and 'without' the intervention scenarios and are likely to include transport modelling and/or desktop analysis.

The majority of transport interventions are assessed using a pre-implementation appraisal approach. The techniques and methodologies are well established and in New Zealand this style of economic assessment would follow the standard EEM procedures.

4.1.1.2 Post- implementation evaluations

A post-implementation evaluation assessment involves the collection and comparison of before and after on-road/real-world data measurements. This can include setting up a bespoke data collection exercise around the initiative and/or making use of existing collection systems.

4.1.2 Practical limitations

Currently in New Zealand, post-implementation reviews are carried out on a small selection of 'standard' transport schemes. The researchers understand that a key goal of this process is to review, update or refine the EEM procedures in order to inform and improve the pre-implementation appraisal process.

In specific relation to 'operation activities', generally the opposite of the above historical focus on pre-appraisal is true. There tends to be more of a focus on the use of observed real-world data following scheme implementation rather than transport modelling and desktop assessment in assessing the benefits of operations activities.

Ideally both approaches would be applied regularly to both operations activities and more standard transport scheme evaluations. This would have the benefit of informing and improving pre-implementation appraisal methods by checking against real-world outcomes, and providing realistic measures of success. However, rarely are both approaches undertaken either for operations or standard transport schemes. This is generally accepted within the transport industry to be due to practicality and feasibility issues such as:

- If a comprehensive pre-implementation assessment is carried out, there is little appetite to expend further resource in carrying out a post-implementation review (often on the belief the pre-implementation appraisal was robust and there may be political consequences of challenging this or finding it was not robust, or more simply wasted effort).

- If an activity is implemented on-road without a pre-implementation assessment (common of operations initiatives), this is on the understanding that the initiative is needed, relatively inexpensive and generally beneficial. Post-implementation evaluation can then be carried out to verify this, or estimate the magnitude of benefits.

It is not within the scope of this research project to challenge either of the above points, and the authors believe that these issues have some level of validity. Therefore the considerations presented in this chapter are based around evaluating the merits of each of the approaches for the particular situation[3], ie to considerations to select either a pre-implementation assessment approach (involving desktop analysis and/or modelling) or a post-implementation evaluation approach (involving on-road data).

The economic framework for estimating benefits of operations activities will be developed flexibility so that it can be applied using either observed before and after on-road data measurements or outputs from transport models, ie so that it can be applied to both pre-implementation appraisals and post-implementation evaluations.

4.2 Analysis methodologies

4.2.1 Approaches required

There are some important differences between pre-implementation and post-implementation evaluations. Of most note, pre-implementation appraisals generally involve using transport models to compare options and estimate the benefits of schemes and post-implementation evaluations almost exclusively use on-road measured data. For clarity:

- Transport modelling is commonly focused on pre-implementation assessments.
- Data analysis using before and after on-road surveyed measurements is the focus of post-implementation evaluation assessments.
- Desktop analysis could involve first-principles traffic flow analysis, application of typical values from comparative examples, could include on-road data, could utilise some level of model outputs, and therefore is a component of a pre-implementation and post-implementation evaluation exercise.

The key considerations of pre-implementation and post-implementation assessments revolve around *transport modelling* and (real-world measured) *data analysis*.

Appendix B, section B1 provides some background into the suitability and availability of on-road data measurement systems and of different types of traffic models. The section below provides some considerations of the balance between a data analysis approach and a transport modelling approach, based on the information in appendix B.

4.2.2 Model and measured-data suitability

4.2.2.1 Suitability of data types

There is the strong potential for existing data detection and collection systems, or simple employment of mobile systems, to provide a robust source of before and after data for use in economic evaluations. Data measurement systems and the analysis of the information from these systems have significant benefits

[3] We note that it is practical to carry out regular network-wide monitoring and assessment and appraise (pre) and monitor (post) success. The decisions and discussions presented in this section of this report relate more to the assessment of individual projects.

over-and-above the evaluation of individual operations projects, eg in developing understanding of the network performance and operation, real-time monitoring etc. These aspects are not included in this section; the focus is on the use of data systems for post-implementation evaluation of specific operation activities. Some broad requirements can be identified with respect to the main areas of operations activities (monitor, inform, manage, optimise) to assess the suitability of the various collection systems to provide data to evaluate the benefits of these activities.

- Benchmark the existing situation: Provide reliable measures of the existing system operation and performance. Likely to require storage of historical data to assess 'average' historical performance, trends and filter outlying data.
- Record the impact/change/effect of the activity: Provide an appropriate level of sensitivity and coverage of key data measurements. For example, if the activity is related to or targets 'peakiness' of travel demand then sampling or recording volume information in hourly or greater time intervals is unlikely to be sufficient.
- Robustly establish critical measures: (Potentially to be considered further during the development of the economic framework.) Core metrics include the volume of travellers affected and their change in travel time (reliability) and to a lesser extent travel distance.

The table below provides an indication of the likely suitability of the broad types of data collection systems and methods in evaluating the benefits of operations activities. Suitability has been broadly graded as below. For more information on the data collection systems used in New Zealand, see appendix B, section B1.

- generally Suitable
- Partially suitable
- generally Unsuitable

Table 4.1 Potential suitability of key data sources to evaluate operations benefits

	Benchmark existing situation	Record the impact of activity	Key measure: volume of travellers	Key measure: journey time (reliability)
'In situ' detection systems (Bluetooth, wifi etc)	S	S	P	S
GPS systems/GIS tracking data	S	P	U	S
Speed//performance estimate from loop systems coupled with volume estimate	S	S	S	P
(Bespoke) journey time collection coupled with volume collection	P	P	P	P
Travel pattern data	P	U	P	U

Table 4.1 indicates that the majority of data collection systems currently in use are likely to have some level of suitability for assessing the benefits of operations activities. In-situ fixed detection systems and speed/performance estimates from loop systems are particularly suitable.

Supplementing the data from one system with data from a different system is likely to be particularly effective. For example, detection system data supplemented with loop volume information would provide generally suitable data across all key requirements.

4.2.2.2 Data system coverage issues

An important caveat on the suitability of using before and after data measurement in evaluating the benefits of operations activities is the coverage of the data system in question. For example, the Christchurch Bluetooth system comprises detectors placed at locations throughout the transport network. Within the central business district (CBD) the detector spacing is relatively dense with detectors roughly 1km apart which provides journey time and volume sample data on the majority of key routes through, and in/out of the CBD. Within suburban areas, the detector spacing is more dispersed and the sampling of trips on links in these areas can be lower. Therefore outside the CBD the system is suitable only for evaluating activity and project impacts in areas or on links/routes which are covered by the system. In general, using this system data to measure impacts and outcomes also needs to consider any bias or issues in the limited sampling of trips, ie the effects of shorter or partial trips, crossing trips, the area of influence, or whether critical links are not covered.

4.2.2.3 Suitability of model types

Appendix B, section B2 provides a high level description of transport models and their general forms and functions. Not all transport model forms and types are suitable for evaluating the impact of operations activities. There are a number of reasons for this and several more notable points specifically related to operations activities include:

- Short term focus: Estimation of impacts for short-term 'shocks' to the system (planned and unplanned events) and of benefits from smaller-scale immediate changes (optimisation) as opposed to potential longer-term 'settling' of the network operation.
- Influence of traveller demand peaks: The influence on the operation of the network due to demand movement and peak period patterns is significant. Management of and influence on recurrent conditions (daily congestion) may be targeted at critical peaks in demand (15 minutes or less, or three to four hours or more) and may include relatively subtle effects (small volume of travellers at crucial times making certain travel movements).
- System-wide influences and knock-on effects: Improving flow in one area of a system may attract more demand to that area or have a greater adverse effect in downstream areas while restricting or metering flow in one area may be beneficial to the overall system.
- Representation and predictive assessment of network components: Suitable representation of the operation of key network features (lay-bys, on-street parking, ITS, merging/weaving etc), investigations into detailed system elements (optimising ramp metering parameters, alternative SCATS system operation etc) and confidence and clarity in predictive outcomes (driver and vehicle influences).
- All of the above components (and others) working together and influencing each other. An example of the scale of these effects is presented in appendix C

Operation activities can be focused on the operation of the network as a whole system, from significant areas/regions of the network through to key strategic corridors (eg in the case of optimisation activities). Similar to data suitability considerations, some broad requirements can be identified against the main areas of operations activities to assess the suitability of the various types of transport models to evaluate the benefits of these activities.

- Provide a suitable representation of the critical components of existing system: Key operational elements such as traffic peakiness, intersection and network elements operations, traveller behaviour (route choice, peak spreading etc), system interactions (queue block back, effects of adjacent features etc), system features (detectors, facilities, lane components).

- Predict the impact/change/effect of the activity: Provide a mechanism for predicting the effect of the activity to a suitable level of sensitivity.
- Robustly establish critical measures: Ability to establish system-wide effects robustly for the purposes of economic evaluation (assessed in the development of this framework, but likely to include traveller volume and journey time (reliability)).

The table below provides an indication of the likely suitability of the broad types of transport models used in New Zealand in evaluating the benefits of operations activities. Suitability has been broadly graded as:

- generally Suitable
- Partially suitable
- generally Unsuitable.

Table 4.2 Potential suitability of types of traffic models to evaluate operations economic benefits

	Represents components of existing system	Predict the impact of the activity	Key system measures
Intersection models (SIDRA)	P	P	U
Short corridor/small network models (LinSIG), TRANSYT)	P	P	U
Regional planning models (EMME, CUBE, TRACKS)	P	U	P
Deterministic network traffic assignment models (SATURN)	P	U	P
Stochastic network microsimulation-style models (AIMSUN, Paramics, VISSIM)	S	S	S

Unlike data systems where a weakness or lack of data in one system may be compensated for by using data from another system, this does not apply to transport models. Generally a lack of suitability in any of these key areas indicates an overall lack of appropriateness of this model type to assessing operations activities. For example, it would be inefficient and unlikely to be successful to use an isolated intersection or small network model to carry out an optimisation calculation, and then apply a regional planning model to attempt to measure the system wide outcome of this activity. From current working practice, there are two exceptions where operations evaluations can make effective use of several forms of models:

- A LinSIG/SIDRA model could be used to carry out an optimisation calculation for input to a more comprehensive microsimulation model assessment and evaluation.
- Regional models are regularly used to provide demand (travel patterns and forecasts) data for microsimulation models.

Microsimulation-style[4] models stand out as providing comprehensive suitability for carrying out evaluations of operations activities: short-term and immediate effects, traveller demand peaks, system-wide influences and knock-on effects, representation and predictive assessment of network components, and the connections and relationships between these elements. These models have been used

[4] 'Meso' transport models, eg AIMSUN's mesoscopic and hybrid methodologies, which include representation of individual vehicle trips through the network are included in models described as 'microsimulation-style stochastic network models'.

commercially for 15–20 years and for economic evaluations of more 'standard' interventions for 10–15 years. Costs are often cited as a downside to microsimulation modelling. However it should be recognised that the advantages listed here will clearly add to the cost of the assessment, ie that the added cost should be considered against the added value. For example, it is possible to develop and apply a microsimulation model of a single intersection in an identical fashion to SIDRA (flat hourly demands, coarse geometric representation, simple calibration/validation etc) and it would cost the same amount. This is rarely, if ever, done and the extra expense associated with microsimulation models relates to the additional work (eg error checking) and capabilities included in the assessment.

Appendix C provides an example of the suitability of microsimulation models for evaluating operations and the general lack of suitability of traditional 'strategic' models with an aggregate representation of traffic flow. An example is presented examining an incident in the northern area of Christchurch during the morning peak with an observed/measured economic impact of around $42,000. Microsimulation modelling was found to replicate the economic impact of the incident robustly, whereas strategic or traditional modelling techniques were found to underestimate the impacts consideration (factor 7–10 lower using SATURN and 2–4 lower using CUBE volume averaging assignment).

In summary, deterministic network or local models may offer some value to informing operations and the assessment of these activities. For robust and comprehensive *economic evaluation* of operations activities utilising transport modelling, microsimulation models are likely to be the most appropriate.

4.3 Selecting an assessment approach

4.3.1 Business case approach

The business case approach considers operations strategies as part of the possible suite or range of solutions following the identification of problems. It is likely that operations improvements would be considered in the context of the lifecycle of potential solution options, eg extending the lifespan of the existing or proposed infrastructure. Assessing operations activities within this context would require a pre-implementation appraisal approach. As noted, this assessment approach would be carried out using desktop analysis or transport modelling. Transport modelling is used often, and therefore the suitability of modelling approaches (as described in the section above) needs to be considered if evaluating operations activities within the scope of potential business case solutions.

4.3.2 TOC working practices

The agile work practices adopted by the agencies that carry out operations activities favour quick turn-around of analyses with a focus on immediate real-world changes and (perceived) low-cost assessment practices. This approach has a *tendency* to rely more on post-implementation evaluation techniques which would be carried out using before and after data system analyses.

4.3.3 Decision areas and key considerations

4.3.3.1 Key decision makers

The key decisions on when and how to carry out economic evaluations of operations activities relate mainly to the ongoing evaluation of activities by the agencies carrying out operations projects. Although there is a tendency to rely on data systems for post-implementation evaluations within the TOCs, this is not always practical or effective, and may be limiting the effectiveness of these activities.

The choice of approach, pre or post-implementation assessment, largely relates to the choice of using on-road data or transport modelling which is not necessarily straightforward. The following section provides some commentary on the advantages and disadvantages of each approach and some recommended strategies for selecting approaches in certain scenarios.

4.3.3.2 Modelling vs data

In discussions regarding transport models and alternative approaches a regular disadvantage noted against transport modelling, and microsimulation in particular, is resource (time and money). This is a simplistic view which does not account for a number of factors, for example the presence of existing models and the fact that transport models (particularly modern flexible network systems) can be used for many transport assessment purposes[5]. The following points should be recognised in relation to the costs of transport models;

- Development of (network-wide) modern flexible transport models is applicable across all forms of transport planning and assessment work: operations activity evaluations and optimisation, project evaluations, policy investigations, land-use planning and development impact assessment, future year planning and testing etc.
- Existing models can be sourced, referenced, maintained and applied to projects where they are available.
- The returns from investment in transport models can be significant: for example, the benefits realised from significant network-wide optimisation adjustments, targeted critical traveller information advice, and optimisation of traffic management programmes and activities will outweigh the costs in the development and maintenance of models with this capability.
- Risk to customer experience of 'getting it wrong' or not knowing the benefits of activities: implementing an activity where there is a risk of an adverse effect to customer experience has a number of risks, including agencies' reputations. In terms of economic risk, a study of incidents carried out by the researchers with assistance from Christchurch Traffic Operations Centre during peak periods in Christchurch demonstrates that the costs of these range from $10,000–$80,000 per day. Alleviating risks of this level via pre-implementation assessment could offer significant value for money. This process could also identify higher or lower benefit achieving activities, enabling even greater gains by rebalancing resource.

Cost is still a factor in a decision regarding an assessment approach. The above points are noted to register that cost is not necessarily an end-all or overriding disadvantage of transport models.

The table below notes a series of key considerations affecting the ability of the two approaches to carry-out an evaluation of operations benefits. Modelling (ie utilising a transport model to evaluate the 'with' and 'without' activity scenario) and data (ie using before and after observed on-road traffic data to evaluate the activity) have been ranked from one (low) to five (high):

- A high ranking indicates the approach covers this consideration well.
- A low ranking indicates the approach is weak in this area.

[5] The view of transport modelling as 'costly' may permeate in New Zealand due to the way in which non-regional models are funded (often project-by-project and discarded once a phase of a project assessment is complete), the lack of inter-agency shared knowledge on the existence/coverage/status of models, and the historical and current lowest-cost-is-best approach which produces models with a narrow focus, short lifespan, and lack of greater, wider and forward value-for-money return from extended applications.

- A ranking of 2.5 indicates the coverage of this area is largely unknown and requires case-by-case consideration. For example, coverage of an area by an existing data collection system is unknown and the availability of existing traffic models and this cost saving is an unknown.

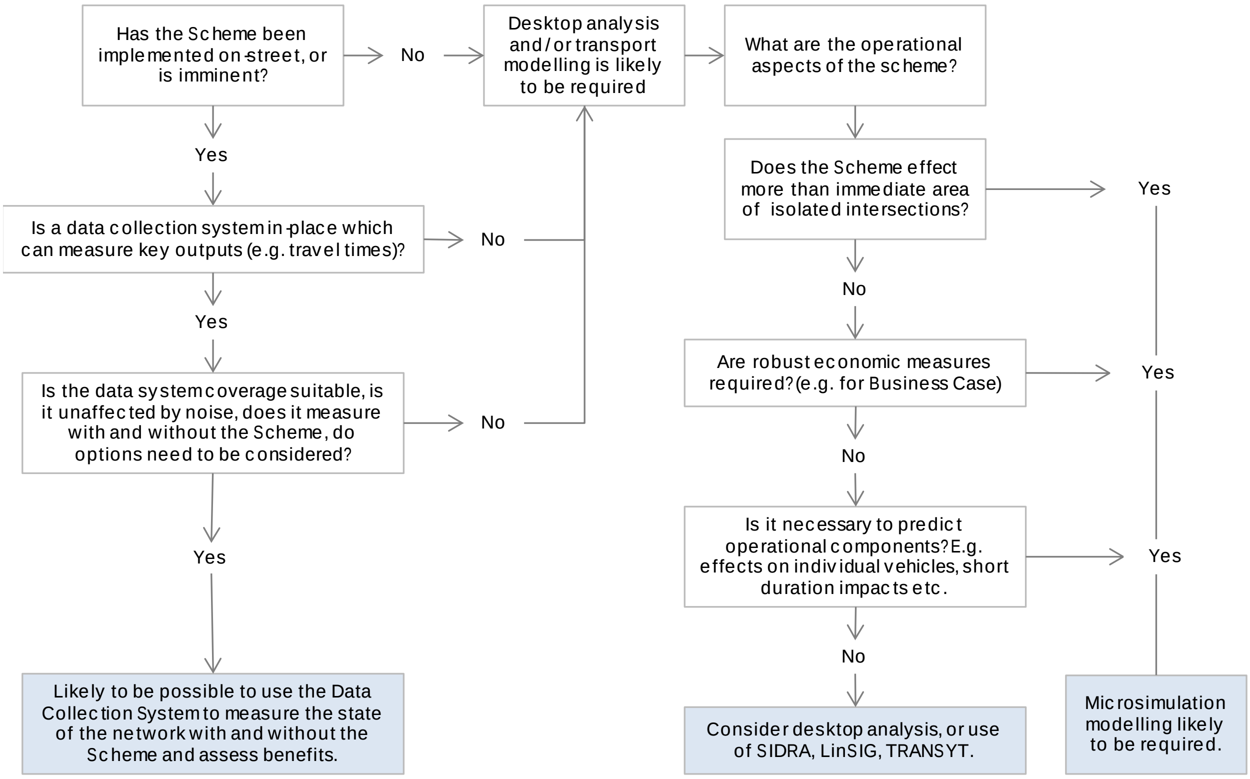
Table 4.3 Considerations of before/after data analysis approach and transport modelling approach

Consideration	Data	Modelling	Comment
Coverage of system	2.5	4	Appropriate representation of study area, time and key traveller movements
Level of assessment control and noise	1	5	Ability to control parameters, network changes influences, consider alternatives, radical approaches etc
Level of investigation	2	5	Ability to investigate and describe causality, scenario and sensitivity test etc
'With' and 'without' intervention	0	5	Ability to test the system explicitly with the intervention removed. Particularly relevant to incident management*
Measurement and outputs	3	5	Ability to provide a wide range of outputs and measures (economic, environmental, graphic etc)
Software and processes established and available	3	5	Software/analysis templates available with well-established processes for carrying out assessments
Expertise/resource availability	3	2	Necessarily skilled people available
Cost to run evaluation	5	2.5	What are the resource (time and money) implications?

In the above table considerations around the level of assessment control, level of investigation, and 'with' and 'without' intervention are related and similar to some extent. The ability to evaluate the system 'with' and 'without' the intervention is worth specific mention, particularly in relation to incident management*. Once an operational system (eg provision of traveller information, advisory messaging, ITS system management) is implemented to manage and optimise the transport system during an incident, the system is immediately altered from do nothing conditions (ie what would occur if the strategy was not implemented or if a historical approach was used). To measure the do nothing baseline system performance (eg journey times) from observed data, it may be possible to compare with historical 'non-managed' incidents or to attempt to infer performance by forecasting from the data/conditions before the management strategy was implemented. However, incidents have such specific characteristics (exact location, start time, duration, type of day, effect on traffic flow) that an approach attempting to use observed data to approximate do nothing conditions would only be approximate and unlikely to be capable of robustly evaluating the benefits of the management strategy. In this situation, there is a benefit in applying transport models with the capability to represent the incident impacts and management strategy effects to measure the benefits of the system strategy – the model can easily and effectively represent the do nothing scenario. An additional benefit is that a model could be used to test alternative strategies and/or optimise existing strategies to provide greater benefits.

Table 4.3 above indicates that transport modelling generally has a number of benefits over a data approach. However, for many operations agencies it is likely that deciding on an approach for an activity evaluation will be based on considering existing data sources as a starting point. This is because current data system coverage in urban areas is fairly significant and largely suitable to evaluation of operations activities (see appendix B, section B1.2). There may be a preference to provide 'real-world' evidence (rather than modelled estimates of outcomes) and a continued bias towards data as a lower cost alternative. The flow chart in figure 4.1 demonstrates key aspects of the decision process to determine whether an observed data measurement or transport modelling approach may be suitable for an assessment. This is based on starting from the perspective of selecting a low-cost data measurement approach (this decision process is also relevant to business case assessments, see chapter 1).

Figure 4.1 Basic assessment approach (data vs modelling) decision flow- chart



The benefits of transport modelling as suggested in table 4.3 are significantly greater than use of measured on-road data. This suggests that the biases noted in the paragraph above may need to be carefully weighed against the benefits of developing an operationally capable transport model. This is particularly relevant if carrying out a number of appraisals of initiatives across an area. This work could include valuable analysis such as considering the balance of investiture across alternative operations activities, comparing operations initiatives against 'typical' interventions, and investigating more extreme operations techniques.

4.4 Summary and conclusions

4.4.1 Assessment requirements

Pre-implementation appraisals are commonly carried out in the appraisal of standard transport interventions whereas post-implementation evaluations tend to be used to evaluate the benefits of operations activities. Ideally both approaches would be employed to assess a project – in order to establish and improve pre-implementation analysis methods and to provide real-world outcomes. However, this is commonly deemed to be impractical for all transport improvements (but should continue for selected projects) and therefore to evaluate the economic benefit of operations activities the merits of each assessment approach will need to be considered for the particular initiative.

4.4.2 Key considerations

Pre-implementation analysis generally involves transport modelling, whereas post-implementation evaluation involves the analysis of before and after on-road traffic data. The suitability and availability (including analyst availability/experience) of data collection systems and of transport models is therefore a key aspect to deciding on the most appropriate assessment method. Other key aspects include;

- A set requirement to consider operations within a fuller business case appraisal. This will generally require a pre-implementation appraisal and application of suitable transport modelling.
- Implementing the project on-street, weighed up against the ability to clearly distinguish the merits or otherwise of the project from the available data measurement systems and the risk to customer experience of a poor project outcome.
- Reducing customer risk and improving outcomes by carrying out pre-implementation analysis, weighed up against the time and cost of the analysis, the margins of potential outcome improvements, and the potential spin-off benefits of the assessment analysis (eg ability to rebalance activities and increase value-for-money, detailed network intelligence gained through the analysis process, opportunities for greater improvement and new strategies/improvements).

4.4.3 Selecting an assessment approach

Both the pre-implementation and post-implementation approaches are relevant and should and will continue to be utilised in assessments of operations activities. Therefore the application, appropriateness, implications and constraints of each approach need to be considered carefully in carrying out an economic evaluation of an operations activity. Asides from overriding considerations such as the need to consider operation strategies as part of a series of solutions within a business case assessment, key considerations in selecting an appropriate assessment approach include:

- system/transport network coverage
- level of assessment control and investigation ability
- ability to measure the system ‘with’ and ‘without’ the intervention
- noise in the analysis process and outputs
- measurements and outputs required to carry out an economic evaluation
- availability and establishment of software, processes, expertise and resource
- costs.

The assessment framework for establishing the benefits of operations activities will need to be developed flexibly and pragmatically so that it can be applied to either a pre-implementation appraisal utilising transport modelling or desktop analysis, or a post-implementation evaluation using data collection systems.

5 Economic assessment framework for operations activities

5.1 Introduction

This covers the development of an evaluation framework oriented to the particular requirements and issues of network operations activities. The framework has been developed with the anticipation that it can be applied as a high-level guide to practitioners carrying out economic evaluations of operations activities. It identifies and highlights issues which are specific to operations activities (eg lifespan considerations) and is designed flexibly so that it can be applied to any form of operational scheme (including PT, pedestrian and freight schemes etc) although examples and focus are towards vehicular benefits.

Following this introduction it contains two main sections:

- NZ Transport Agency (2014c) *Investment assessment framework* (IAF). This section provides an overview of the Transport Agency's current assessment framework, including its business case requirements, which is at the heart of its investment decision-making process. The IAF and policies are independent to some degree from the findings of this research project and from the evaluation procedure, which concentrates on the core economic principles of assessments. Changes to the overarching Transport Agency policies should not significantly alter the application of this evaluation framework.
- Economic assessment guidelines. This provides guidelines for the economic appraisal of network operations activities. The primary focus of the guidelines is the economic assessment of operations schemes; this follows a process that is consistent with appraisals generally carried out in New Zealand currently/historically for larger transport projects prior to implementation. This guide can be applied to assess operations activities based on forecasting economic savings (eg from modelling and/or desktop analysis), or based on analysis of observed on-road traffic data (eg from before/after measurement), or a combination of these approaches. Each of these three situations is illustrated in the research case studies.

5.2 NZ Transport Agency investment assessment framework

The IAF has been developed for use in conjunction with the publication of the *Government policy statement on Land Transport, 2015/15 – 2024/25* (MoT 2014). The Transport Agency gives effect to the Government Policy Statement by using the IAF to determine which activities will receive funding within the overall funding range specified in the statement.

As under its earlier assessment framework, the Transport Agency continues to use three high-level criteria as the basis for determining funding priorities:

- strategic fit
- effectiveness
- economic (benefit and cost) appraisal.

Central to the IAF are four stages of business case analysis:

1 Strategic business case

2 Programme business case

3 Indicative business case

4 Detailed business case.

The economic (benefit and cost) appraisal is a component of stages 2, 3 and 4, as outlined in table 5.1. In practice, for most network operations activities, it may be feasible to reduce the requirements for economic appraisal from three sets of analysis to two sets (but advice would be required on this for specific cases).

The next section of this chapter provides guidelines for the economic appraisal work required, consistent with the EEM, and including specific issues relating to network operations projects.

Table 5.1 Roles of economic appraisal in business case assessment

Business case stage	Role for economic appraisal in NZ Transport Agency business case assessment
1. Strategic business case	Not applicable
2. Programme business case	Indicative appraisal, at overall programme level
3. Indicative business case	More detailed appraisal of options, resulting in selection of preferred option and assessment of its economic performance (BCR)
4. Detailed business case	More detailed economic appraisal of preferred option, resulting in refined assessment of its economic performance (BCR)

5.3 Economic assessment guidelines

The guidelines set out in table 5.2 have been developed from the perspectives that:

- The guidelines focus on quantifying and valuing the benefits within an economic framework of network operations activities and, in particular, identifying aspects that may be unique and specific to these (relative to more typical transport schemes generally involving larger investment).
- The guidelines have been designed to cover methodologies which include forecasting savings (modelling, desktop analysis, etc akin to typical transport appraisal) and/or measurement of before/after on-road data. Before and after observed data measurement is often used to evaluate operations activities for the purposes of investigating economic returns and potentially developing funding cases (sometimes in retrospect, sometimes via live system implementation and measurement)[6]. The framework is designed to provide guidance on the assessment of operations and the development of a funding case for this style of scheme.
- As identified through part 1 of the research project, the categories of economic benefit relevant to network operations activities are essentially the same as those applying to road infrastructure activities (in most cases) or to other types of activities covered in the EEM. Given this, and the desirability of being able to directly compare the economic performance of network operations activities with other transport investments, the EEM provides the base for the economic appraisal of network operations activities.

[6] This approach should not be confused with transport scheme post-implementation reviews which are likely to focus on reviewing the pre-scheme appraisal findings against the real-world post-scheme measurements. This is generally not the objective of this form of before/after data measurement for an operations activity assessment.

For each of the appraisal aspects, table 5.2 first summarises the relevant EEM specifications and requirements and then provides additional material to assist the analyst in applying these specifications to the economic evaluation of network operations activities.

Table 5.2 Economic assessment guidelines

Aspect	NZ Transport Agency specification	Guidelines/considerations for operations activities
A. ECONOMIC BACKGROUND PRINCIPLES		
A1. Analysis period (EEM 2.6)	• Length of time period used in economic appraisal. • Intended to capture at least 90% of present value (PV) of future costs and benefits. • Standard analysis period is 40 years (at 6% discount rate), from the first year in which significant benefits or costs occur. • May choose shorter periods where appropriate	• Shorter (<40 years) periods are generally appropriate and limited to the lifespan of the operation, eg lifespan is shorter if the effect is short lived (roadworks, incidents, events etc), expires over a relatively shorter term (optimisation, specific travel management), changes in network conditions require a refreshed approach (management strategies, traveller information etc), or the main assets involved have significantly shorter lives in physical terms (wear out) or technological terms (likely to be superseded). • When comparing options with differing lives (eg infrastructure vs operations), should adopt the effective life of the longer-life option.
A2. Time zero (EEM 2.6)	• Date to which all benefits/costs are discounted. • 1 July of first financial year in which activity is submitted for commitment to funding. • All options assessed for an activity use the same time zero	• The choice of time zero will not affect the economic performance ratios (BCR etc) of options.
A3. Base price (EEM 2.6)	• This is base date for expressing all cost and benefit values. • 1 July of the financial year in which the appraisal is prepared. • Factors for adjusting costs and benefits for different price dates are given in EEM app A.12.	• By expressing all costs and benefits in prices at the same date, no allowance needs to be made for general price escalation (inflation). • The base price date does not need to be the same as time zero; typically it is 12 months earlier than time zero. • Choice of base price date will not affect economic performance ratios (BCR etc) of options (provided they all use the same base price date).
A4. Discount rate (EEM 2.5)	• This represents the rate at which society is willing to trade off present benefits and costs against future benefits and costs. • The standard discount rate adopted is 6% pa for all evaluations. • Sensitivity testing at 4% pa and 8% pa is required for activities appraised through the full EEM procedures.	• The discount rate is expressed in real terms, ie in constant prices, excluding any allowance for inflation. • For most operations activities, detailed sensitivity testing (including testing of discount rates) is not normally required. • Approximate sensitivity estimates may be derived by applying a factor of 1.25 to the base estimates of BCRs for the 4%

Aspect	NZ Transport Agency specification	Guidelines/considerations for operations activities
		discount rate, 0.83 for the 8% discount rate (EEM 2.5).
A5. Present value (EEM 2.5)	• The present value (PV) of a future benefit or cost is its discounted value to time zero.	• The present value of benefits (PVB) and costs (PVC) is the discounted sum of all benefits/costs discounted to time zero. • The net present value (NPV) is the difference between the present value of benefits (PVB) and that of costs (PVC).
B. OPTIONS FOR ASSESSMENT		
B1. 'Do minimum' option (EEM 2.7)	• A do minimum option is defined as the base with which other options may be compared. • The do minimum is defined in terms of the minimum essential expenditure required to maintain a minimum level of service over future years (which may be lower than the current level of service or future desired level).	• For many operations activities, the do minimum expenditure or capital option costs may be very low (in contrast the travel costs (delays) could be high). Often the do minimum will be a 'do nothing' option as the operations scheme itself generally does not involve large expenditure. • Some care needs to be taken with certain types of operations activities to define a realistic do minimum, eg evaluation of signal optimisation strategies should be carried out against a 'real' do minimum (eg a scenario with some form of realistic sub-optimal (existing) strategies) rather than unrealistic strategies such as fixed times or similar.
B2. Range of options – more significant aspect for infrastructure appraisals		• Operations activities are often an efficient means of addressing traffic and transport problems in the short/medium term. When considering a larger infrastructure option to treat problems, practical operations schemes may need to be considered within the assessment. • Such analyses should address the optimum timing for introducing the infrastructure options relative to any lifespan benefits that may be generated from operations schemes, and hence draw conclusions on the optimum economic life of the infrastructure and operations options.
C. ECONOMIC BENEFIT ESTIMATION AND OPTION SELECTION CRITERIA		
C1. Costs and benefits overview (EEM 2.2, 2.4)	• Costs relate to the provision of transport infrastructure and services. They cover all costs incurred over the appraisal period, including capital, operating and maintenance components. • Benefits accrue to transport users and other parties as a result of usage of the transport system.	• Capital costs are generally to be included in the appraisal as cash flows according to when the work is carried out, irrespective of any financing arrangements (eg through loans and interest payments). • Any 'sunk' costs (costs already incurred, which are not realisable) are not to be included in the appraisal. For an

Aspect	NZ Transport Agency specification	Guidelines/considerations for operations activities
		operations activity these could include the costs of existing infrastructure which is used for new purposes (eg VMS, historical software/ hardware purchased such as SCATS). • Benefits may be positive or negative (disbenefits), for example, an increase in vehicle operating costs or travel time would be counted as a negative benefit.
C2. Benefit-cost ratio (BCR) (EEM 2.8)	• The BCR of an activity or option is the ratio of the present PVB to the present PVC. • An activity is considered as potentially worthwhile (ie dependent on comparison with competing projects) in economic terms (in the absence of funding constraints) if its PVB exceeds its PVC, ie its BCR exceeds 1.0. • The Transport Agency uses two BCR measures: BCR_N from the national perspective, or BCR_G from the government funding perspective.	• The appropriate BCR measure for operational projects will almost always be BCR_N. BCR_G is only relevant where there is a private service provider or other non-government contributions, tolls or fares.
C3. Benefit and cost assessment (IAF)	• As part of the Transport Agency's IAF, transport improvement activities are rated into one of four categories, according to their BCR_N values: no rating, 1.0 to 3.0, 3.0 to 5.0, 5.0+. (Other criteria are also used to rate schemes)	• In selecting activities to be funded (through regional land transport programmes and the National Land Transport Programme, their rating in terms of the efficient assessment factor (benefit and cost performance) is considered along with their strategic fit and effectiveness assessment factor ratings.
C4. Incremental cost benefit analysis (EEM 2.8, A12.4, A19)	• Incremental CBA is used to identify the optimal economic solution when considering mutually exclusive options to address a problem. • Incremental BCR between two options (A, B) is defined as incremental benefit (A-B)/incremental costs (A-B).	• Procedures for calculating incremental BCR values are detailed in EEM A19. • In relation to operations – the incremental analyses may be important for choosing between potential options (operations-focused or infrastructure-focused) and the sequencing/timing of these.
C5. First year rate of return (EEM 2.9)	• The first year rate of return (FYRR) is used to indicate the best start date for activities. It should not be used to assess whether an activity should proceed at all; but may be useful for sequencing mutually exclusive activities within a constrained budget. • FYRR for an activity is defined as the PVB in its first full year of operation divided by the PVC over the full analysis period. • As a general rule, if FYRR is less than BCR/15.4 (EEM 2.9), then the investment should be delayed.	• For most operations projects, with typically relatively high BCRs, there would be no case for delay. • There may potentially be some overlap between the incremental CBA method (above) and the FYRR method for sequencing mutually-exclusive activities or options. • If in doubt, we suggest use the incremental CBA approach (or seek further advice, eg from Transport Agency staff, the EEM, or experienced transport planning and economic advisors).

Aspect	**NZ Transport Agency specification**	**Guidelines/considerations for operations activities**
D. COST ASSESSMENT CONSIDERATIONS		
D1. Cost categories (EEM 2.4, 4.3.4)	• For road improvement projects, relevant costs may be categorised as follows: construction costs, maintenance costs, operating costs, land costs (net), decommissioning costs, environment mitigation costs, investigation, planning and design costs.	• Costs need to be carefully developed for operations activities. This process differs from infrastructure projects, which are likely to have larger capital costs which significantly outweigh any other cost components (such as analyst staff time) and the need to consider these components in any detail. • The relevant costs for consideration of operations activities are generally the incremental costs – the additional costs that would be incurred from implementing the activity (relative to not implementing it). • Operations activities have the potential to generate large BCR values due to benefits swamping cost elements, therefore cost components need to ensure that all cost components are reasonably covered. Costs could include staff time in implementing and managing systems, staff time in analysing data, evaluation and reporting, software costs (eg maintenance, renewal, support), hardware/infrastructure maintenance). • Any ongoing costs to maintain an operations activity over its appraisal period should be included. • Analysts may need to seek further guidance re inclusion/exclusion of such costs, should they be significant.
E. BENEFIT ASSESSMENT CONSIDERATIONS		
E2. Key benefit categories	• Generally for road infrastructure improvements three categories account for the great majority of total benefits – value of time savings, vehicle operating cost savings, and safety savings. EEM provides detailed procedures for estimating benefits in these three categories.	• This point is even more pertinent for network operations activities. It is possible the activity may generate significant savings (relative to costs) from just one main category of benefits (eg value of time savings from an optimisation project, crash savings from a safety scheme). Therefore most analysis resources should focus on the category or categories returning the major benefits (but not ignoring any categories which could have significant disbenefits) and it may not be worthwhile investing further resource in analysing benefits from other sources. The sections below focus on the three main benefit categories. • Two alternative approaches (or a combination) are generally appropriate for

Aspect	NZ Transport Agency specification	Guidelines/considerations for operations activities
		measuring the key savings of an operations activity – modelling (typically using microsimulation rather than deterministic models such as SIDRA, SATURN etc.) or observed measurement via on-street data collection systems. See chapter 4 for guidance on these two approaches, and specifically section 4.3.3. For key considerations relating to the choice of using modelling vs data observation.
E3. Benefit category 1 – Value of time and congestion (EEM A4) Frustration (EEM 4.4) Reliability (EEM A4.5).	• The average value of travel time (or 'value of time') savings are often the main benefit contribution for roading improvements. • As well as average savings, value of time savings also include congestion, reliability and frustration benefits.	• Travel time (mean) savings are commonly a critical measurement for operations activities. • Travel time reliability (variability). These benefits may often be as large (in $ terms) as those for mean travel time savings. While EEM has procedures for estimating changes in reliability, on a whole-of-journey basis, these are relatively demanding: and simpler, rule-of-thumb estimates may not be appropriate. Both microsimulation modelling and certain observed data sources (eg Bluetooth, wifi, GPS travel times which provide day-to-day data) offer the possibility of measuring and assessing reliability improvements directly.
E4. Benefit category 2 - Vehicle operating costs (EEM A5.4, A5.5, A5.6) emissions reductions (A9.6)	• Vehicle operating cost savings, including fuel consumption savings. • Vehicle emission (local and global) impacts (on public health and environment).	• Vehicle operating costs (fuel consumption) and global/local emissions costs. For some types of operations activities (eg signal optimisation) a major source of benefits may be smoother traffic flows (less stop/start operation), resulting in improved travel time reliability, reduced fuel consumption and reduced global and potentially local emissions. This is difficult to measure from observed data sources and may be estimated directly from microsimulation modelling.
E5. Benefit category 3 – Crash analysis and savings (EEM A6)	• Crash cost reductions	• Some types of operations activities have a primary focus on reduction of crash numbers and crash costs, for such schemes this aspect requires careful attention due to the sensitivities around crash analysis. The EEM procedures can be followed and the need for caution is not necessarily unique to operation activities.
E6. Other benefits	• Other environmental impacts (generally not expressed in monetary terms).	• It is unlikely that operations activities will offer any significant savings in these benefit areas. Therefore effort in

Aspect	NZ Transport Agency specification	Guidelines/considerations for operations activities
	• Risk reduction benefits. • Wider economic impacts – benefits on the wider economy including agglomeration, benefits of increased labour supply, effects of imperfect competition. • National strategic factors – including security of access and investment option values	analysing these benefits may be wasted. An exception to this would be the introduction of a significant area-wide operations activity offering the potential for substantial network improvement, this may merit investigation into these benefit areas.

6 Case study applications

6.1 Case studies overview

The economic assessment framework was applied to three operations activity case studies:

- Study 1: An incident management system utilising traveller information and intelligence monitoring to advise alternative routes during incidents on Auckland's North Shore.
- Study 2: A SCATs signal optimisation option study at the Curletts Road/Blenheim Road intersection in Christchurch.
- Study 3: An investigation into lifespan issues, considering the Rural Intersection Advanced Warning System (RIAWS) safety treatment and a grade separation option at the Pineacres intersection north of Christchurch.

Each of the case studies should be considered an indicative application of the assessment framework to illustrate how such options may be evaluated within the framework. The case study applications have aided the development of the framework by identifying key aspects to highlight within the framework. The case studies should not be considered exhaustive and complete evaluations of the operations schemes analysed. This is particularly notable in relation to the third case study (RIAWS and grade separated options); the focus of this case study is the principle of the lifespan-style assessment (extension of infrastructure lifespan through operations activities) rather than a full comprehensive assessment of the benefits of RIAWS and a complete study into intersection upgrade options at this specific location.

6.2 Case study 1: Incident management system: North Shore, Auckland

6.2.1 Introduction

6.2.1.1 Background

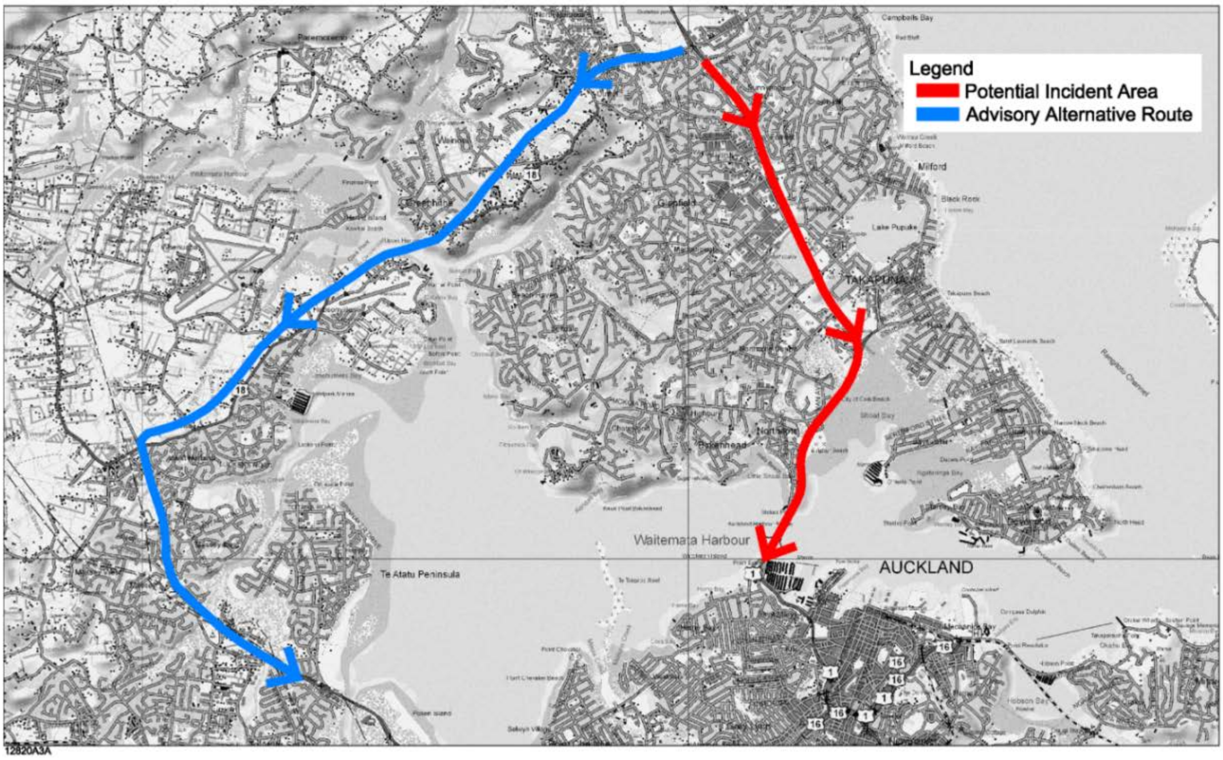
Unplanned incidents such as crashes, breakdowns, extreme weather etc can have significant effects on travel. If these incidents occur during peak travel times (eg AM and PM commuter periods) in sensitive areas of the network (eg high-flow/high-speed transport links) they can produce long delays for large numbers of travellers and have serious consequence for individuals (eg missed transport connections). Low-cost options, which minimise delays to travellers, provide viable alternatives to avoid the incident area, and improve network recovery, have the potential to offer significant benefits. This case study investigated the potential economic returns of one such system – providing traveller information to encourage drivers to travel via the alternative SH18/SH16 route when incidents occur on SH1 north of the Auckland Harbour Bridge. The case study only considered the benefits of implementing the system in the southbound direction when the incident is located on SH1. It did not consider the reverse direction and the possibility of implementing the system to manage incidents on the SH16/SH18.

6.2.1.2 Location

SH1 through the North Shore is an example of a sensitive transport link. It carries high traffic volumes and suffers from reasonably high levels of day-to-day delays particularly during the morning commuter peak (travel towards Auckland's CBD). If incidents occur in this section of the network large delays and queues can form, affecting travel conducted for a range of purposes including business and freight.

To avoid extreme delays (greater than 20 minutes) in this section of the network, an alternative route exists via SH18 and SH16. This route is roughly an additional 15km to the CBD, taking roughly an additional 15 minutes during uncongested times. The area of the network and potential alternative route is shown in figure 6.1.

Figure 6.1 North Shore incident area (SH1) and potential alternative route (SH18/SH16)



6.2.1.3 Incident response

The Auckland TOC has implemented an incident management system through this region of the network. If an incident occurs (notably around the time of AM commuter period, or a significant incident during this period or at other times) in the section of SH1 south of Constellation Drive, the TOC may decide to advise travellers to reroute via SH18 and SH16 based on network conditions (the extent of delays on SH1 and the likely growth and duration in delays). Information on the alternative route and SH1 conditions is provided to customers on VMS north of Constellation Drive (providing drivers with the opportunity to reroute at Constellation Interchange) and via media channels (any specific advice to travellers to use the alternate route is generated from the TOC).

6.2.2 Incident management assessment

6.2.2.1 Core measurements required

A number of measurements and values need to be estimated in order to establish the potential savings of the incident management strategy. These are set out below. Note, in the descriptions below and throughout this case study report, ‘delay’ is the additional travel time on a day with an incident compared with typical travel times at the same time of day. .

1. The delays (magnitude and period over which delays occur) on the core route (SH1 southbound) due to a common incident impact, or ideally a range of delay magnitudes from various incident types occurring at various times.

2 The reduction in delays experienced on SH1 due to the reduced volume travelling southbound on SH1.

3 The travel time for vehicles choosing to reroute via SH18/SH16.

4 Any increase in travel time on SH18/SH16 due to the additional volume on this route.

5 The volume of vehicles on SH1, SH18 and SH16.

6 The volume of vehicles choosing the alternative route.

The following sections set out how the above measurements were established and the economic assessment conducted on the basis of these.

6.2.2.2 Identification of incident days

Historical records of incidents in the Traffic Road Event Information System and Incident Logging System records were reviewed by TOC staff to identify historical incidents that had occurred in this location during the AM period. The objective of this review was to identify incidents with characteristics that could generate the conditions where the management system could be implemented. Table 6.1 identifies these days, incident times, locations and a description of advisory information provided to the public.

Table 6.1 Historical incidents in key area during AM peak

Date	Day of week	From time	To time	Location (southbound on SH1	Description/advisory information
8 August 2013	Thurs	10.06	10.58	South of Northcote on-ramp	Due to a crash the right-hand lane on this section of highway is blocked. Expect delays. Use SH18/SH16 as an alternative route south
28 March 2014	Fri	07.27	08.56	Greville Rd to Northcote Rd	Due to a crash the right lane is currently blocked between the Northcote Rd off and on-ramps. Expect delays or avoid the area if possible. If heading to the CBD or further south consider using Upper Harbour Highway and North Western Motorway.
13 August 2014	Wed	09.15	11.12	Greville Rd to Tristram Ave	Due to a crash the right lane is blocked between the Tristram Ave off-ramp and on-ramp. Expect long delays and avoid the area where possible.
21 October 2014	Tues	10.00	10.45	Northcote Rd to Esmonde Rd	Crash sbd, expect long delays. Lanes 2 and 3 initially blocked. Lane 2 open 10.14, lane 3 open 10.45.

For the last example, 21 October 2014, the TOC employed the incident management strategy and gathered data on the timeline of events and actions, traffic volumes and information on delays. During this incident the TOC estimated 600 vehicles were rerouted via SH18/SH16.

6.2.2.3 Assessment approach

Route travel time from the Transport Agency TomTom GPS data system was extracted for the above incident days along with typical weekday volume information from the Transport Agency traffic management system (TMS) loop counter. This information was gathered over five key sections of the network:

1 SH1 southbound, Silverdale to Constellation

2 SH1 southbound, Constellation to Fanshawe Street

3 SH18 westbound, from SH1 to SH16

4 SH16 southbound, from Coatesville/Riverhead to SH18

5 SH16 southbound, from SH18 to CBD (linking to Fanshawe Street).

The objective was to establish a flow and delay profile on the key sections of the network for three scenarios: typical weekdays, incident days where the specific alternate route advisory management strategy was not employed[7] and incident days where the incident management system was employed.

6.2.3 Data analysis and indicative modelling

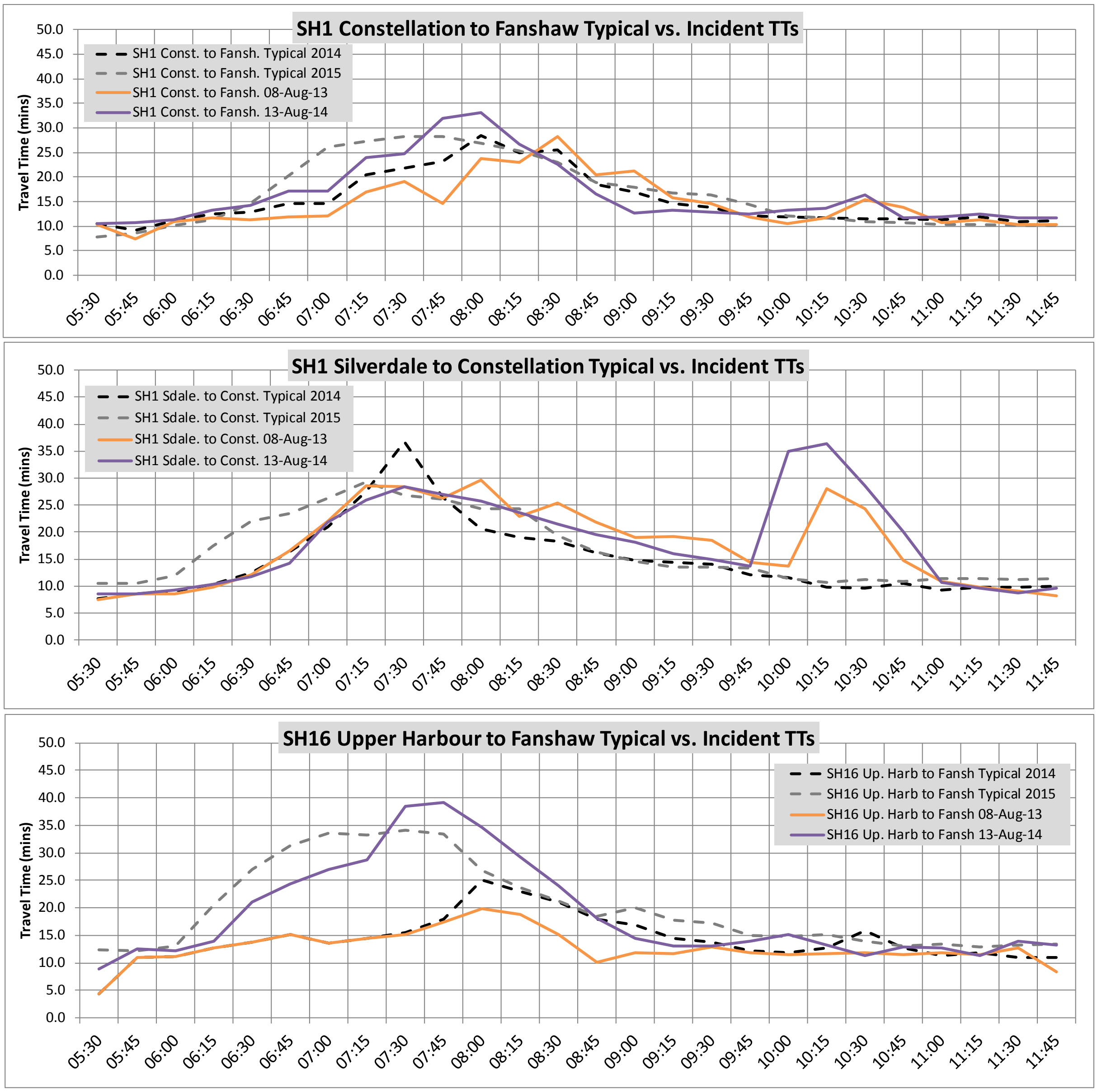
6.2.3.1 TomTom travel time data

As noted above, travel times on the five key route sections were extracted from the Transport Agency TomTom data system for the above incident days and more recent typical travel times. Analysis and inspection of this data demonstrated that the travel time outcomes were, to some degree, inconclusive. The incident on 8 August 2013 is relatively identifiable in the link travel times on SH1, showing a large spike in delay. Data from 13 August 2014 shows a spike in delays in the network location where the incident was recorded, but not at the exact times matching the records above. Data from 28 March 2014 is incomplete and surprisingly the incident on 21 October 2014 is not identifiable in the travel time data, ie there is no discernible increase in travel times relative to typical times over the time of the incident. The surprising element is that the TOC data from 21 Oct 2014 reasonably conclusively identifies additional delay – at 10:04 images from traffic cameras show a large queue southbound around the Northcote Interchange and further images from social media feeds demonstrate significant queuing at later times. To overcome this issue, the information provided by TOC staff, extent of delays from clearly identifiable incidents and some investigative transport modelling was used to estimate incident delays. This is described further below.

Figure 6.2 shows the incident travel times from August 2013 and August 2014 compared with typical travel times (estimated from non-incident days and times not affected by incidents) from the TomTom data for three key sections (SH1 northern section, SH1 southern section and SH16).

[7] The particular approach considered in this case study was not carried out in the past as comparative SH1 vs SH16/SH18 travel times were not readily available – advice was somewhat ad hoc to ‘consider’ or ‘use’ the alternative route. With comparative travel times readily available the TOC has developed a standard operating procedure to guide the promotion of the alternative route resulting in a more regular and effective use of the SH16/SH18 route.

Figure 6.2 TomTom AM period southbound travel times – incidents vs typical



The two August incidents provide some indication of the potential magnitude of incident delays, particularly in the northern section of SH1 (north of Constellation Drive). The maximum delays were approximately 25 to 30 minutes (more than double typical travel times) on the SH1 southbound route and delays were present for 1.0 – 1.5 hours. This is particularly identifiable in the central graph, the incident delays are shown on the purple and orange lines relative to the typical travel times demonstrated with the grey and black dotted lines.

Figure 6.2 indicates no significant change in SH16 travel times during the period of high delays on SH1 south-bound (09:45–11:15). Analysis of SH18 travel times similarly shows no real effect during incidents on SH1.

6.2.3.2 Indicative transport modelling

A microsimulation transport model has been developed covering the Auckland Southern Motorway corridor from East Tamaki in the south to the Broadway overbridge in the north (north of Green Lane). The model has been used for several Transport Agency studies in this area, including an investigation into the Mt Wellington overbridge 3-to-2 lane reduction.

This area of the network has similar characteristics to the SH1 Auckland Northern Corridor. The model was run to investigate the magnitude of delays in the AM period in a similarly sensitive area of the network. This modelling was carried out because of the partially inconclusive results from the TomTom data, the coverage of the model and the similarities between the northern and southern corridors, and the ease of running a model of this form to investigate incident impacts. The model was used in several key ways:

- To investigate the impact of incidents that occur closer to the time of the AM peak travel flow.
- To investigate the possible improvement in delay recovery time where demand is reduced by an incident management strategy (eg rerouting traffic).
- To cross-check the economic saving values from the North Shore estimates.

The model was run with an incident beginning at 07:40 which closed lane 1 (left-hand lane) for 30 minutes in the section of the network between the Princes Street interchange and Mt Wellington interchange (south of Mt Wellington). Figure 6.3 shows the typical (base), incident and mitigated incident travel times and flows when the demand on the route is reduced by 500 vehicles. The bottom graph shows the percentage saving in delay (recovery time) due to the mitigation (reducing the flow by 500 vehicles). The 500 vehicle reduction was applied as a sensitivity test, based on the magnitude of demand (600 vehicles) which were estimated to reroute during the 21 October 2014 incident on the North Shore.

Figure 6.3 Southern motorway modelled incident travel times and flows

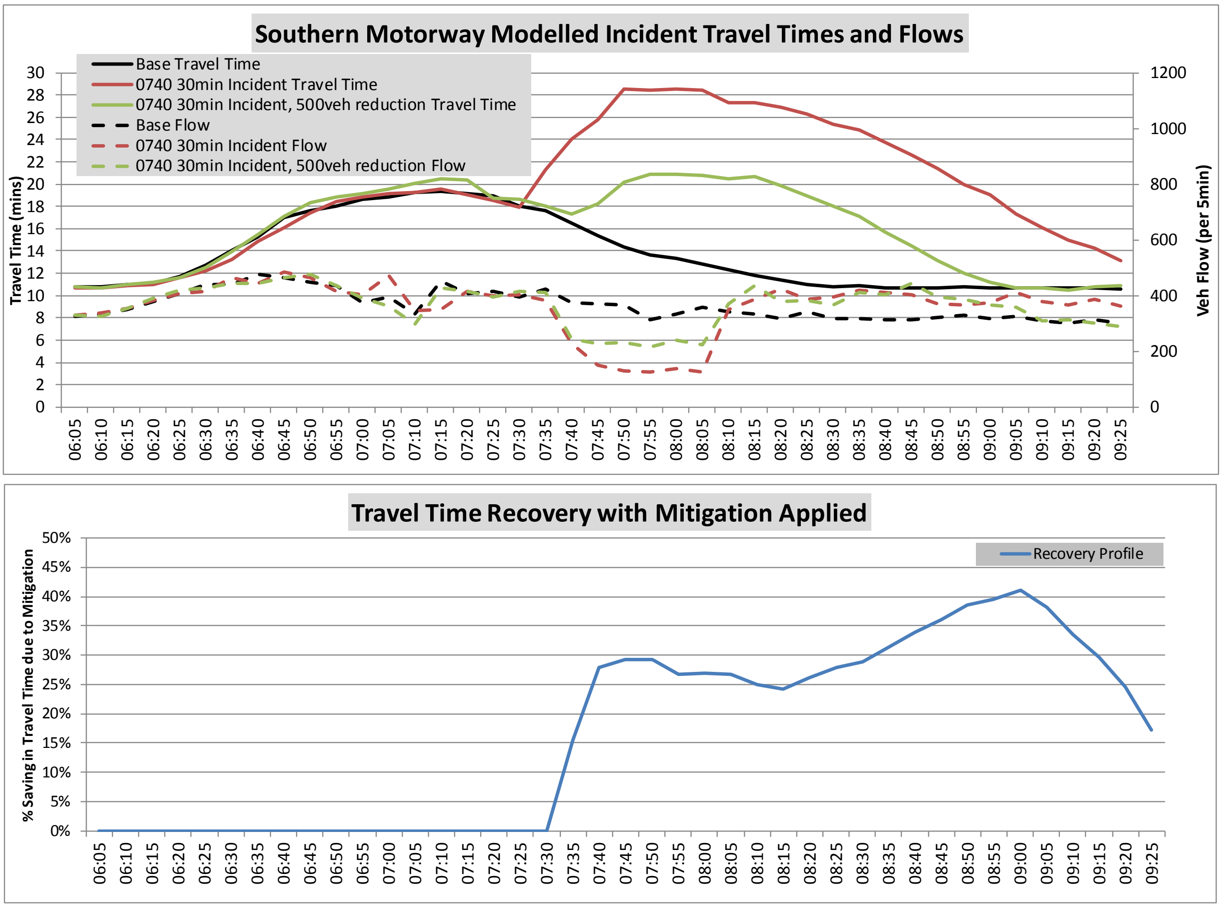


Figure 6.3 shows that a 30-minute incident affecting one lane during the peak in traffic flow can generate delays of around 16 minutes. Again this is more than double typical travel times – the TomTom data shows peak delays of 133% of typical times in 15-minute time intervals, the modelling indicates peak delays of up to 137% of the base travel times in five-minute intervals (ie very similar magnitudes of delay peak). The modelling demonstrates delays were present for 1.5–2.0 hours, indicating a longer recovery time for incidents that occur closer to the peak travel flow period, compared with the TomTom data.

6.2.3.3 Magnitude of incident delay and duration

The modelling exercise provided a useful crosscheck of the observed travel time data and the potential effects of an incident management strategy which could reduce the traffic flow (using the North Shore example to provide an estimate of the magnitude of diverted traffic) passing through an incident area. From this data, it is possible to estimate roughly some ranges of delay magnitude (maximum delay compared with typical travel times) and duration of the overall presence of delays. Table 6.2 presents a summary of this information, identifying the broad ranges of delay magnitude and delay duration on sensitive high-flow/high-speed traffic corridors.

Table 6.2 Approximate incident delay magnitude and duration

	Magnitude of delays compared with existing travel times			Duration delays persist (mins)		
	Incident duration			Incident duration		
	Short (>30 mins)	Medium (~30 mins)	Long (~1 hr)	Short (>30 mins)	Medium (~30 mins)	Long (~1 hr)
High flow period, not peak	50%	100%	130%	45	60	90
Close to peak	75%	120%	140%	60	100	120
During peak travel period	100%	140%	?	90	120	?

The '?'s in table 6.2 indicate that the magnitude of a more extreme incident (during peak, with long duration) is difficult to estimate.

6.2.4 Economic analysis

6.2.4.1 21 October 2014 incident

The particular focus of this case study was the incident that occurred on 21 October 2014 on the North Shore. This is because the actions employed to mitigate the incident have been clearly described, the volume of traffic rerouted on the alternative route identified (600 vehicles, measured via loop detection data at the Constellation Drive interchange), the details of lane closures and duration of these closures noted, and the peak travel times on SH1 and SH18 measured. The economic benefits of this strategy were estimated against the literal do nothing scenario (ie no strategy to re-route traffic).

6.2.4.2 System and staff costs

It is difficult to put costs against implementing the incident management strategy because large proportions of this work are part of the day-to-day TOC activities. The TOC monitors conditions, travel times, and puts out traveller information messaging irrespective of whether the incident strategy is implemented. The strategy also makes use of existing infrastructure (existing VMS, media channels etc) so has no material costs.

It is likely there are some minor additional staff costs associated with on-going monitoring of the network and incidents to identify the potential for implementing the management strategy, time monitoring conditions and implementing messaging during the incident, and post-analysis to refine the process and determine the success or otherwise of the strategy. These costs are estimated below.

Table 6.3 Approximate cost per incident (akin to 21 October 14 incident)

Task	Cost per incident NZ$
Monitor conditions to identify possible incident conditions	300
Monitor conditions during incident for key decisions	300
Implement messaging	150
Data analysis during and post-incident to refine process	1,100
Before and after success analysis (economic analysis)	1,800
Total cost	**3,650**

6.2.4.3 Benefit calculation

The economic benefits were calculated from the typical weekday 15-minute traffic demand flows on the key sections of the network and 15-minute profile of travel times on these routes (SH1, SH16 and SH18). The TOC write-up of the incident details included estimates of peak travel times on SH1 and SH16 during the incident. Therefore the critical aspect of this assessment is the estimate of travel times on these routes had the incident strategy not been implemented (do nothing scenario). The SH16 and SH18 do nothing travel times were estimated from typical historical times, and the SH1 times were based on the modelling and TomTom travel time profiles described in section 6.2.3 above.

The EEM July 2014 values of time for the interpeak including the congestion increment were applied to the 15-minute time saving per vehicle to calculate the benefit stream through the period of the incident (10:00am to 12:00pm).

Due to the additional travel distance experienced by the vehicles that rerouted to avoid the SH1 delays (roughly 600 vehicles in total), the EEM July 2014 VOC disbenefits incurred by these vehicles was included in the assessment of benefits.

Environmental benefits were not assessed. It is probable that travel time reliability and frustration benefits would accrue from reducing the impact of the incident. These were not evaluated in this assessment as the value of time savings outweighed the costs by a reasonable margin and therefore the return from the effort of carrying out this analysis was limited.

Table 6.4 shows the savings (negative value, ie benefit) and costs (positive value, ie disbenefit) for each of the traffic streams through the network. Due to the need to estimate the delay profile for the do nothing scenario, the benefits described below should be treated as approximate estimates.

Table 6.4 21 October 14 incident benefit and cost streams (intervention vs do nothing)

Component	$ benefits
SH1 traffic – time (saving)	25,000
SH16 traffic – time (cost)	-3,000
SH18 traffic – time (cost)	-500
Diverted traffic – time (saving	5,000
Diverted traffic – distance (VOC) (cost)	-3,000
Total cost	**23,500**

6.2.5 Cost/benefit assessment and potential extrapolation

6.2.5.1 North Shore incident management strategy BCR

The BCR from implementing the incident strategy for the 21 October 2014 incident was estimated as roughly 6–7, a high return from the associated investment in developing and implementing the strategy.

The above analysis, modelling and information collected provide a mechanism and background to set some economic return ranges based on the severity of incidents in the North Shore SH1 southbound area of the network. The 21 October 2014 incident is considered to be of moderate impact (it occurred after the AM peak, two lanes were opened relatively quickly (within 15 minutes), and the incident was completely cleared reasonably quickly (within 45 minutes). Ranges of economic saving based on low, moderate and high impact incidents were estimated following the methodology used to assess the 21 October savings:

- low impact incident: potential saving $5,000–$10,000
- moderate impact incident: potential saving $20,000–$25,000
- high impact incident: potential saving $40,000–$50,000.

The incident record data was used to roughly establish the number of incidents in these categories each year, with low, medium and high occurrence rates being estimated. The occurrence rate, along with the saving ranges above provided a methodology to assess a range of annual benefits from the North Shore incident management strategy.

For some incidents with lower impacts, during periods of lower traffic flow, it may not be warranted to divert traffic via SH16/SH18 as the disbenefits from the diversion could outweigh the possible savings. In the analysis presented below the incident severities were all assumed to cross this threshold and generate benefits from diverting traffic. It would be possible to extend this analysis to investigate time periods and incident severities where it would be better not to deploy the diversion notification.

Table 6.5 Incident occurrence rate and range of annual benefits (North Shore SH1 southbound area)

Incident severity	Number per year			Annual benefits (low range)			Annual benefits (high range		
	Low	Med	High	Low	Med	High	Low	Med	High
Low	4	6	8	20,000	30,000	40,000	40,000	60,000	80,000
Moderate	3	4	5	60,000	80,000	100,000	75,000	100,000	125,000
High	1	1.5	2	40,000	60,000	80,000	50,000	75,000	100,000
Totals				**120,000**	**170,000**	**220,000**	**165,000**	**235,000**	**305,000**

Based on the above analysis, the average annual benefits are around $200,000, with a likely range (33rd to 66th percentile of above range) of benefits being $165,000–$230,000 annually.

A similar approach can be used to estimate the costs. Some cost efficiency (ie cost reduction) is anticipated with repeated implementation of the strategy, eg the need to analyse the results and identify benefits with each successful implementation is reduced. Accounting for this efficiency, the estimated cost range is around $21,000–$32,000 annually.

Based on the above estimates, the annual BCR for the North Shore incident management strategy is estimated at approximately 7–8.

6.2.5.2 Extension to other locations

The principles described in this case study can easily be applied to other locations in New Zealand where incident management strategies may be plausible. This assessment methodology can be used to estimate and establish the potential economic returns from deploying strategies similar to the technique deployed on the North Shore in other locations.

The data required to carry out an assessment in different locations is relatively straightforward. The key data is outlined below; flows and approximate travel times are the more important values. Microsimulation traffic modelling can be used either to fill in gaps in the dataset and/or as a crosscheck of saving estimates, or in a more comprehensive role to provide a direct measurement of the incident management strategy benefits. If a calibrated microsimulation model of the area exists, it is worth noting that it is very straightforward to apply a model of this form in this gap-filling/cross-checking role.

The indicative data requirements for assessing further locations include:

- typical traffic flows and travel times on the main route and the potential diversion route
- length of diversion route and any impediments to travel on this route (capacity, attractiveness etc)
- potential mechanisms for delivering messages (eg any need to install VMS)
- susceptibility to incidents and ideally records of incident occurrences, descriptions and travel times.

The costs of implementing the North Shore strategy as presented in this case study consider only the marginal additional costs for monitoring incidents, implementing diversion messages and analysing results. If a fuller or new traffic monitoring/VMS/traveller information scheme for incident management is considered then there would be a need to consider the overall capital and operating costs of the system relative to the overall benefits. In this situation, the costs would need to be more fully developed and would be another data requirement additional to those noted above. Benefits from the system being implemented over a number of years would need to be evaluated, rather than the annual approach presented in this case study.

6.3 Case study 2: SCATS intersection option evaluation: Blenheim Road/Curletts Road, Christchurch

6.3.1 Background

6.3.1.1 Description

The Blenheim Road and Curletts Road intersection is a critical connection in Christchurch's arterial road network. Blenheim Road is a key east-west corridor, linking industrial and commercial areas with the central city and Curletts Road is a key section of the inner ring route, linking to the Southern Motorway.

The intersection was selected for a case study investigation into SCATs operations options due to the local TOC's desire to investigate optimisation strategies at this intersection and its relative convenience as a test site (isolated, 'standard' layout, peak period delays and ability to transfer learnings to other sites).

The intersection is a large signalised intersection with right and left turn bays on all approaches, a double right turn from the west approach towards the Southern Motorway, and two through lanes on all approaches. Figure 6.4 shows the intersection layout, approach lanes and turning bays.

Figure 6.4 Blenheim Road/Curletts Road signalised intersection layout

6.3.1.2 Signal operation

The intersection is largely isolated from the effects of any significant adjacent intersections and coordination with other signalised corridors is not critical on three approaches. To the west is a roundabout, the intersection to the north is a reasonable distance away for this not to be a significant issue, and intersections to the south have significant capacity so that progression is not critical. The exception is to the east to/from the CBD; the Blenheim Road/Curletts Road intersection effectively forms the start of Blenheim Road corridor. Importantly, the Blenheim Road/Curletts Road intersection is coordinated with the Hansons Lane/Annex Road offset 'T' intersection 500m to the east.

The intersection typically runs the common 'diamond' signal phase arrangement. The phasing and intersection layout is shown in the SCATS graphic below.

Figure 6.5 Blenheim Road/Curletts Road SCATS intersection phasing

6.3.2 SCATS option assessment

6.3.2.1 SCATS options and alternatives

The SCATS signalised intersection control software has a range of abilities to manipulate and control signal timings and operations. Implementing effective settings requires the signal engineer to apply and adjust a range of settings.

Evaluating alternative options and establishing the optimal approach can be difficult due to the need to test settings within the real world where conditions can vary, travel demand may change, and there is the risk of adversely effecting travellers. One option to carrying out testing is linking SCATS with a microsimulation traffic model. This requires either a signal engineer with reasonable proficiency in modelling, and/or a close working relationship between the signal engineer and modeller. A modelling approach is likely to be particularly effective to test 'high-risk' signal strategies (eg more radical concepts), testing strategies across large areas (corridors, regions, or the whole network), and/or for testing strategies in areas of the network under high pressure, where the risk of significant delays is high. This is effectively a risk trade-off consideration, ie the risk of increasing user costs while testing 'live' on-street balanced against the added cost and value of modelling.

For this example, the relatively isolated nature of the intersection meant that several options could be tested in the real world without the risk of significant delays through the wider network. Testing strategies at intersections within key corridors, which influence a number of adjacent network features etc, would carry a significantly higher risk of adverse effects to travellers. Tests were carried out over a two-week period (to allow traffic demand to settle in response to any changes and to allow a suitable length of time over which to measure the effects) during non-holiday weekday periods in August – September 2015. The following tests were conducted:

- Baseline (August): Effectively the current 'base' operation. Curletts Road is the stretch phase (main phase given spare green time) and the west and south right-turn movements have calibration factors applied (to reduce the potential for the right-turn bays to fill with queued vehicles).
- Test 1: Reduced cycle time, locked at 90 seconds, particularly focused on the AM peak. Due to the reasonably isolated nature of this intersection, the focus of this test was to investigate more optimal discharge of the approach stacking space and avoid possible inefficient green time towards the end of green phases as platoons are more dispersed.
- Test 2: Changed Blenheim Road to stretch phase (potentially improves coordination to east with Hansons Lane/Annex Road intersection) and removed right-turn calibration factors.

6.3.2.2 Assessment approach

Approach delays were measured in 15-minute intervals over the test period from Christchurch Traffic Operations Centre's Araflow Bluetooth travel time monitoring system. The Bluetooth system detects the Bluetooth unique identifier as it passes each detector and provides travel times between detectors. It samples roughly 10% of traffic in the Christchurch network, and the sample rate increases during the AM and PM peaks (12%–14%). A Bluetooth detector is located at the Blenheim Road/Curletts Road intersection, and the adjacent detectors are located at the major intersections immediately upstream (1–3km away):

- North approach, at the Curletts Road/Main South Road/Riccarton Road intersection.
- East approach (and exit), at the Blenheim Road/Whiteleigh Avenue/Clarence Street intersection. Note, this link includes the Hansons Lane/Annex Road intersection (the linked intersection immediately to the east) and will measure any associated improvement/detriment from changed coordination with this intersection and the Blenheim Road corridor to the east.

- South approach, at the Curletts Road/Southern Motorway interchange and will measure any associated improvement/detriment from changed coordination with the intersections to the south (Parkhouse Road and Lunns Road).
- West approach, at the Sockburn roundabout.

The Bluetooth system is ideally suited to robustly measure the approach delays during each phase of the testing.

Volumes estimates by approach were extracted from SCATS detector information to provide an estimate of vehicle demands.

6.3.2.3 Travel time and volume outcomes

Figures 6.6 and 6.7 show the weighted average approach travel time (the average approach travel time from the upstream detector to the intersection detector, weighted by the volume on each approach) and the estimated approach volume across the three test periods.

Figure 6.6 Weighted average intersection travel time

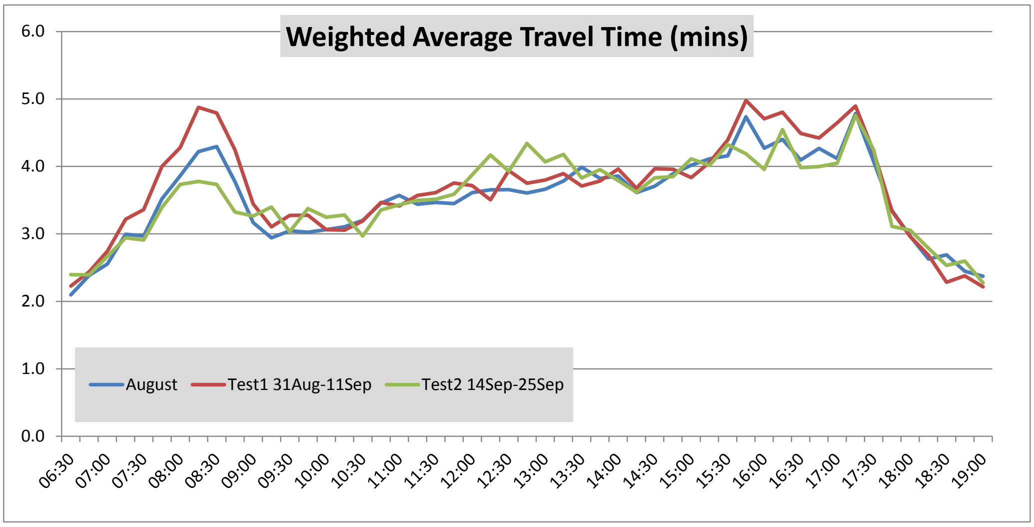
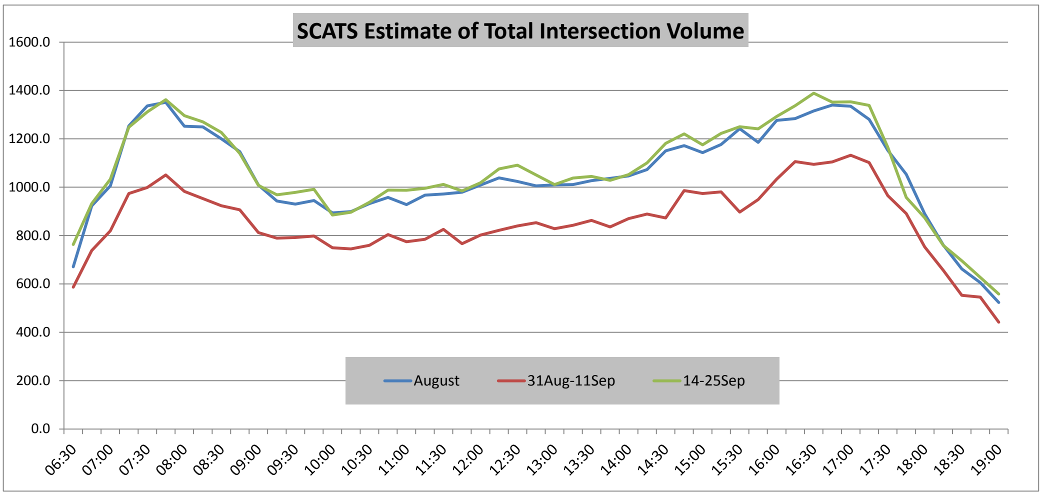


Figure 6.7 Overall intersection volume estimate (SCATS detector observations)



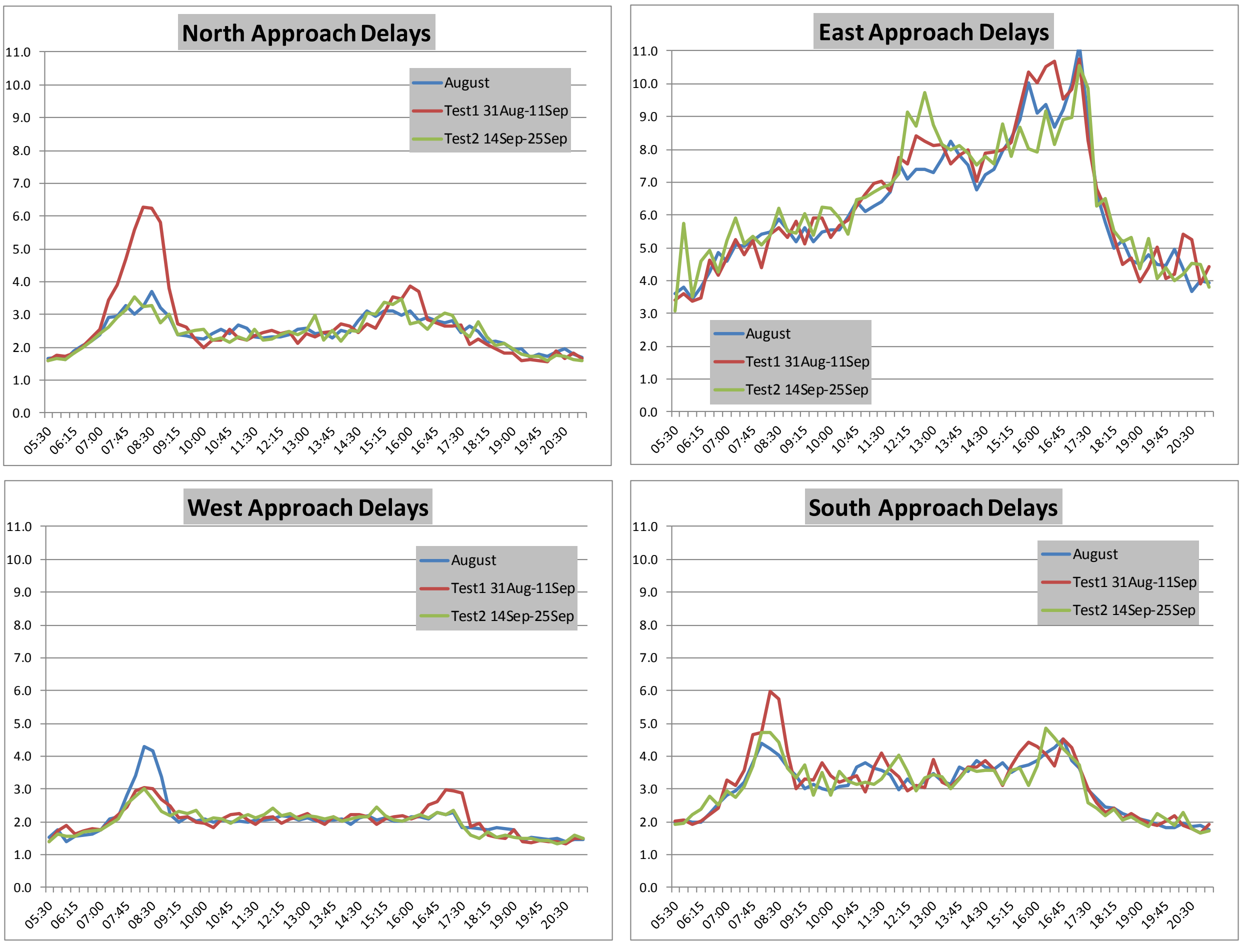
The above graphs show that the shorter cycle time test (31 August – 11 September) deteriorated performance relative to the base and other test.

The SCATS volume estimate shows a significant drop in volumes during the shorter cycle testing (31August – 11 September). Volume reductions were unlikely to have been as significant as shown in this figure. The effect was likely to be due to the reduced cycle time affecting the SCATS detection algorithms. It should be emphasised that SCATS volume information is only an estimate.

Delays were higher particularly in the AM peak. Figure 6.8 shows the delays by approach. This demonstrates that the shorter cycle test was particularly problematic on the north and south approaches, but reduced delays reasonably significantly on the west approach in the AM peak.

The recalibration test (14 September – 25 September) produced notably lower delays in the AM and PM peak periods. This was largely due to improvements on the west approach. The results on the other approaches were similar to the August 'baseline'. The eastbound exit link from the intersection towards the CBD also demonstrated some minor peak period travel time savings, which were likely to be from improved coordination through the intersections to the east (Hansons Lane, Annex Road and further east).

Figure 6.8 Individual intersection approach delays



6.3.3 Economic assessment

6.3.3.1 SCATS and staff costs

Economic assessment needs to consider both the benefits and costs of implementing schemes. Although the cost component of this work is potentially small, it should not be discounted from any economic assessment. The costs were calculated assuming this exercise could be carried out roughly once per year for intersections of this nature to verify the optimal operation strategy. There are three cost components to include:

- SCATS software annual maintenance cost to enable options and optimisation: $700–$900 (per intersection)
- signal engineer time to develop options, programme SCATS and monitor: $2,700
- analyst time to analyse SCATs and Bluetooth data and assess optimal strategy: $1,500

The total cost of assessing and developing optimisation options for an intersection of this nature is approximately $5,000 annually. The cost of collecting the Bluetooth data was not included in this assessment as the Bluetooth system exists in-situ in the Christchurch network and is generally used for other purposes (eg real-time network monitoring).

The infrastructure costs associated with physically running the traffic signals (power, communications, maintenance etc) were not included in this assessment. These are part of the existing infrastructure and costs would have been evaluated when the signals were installed, rather than being part of this project to optimise the infrastructure.

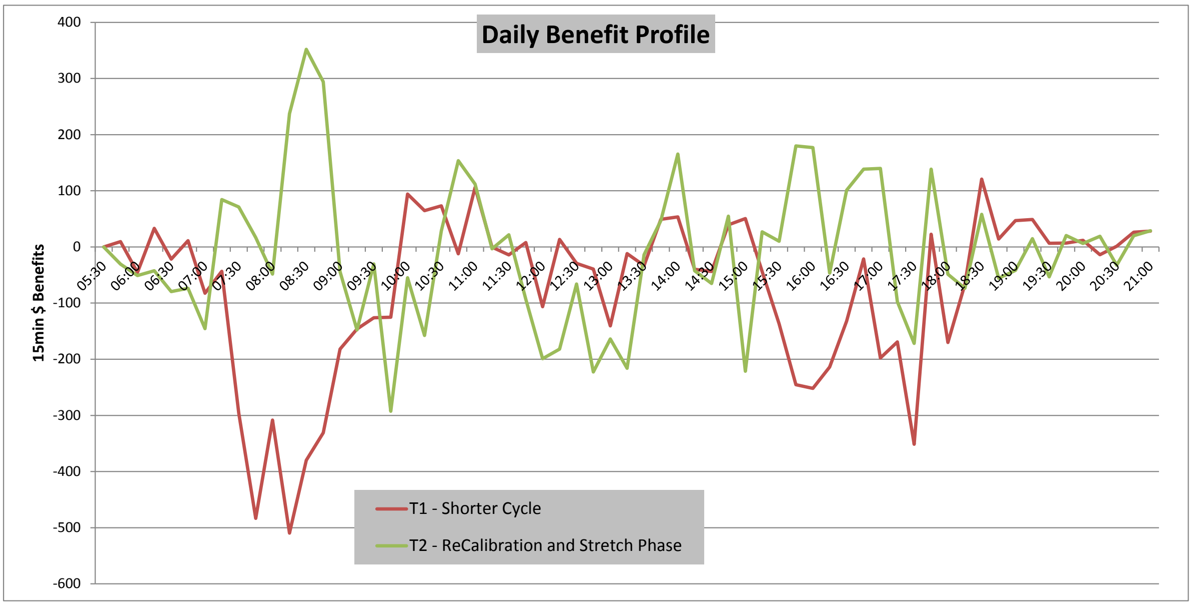
6.3.3.2 Benefit calculation

The economic benefits of the two test options were calculated from the 15-minute travel demand estimate and delay saving (difference between the 'baseline' and test option). The EEM July 2014 values of time for the AM, interpeak, PM and night, including the congestion increment, were applied to the 15-minute time saving per vehicle to calculate the benefit stream through the day.

Small operational changes to a single intersection are unlikely to significantly affect the total travel demand and vehicle distance travelled. Therefore VOCs and environmental benefits were been assessed. It is possible that travel time reliability and frustration benefits could accrue from improved signal settings and reduced peak period delays. These were not evaluated in this assessment as the value of time savings significantly outweigh the costs and therefore the return from the effort of carrying out this analysis is limited.

Figure 6.9 shows the daily benefit profile from VOT savings. A positive $ value indicates a benefit saving of the option and a negative a disbenefit.

Figure 6.9 Daily benefit profile of SCATS options



The lower cycle time test generates disbenefits through the majority of the day. These daily disbenefits were annualised across non-holiday weekdays, giving a total annual disbenefit of $1,000,000–$1,100,000. This is an important result; it demonstrates that if sub-optimal or untested signal settings are implemented over a long period there can be significant economic detriment. It also emphasises the usefulness of analysing data (or modelling) to check and confirm optimal approaches and the work of the signal engineer/SCATS system to develop signal options.

The second test option demonstrated reasonably significant benefits in the AM and PM peak periods, but disbenefits in the interpeak and shoulder periods. This suggests that the optimal approach is to implement the 'baseline' settings in the shoulder periods and interpeak, ie apply the baseline before 7am, 9am–3:30pm, and after 6pm, and the 'test 2' settings during the peaks. If this approach was employed, the shoulder and interpeak disbenefits would not occur and the additional benefits from employing test 2 would be approximately $320,000–$340,000 annually.

The total disbenefits (delay to travellers) from carrying out the four weeks of testing was $40,000–$50,000, which could arguably be taken from the annual benefits noted at the end of the paragraph above. However, this cost is common to all options assessed and therefore can be cancelled from the BCR evaluation. It is also more likely that the optimal settings will be in place for a period greater than a year and returns will be greater than these figures.

6.3.3.3 Cost/benefit assessment and potential extrapolations

The assessment outlined above demonstrates potentially high returns from small investments of staff time and short periods of on-street testing to develop optimal signal strategies. The BCR from the above work is estimated at around 65.

In the Canterbury region there are around 330 signalised intersections. Assuming conservatively that 5% of these intersections have similar characteristics, then carrying out a similar exercise across the Christchurch network has the potential to save very roughly $4,500,000 annually.

6.4 Case study 3: Operations treatments lifespan investigation: Pineacres intersection

6.4.1 Background

6.4.1.1 Case study context

Operations treatments such as ITS measures have the potential to improve network performance and safety and in some cases to extend the lifespan of existing physical infrastructure, and as a result defer costly infrastructure upgrades. Assessments exploring these issues and investigating the potential for operations treatments to provide these benefits could be carried out as part of the business case assessment framework. Such assessments would generally involve modelling, data and economic analysis.

RIAWS is an example of an operations treatment which could defer more costly intersection upgrades. The RIAWS treatment is described further below; the key concept is to display a reduced speed warning sign on the main route when side road traffic is detected at rural priority intersections with poor safety records. This case study demonstrates how the modelling and economic analysis processes of a wider business case assessment could be carried out to include evaluation of the operations treatment and lifespan/economic optimisation considerations.

The purpose of this case study investigation was to demonstrate the principles of carrying out these analyses which could support a business case assessment, particularly incorporating operations treatments and assessing how these might increase the lifespan of existing physical infrastructure. This case study should not be considered a robust estimate of the benefits of the RIAWS treatment or a robust exploration of physical infrastructure options at the Pineacres intersection. The reason for this is because the case study was focused on the lifespan investigation elements rather than the detail of each option; therefore a full and comprehensive safety investigation was not applied to the RIAWS scheme and a full and comprehensive design and costing exercise was not carried out for the grade separation scheme (a comprehensive study would involve a more substantial transport planning exercise).

6.4.1.2 RIAWS scheme: Pineacres intersection

A RIAWS scheme has been operating at the intersection of SH1 (Main North Road) and William Street north of Kaiapoi for several years (generally referred to as the 'Pineacres' intersection). The intersection is a seagull 'T' priority control, with several merge lanes which tend to operate to some degree as priority controlled movements rather than conventional merges. The layout of the intersection is shown below in figure 6.10.

The RIAWS scheme applies a 70km/h advisory speed warning system to the north and south SH1 approaches (existing speed limit 100km/h) to the intersection when vehicles are detected on either the Williams Street side road east approach (turning right out of the side arm), or in the SH1 right-turn bay from the south approach (adjacent to the 'Main North Rd' text in the figure below).

Figure 6.10 Pineacres intersection layout

(Note that the Pineacres intersection is at the northern extent of the area analysed in the incident investigation presented in appendix C. This case study is not linked with the analysis in appendix C, but the intersection model has been cut out of the wider area network.)

6.4.1.3 Intersection upgrade options

Although the RIAWS scheme is currently in place, the case study was carried out assuming this operations system had not been installed and the base (do minimum) scenario was the core priority controlled intersection. The RIAWS system was evaluated as an upgrade option, along with a basic grade separated option. The grade separated layout includes northbound and southbound on and off-ramps, and a straightforward priority intersection layout where the ramps intersect on the overbridge. The grade separated option was considered as a treatment to accommodate future traffic growth and was estimated from the regional transport model.

6.4.2 Crash analysis and transport modelling

6.4.2.1 Crash analysis

RIAWS schemes have been installed at a number of intersections around New Zealand. At six sites the scheme has been operational for some time – on average two years at the time of this analysis. Crash Analysis System (CAS) analysis had been conducted at these six sites for five years prior to the RIAWS installation, and for the period of time since the RIAWS scheme has been in place. This analysis, along with the trial data and investigations carried out by the Transport Agency, indicates it is likely the RIAWS scheme is an effective low-cost safety treatment.

For the grade separated option, CAS analysis has been carried out on two interchanges south of the Pineacres intersection, which have similar layouts and traffic flow characteristics to this option. Crash rates at these two interchanges have been averaged and factored by the volume in this section of the network relative to the volume at Pineacres. This indicative analysis shows that the grade separated option has crash benefits relative to the do minimum, but has disbenefits relative to the RIAWS scheme. Although the grade separated scheme has safety benefits relative to the do minimum, fatal and serious crash rates are still marginally higher than the RIAWS scheme due to the higher speed environment and conflicts at higher speeds (around the merges), and the increased risk due to physical infrastructure (eg bridge abutments) adjacent to the state highway. Detailed crash data is provided in table 6.4.

The CAS analysis was used to estimate annual crash rate reductions from the installation of the RIAWS and grade separated options.

6.4.2.2 Transport modelling

The RIAWS scheme is a dynamic treatment. The 70km/h reduced speed limit is only invoked when vehicles are detected on the side arm, and then will only have an effect if vehicles on SH1 travel past the reduced speed warning sign during the period when vehicles are present on the conflicting movements. When the intersection volumes are low, particularly on the side road, the reduced speed effects will be intermittent and are not significantly detrimental to the state highway traffic.

The system was directly modelled in a microsimulation model. A simple ITS controller was developed by SIAS (developers of the Paramics microsimulation software) and linked to a model of the Pineacres intersection. The model and controller replicate the RIAWS system and intersection operation based on the on-site operation – individual vehicles are detected in the model on the side arm and right-turn bay, the speed reduction is applied to the state highway and vehicles which pass the speed reduction sign respond to the 70km/h reduced limit (the RIAWS evaluation report indicates a high level of compliance with the advisory speed limit sign). Replicating the RIAWS system within the model also assesses any alteration to the ability of vehicles on the side road to find gaps in the oncoming traffic due to the reduced speed of oncoming traffic on the state highway.

A 24-hour weekday 2014 base-year model was developed based on link counts on William Street, TMS link count data on the state highway and turning movement proportions at the intersection. Flows in the microsimulation model were profiled in five-minute intervals through the 24 hours (profiles calculated from the detailed 15-minute traffic data) to account for the traffic peaks and tidality.

The Pineacres intersection is within the northern Christchurch commuter area. Some land-use development and transport growth is expected in this area in the future. Growth from the Christchurch Transportation Model (CTM) was estimated for the intersection surrounds for 2041, and two intermediate forecast years (2023 and 2032) were calculated. The three model scenarios (base, RIAWS, grade separation) were run over the four demand scenarios (2014, 2023, 2032 and 2041).

6.4.3 Economic analysis

6.4.3.1 Option costs

Costs for installation of the RIAWS scheme were taken from the RIAWS evaluation report (Mackie and Scott 2015), as an average of the range presented ($120,000 – $180,000). The report notes the importance of including a reliable monitoring system and scheduled preventative maintenance to minimise down time. Therefore annual maintenance costs were considered as being higher than typical road schemes.

Rough estimate costs were:

- RIAWS: $150,000 installation; 7.5% of installation per annum maintenance.
- grade separation: $2,600,000 installation; 2% of installation per annum maintenance.

6.4.3.2 Safety benefits

The EEM crash-by-crash analysis method was used to estimate the annual crash savings of the two options. EEM factors for converting reported to total crashes were applied to the July 2014 updated $ cost per crash values for fatal, injury, non-injury and minor crashes. Year-to-year savings were calculated by factoring according to the estimated traffic growth. The crash rates from CAS analysis and benefits (relative to the do minimum) are provided in table 6.6.

Table 6.6 RIAWS and grade separation annual crash rates and annual benefits

	Fatal	Serious	Minor	Non-injury	Total
Annual crash rate – do minimum	0.03	0.40	0.70	1.27	2.40
Annual crash rate – RIAWS scheme	0.00	0.00	0.26	0.60	0.85
Annual crash rate – grade separation scheme	0.02	0.03	0.35	0.95	1.35
RIAWS – total annual benefits ($ 2014)	157,000	382,000	60,000	37,000	636,000
Grade separation – total annual benefits ($ 2014)	79,000	350,000	47,000	18,000	494,000

6.4.3.3 Value of time savings

The EEM July 2014 value of time for the night, AM, interpeak and PM periods were applied to the hourly saving per vehicle. The benefits were annualised across corresponding weekdays and the interpeak and night benefits annualised across weekends where weekend flows were approximately equivalent to the weekday flows.

Environmental, reliability and frustration benefits/disbenefits were not assessed as these were likely to be minimal.

6.4.3.4 Benefit profiles

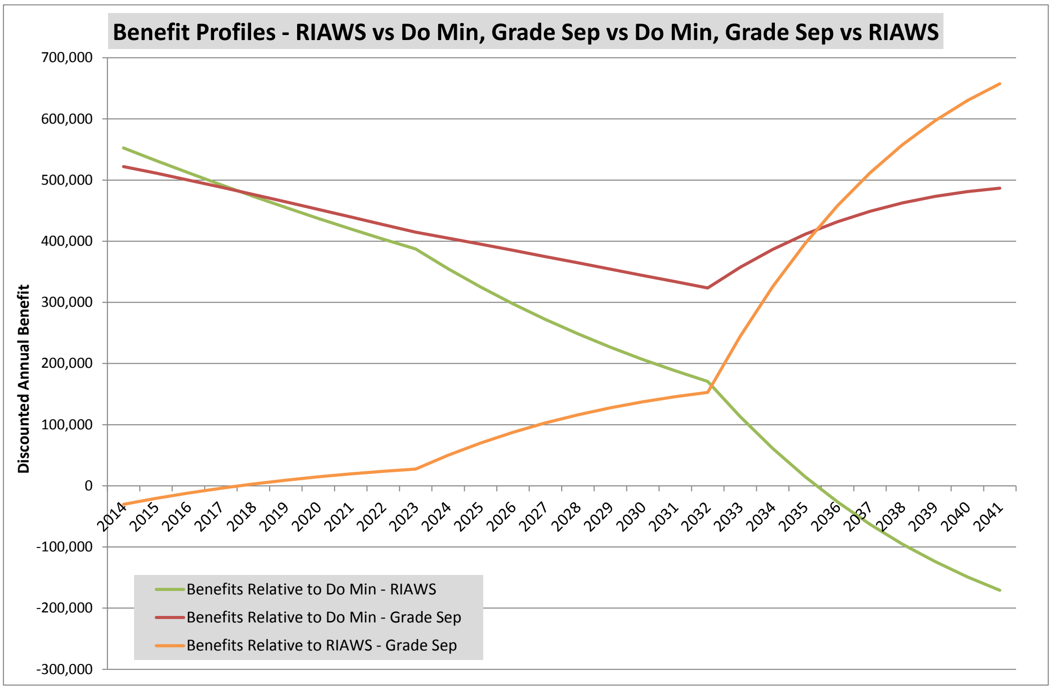
The RIAWS option showed benefits for the initial period of the assessment, particularly due to the safety savings. After a period of traffic growth, the intersection capacity began to be exceeded and delays built up. When traffic volumes became greater, the RIAWS scheme produced a disbenefit in time saving relative to the do minimum due to the slowing of vehicles on the state highway and operation of the intersection. In the do minimum, state highway vehicles travelling north–south remained unimpeded and largely unaffected by traffic growth. When the disbenefit in time savings began to outweigh the safety benefits, the RIAWS scheme returned a negative annual benefit indicating that its lifespan was effectively expired.

The benefits from the grade separation option were not high in the initial assessment period. This option did not offer safety benefits that were as substantial as the RIAWS scheme. The grade separation option has safety benefits relative to the do minimum, but the arrangement of the intersection resulted in conflict areas (eg ramp merges) at 100km/h speed limit whereas the conflict areas in the RIAWS option were at reduced speeds. This is an assumption of the assessments based on the indicative CAS and safety analysis. The travel time savings of the grade separation option did not begin to become significant until traffic growth was higher and delays in the do minimum became more significant. The benefits of the grade separation option became more significant later in the assessment period as the intersection capacity was exceeded.

To carry out the incremental BCR assessment, the benefits of the grade separated option were calculated relative to the RIAWS scheme (as opposed to relative to the do minimum, the benefits of the grade separated option were also calculated relative to the do minimum for comparative and descriptive purposes). The RIAWS scheme has greater safety benefits in the initial years and therefore the grade separated option showed negative savings as travel time benefits were not significant enough to outweigh the safety disbenefit. However in later years the travel time savings of the grade separated option became more significant relative to the RIAWS scheme. Eventually the benefits of the grade separated option relative to the RIAWS scheme outweighed the benefits relative to the do minimum because of the slower state highway speeds in the RIAWS scenario.

The benefit streams, as described above, are shown below in figure 6.11.

Figure 6.11 Annual discounted benefit (safety and time) profiles



6.4.3.5 Incremental BCR calculation

An incremental BCR analysis was carried out. The BCR of the RIAWS option as the lowest cost scheme was evaluated against the do minimum and the BCR of the grade separated option against the RIAWS scheme. As indicated above, the RIAWS scheme has a limited life and therefore benefits were evaluated over its lifespan (approximately 10 years due to benefit profile). The benefits of the grade separation option were evaluated over the full 40-year evaluation periods as per EEM guidance. The incremental BCR (BCR of grade separated relative to RIAWS), along with the BCR of the grade separated option compared with the do minimum, were calculated based on the year of implementation of each scheme. The results are shown in table 6.7.

Table 6.7 BCR results based on year of implementation

	BCR		
	RIAW vs do minimum	**Grade separation vs do minimum**	**Grade separation vs do minimum**
2014	20.6	4.6	3.1
2015	21.3	4.8	3.4
2016	22.0	4.8	3.4
2017	22.5	5.2	3.9
2018	22.9	5.4	4.2
2019	23.3	5.6	4.6
2020	23.5	5.8	4.9
2021	23.5	6.1	5.2
2022	23.4	6.3	5.6
2023	23.3	6.5	6.0
2024	22.3	6.8	6.4

Table 6.7 shows the BCR of the RIAWS scheme is immediately viable (ie can be installed in year 1) and would return a BCR of approximately 20–21.

The NZ Transport Agency's (2014c) *Investment assessment framework* identifies BCR thresholds of 1 to 3, 3 to 5, and 5+. Using an improvement efficiency criteria weighting of BCR 5.0+ as a guide to scheme viability and the incremental BCR assessment approach, the grade separation option in isolation would pass this threshold around 2016–2017 (relative to the do minimum).

Evaluating the benefits of the grade separation option relative to the RIAWS scheme, the grade separation option would pass the efficiency criteria around 2020–2021, ie by 2021 the incremental benefits of the grade separation option (over RIAWS) would be sufficient to justify its implementation (based on an incremental BCR threshold level of 5.0).

6.4.3.6 Lifespan and deferment savings

As described above, the incremental BCR exceeds 5.0 for the grade separation option at 2020–2021. This BCR threshold and incremental analysis indicates it may be possible to defer the grade separation option for around five to six years. If the RIAWS scheme had not been assessed, or if the RIAWS scheme was not as beneficial, the grade separation would exceed the BCR 5.0+ threshold earlier, at 2016.

This deferral of expenditure is around $700,000–$800,000 (saving in discounted scheme costs).

It should be noted that at 2020 the RIAWS scheme would still demonstrate significant benefits and the benefits would not degrade more significantly in the next five years.

6.4.4 Pineacres case study conclusions

The case study and analysis presented above illustrate the principles of assessing an operations activity within the wider Transport Agency assessment framework, including the application of the EEM incremental analysis methodology. They demonstrate the principles of extending the lifespan of existing infrastructure through operations treatments and potential savings due to deferring more costly improvements.

7 Application to business case assessment

7.1 Background

The Transport Agency currently uses a business case approach to guide planning, investment and project development. This links the transport strategy to outcomes and defines problems and their consequences before identifying solutions.

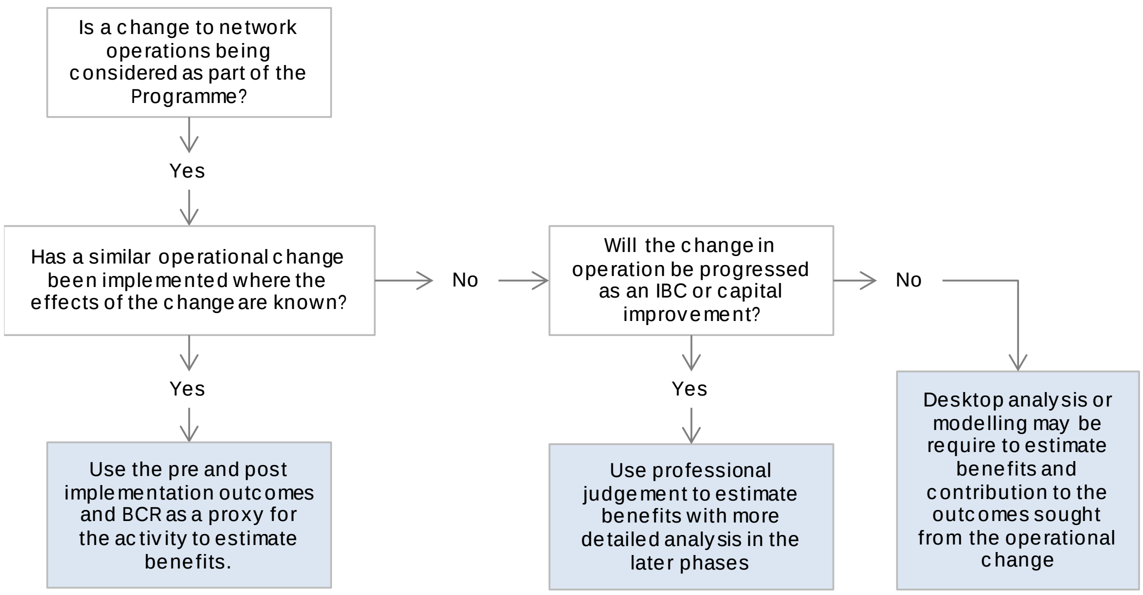
Operations activities should be considered within the suite or range of potential solutions following the identification of problems and in the development of the strategic case. This ranges from problems which are strongly linked with operational solution (eg signal optimisation opportunities, incident management) through to considering the potential operations activities may have for extending the lifespan of existing infrastructure and delaying more costly investiture (eg infrastructure upgrades), being a substitute activity for more expensive infrastructure upgrades and inclusions of operations systems within newer transport schemes or as part of other upgrades (eg widening, intersection reconfigurations).

The findings of this research project and the economic assessment framework outlined in chapter 1 provide a foundation and an evaluation system for carrying out the assessment of operations solutions within a business case assessment. The sections below outline the elements of the research and key decisions as they apply to the programme and indicative business case stages (if operational activity components are progressed to a detailed business case, this would build from the analysis and assessment carried out at the indicative business case stage).

7.2 Programme business case

The programme business case stage identifies programmes of work and/or activities that deliver on the strategic case and identifies alternative and options. Data and evidence gathering is a key step in this stage of the assessment and the figure below indicates key decisions on potential methods for carrying out this analysis for operations activities.

Figure 7.1 PBC key assessment decisions relating to operations activity evaluation



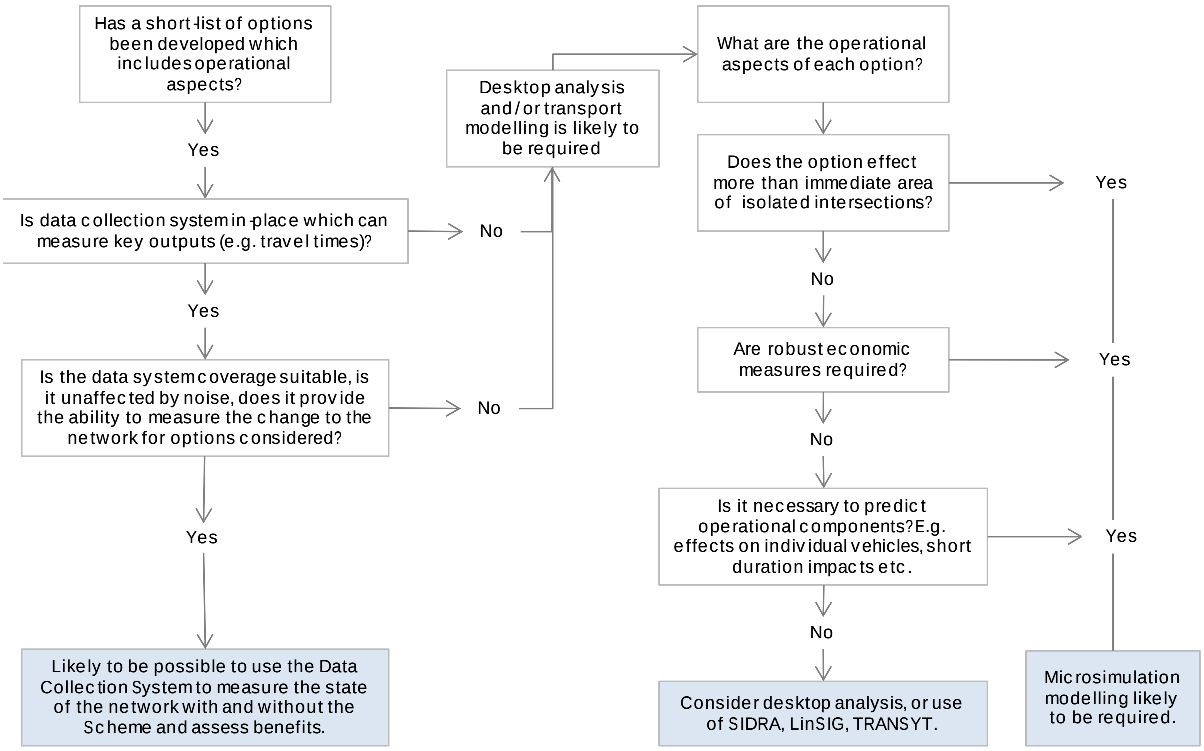
At the programme business case stage and linked to the figure above, the key sections of this research report are:

- section 4.1.1: background on pre- and post-implementation assessments
- section 5.3 (economic framework): notably C2 (background to BCR calculation) and sections D and E (estimation of cost and benefits)
- section 4.3.3: background information on analysis method considerations (data measurements systems and/or transport modelling approaches).

7.3 Indicative business case

The indicative business case (IBC) progresses individual activities each of which has an IBC developed where necessary. At this stage a fuller assessment of costs and benefits is required and this will involve a more detailed consideration of the assessment approach. Figure 7.2 outlines key decisions relating to the assessment of any operations activities which have IBCs developed,

Figure 7.2 IBC key assessment decisions relating to operations activity evaluation



At the IBC stage and linked to the figure above, the key sections of this research report are:

- section 4.3.3: background information on analysis method considerations (data measurements systems and/or transport modelling approaches)
- appendix B2: considerations relating to specific forms of transport modelling approaches
- section 5.3 (economic framework): table 5.2, sections A1 (time period), B1 (do minimum definition), B2 (range of options, operational components, and project improvement timings), section C (BCR, incremental BCR, and first year rate of return) and sections D and E (estimation of cost and benefits).

8 Conclusions and recommendations

8.1 Conclusions

A number of key conclusions were developed from the work undertaken during the initial investigation phase of the research into economic assessment frameworks and methodologies. The core conclusions are summarised below and these form key points of consideration within the economic framework:

- Key elements of the day-to-day TOC and journey manager work (optimisation, planned and unplanned events, and provision of traveller information) have an economic impact on the transport system. The key findings from this research project establish the principles, methodologies and analysis techniques for assessing the economic benefits of these operations activities.
- The framework developed, and key economic principles described below, fit within the wider Transport Agency policies and assessment framework. Importantly, the research findings and economic framework provide a practical tool for assessing operations treatments which may extend the lifespan of existing infrastructure potentially delaying more costly capital expenditure. Such operations treatments should routinely be considered within a business case assessment of potential solutions.
- A similar assessment framework is applicable (in principle) to pre-implementation and post-implementation economic assessments of network operations activities (ie analysis carried out from forecast results using transport models, and/or analysis carried out from on-street data measurement).
- The appropriate framework in both cases will be that provided through social CBA, ie a similar framework to that underpinning the EEM.
- The economic impacts that are relevant for operations activities are all covered in the EEM.
- It will generally be appropriate to adopt the same economic parameter values as used in the EEM (except in particular cases).
- The main economic ranking criterion for projects assessed through CBA will generally be the BCR (as defined in the EEM), where:
  - benefit and cost items are based on the national economic viewpoint
  - costs are those items funded by governments (at all levels)
  - benefits are those economic impacts accruing to transport system users or businesses
  - all benefits and costs are to be discounted at the standard EEM discount rate (currently 6% pa, in real terms).
- For projects with minimal (net) costs to government, project options may be ranked in terms of benefits only. For projects where all options involve similar benefits (eg to provide a specified standard or level of service), options may be ranked in terms of minimum discounted costs.
- The economic life of an activity is to be based on the effective ‘operational’ life of the main assets involved. For temporary traffic management and similar schemes, the project life would be the time period for which the temporary measures are in operation.
- Requirements for sensitivity testing of economic parameters for operations activity assessment (eg sensitivity testing of the EEM discount rate) are limited.

- All economic assessments compare the merits of two scenarios – the 'project' case and a 'do minimum' case (without the project). The do minimum case needs to be carefully considered for each project:
  - often it may be a literal do nothing situation
  - it may include some minimal level of ongoing investment, required to keep the network operating at a minimum level of service
  - it should not be an unrealistic scenario, eg evaluation of a signal optimisation option against an unrealistic alternative such as fixed timings.

8.2 Case study findings

The application of the economic assessment framework to the three case studies generated the following more generalised findings. These points may be of specific interest to the Transport Agency and in general may provide guidance or assistance on the further economic analysis of network operations initiatives:

- Generally operations activities generate high BCRs, indicating they are highly cost-effective treatments. This is particularly notable for optimisation projects – small investment of staff and analyst time alongside existing software and system capability (eg SCATS) can offer high relative returns. This finding supports much of the evidence gathered through the New Zealand and international literature review.
- Operations activities can extend the lifespan of existing infrastructure and offer savings due to deferring more costly improvement options. In particular, this has been illustrated within the Transport Agency business case and economic evaluation framework.
- An aspect noted during the literature review was that often operations activity assessments evaluate a single option, eg optimisation projects which appeared to develop and analyse just one (final) approach. It is clear from the SCATS case study that development of several options can be of some benefit. In the example presented, the optimal strategy and significant benefits were generated by a mix of two alternative approaches (one during the peak periods, and an alternative in the interpeak).
- There is the potential to develop more generalised operations 'strategies' (eg generic signal optimisation strategies, incident management guidelines and similar) from carrying out a smaller number of economic case studies and confirming high returns. These strategies could be applied across wider areas of the network on the assumption that the majority will generate benefits and, due to the high returns, the risk of detriment to travellers is minor.
- Some care needs to be taken with economic analysis due to potential for factoring and missing/incorrect parameters to have a significant effect. It is suggested that economic assessment of activities should generally be reviewed by a practitioner with experience in transport planning and economic principles. This point comes from discussion with TOC staff on previous analyses completed, sensitivity testing results, and (critically) review of the case study analyses by the wider research team members and research project peer reviewers.
- The quality of the data that feeds the assessment is an important consideration in evaluating operations activities (also relates to above point re: reviewing). This is a somewhat inane point as it is well established and understood in the transport planning industry (often expressed as 'rubbish in = rubbish out'). However, in contrast to larger infrastructure planning projects, operations activities may rely on more marginal savings – estimating these savings robustly becomes critical to the overall

assessment outcomes and places significant emphasis on the techniques used to provide these measurements (the on-street data system, and/or the transport model).

8.3 Recommendations

A number of areas of extension, further investigation and more detailed consideration have been identified through the research project, and notably from the case study investigations. These are set out below, and most involve the application of the economic assessment framework and the general findings of the research project to extended areas of exploration and/or real operations project work.

- The strong potential for high economic returns from operations activities was identified through the literature review and is demonstrated in the case studies. In discussions with operations staff and through industry knowledge, the authors understand there are various mechanisms for prioritising and funding capital works projects. This includes minor efficiency projects which may be in the order of several hundred thousand dollars (eg extension of right-turn bays, provision of staggered pedestrian crossings). Case studies 1 and 2 (incident management and SCATS options) demonstrate high economic return from staff and systems (data collection, monitoring etc) investment. It is possible, or even probable, that investment in non-capital costs could have significantly greater value-for-money than infrastructure investment, particularly at the levels of minor efficiency funding. The research could be applied to explore this potential further and possibly identify more optimal funding strategies.
- Further research into the suitability (or otherwise) of alternative transport modelling techniques for robustly measuring the benefits of operations activities. Given that operations activities generally have short lifespans and often before/after data measurement can be carried out, it is suggested that this investigation should consider modelled predictions (of key economic parameters) against observed outcomes (refer section 4.2.2 and appendix C).
- Implementation and application of systems which measure network performance, notably point-to-point or link travel times, is currently of significant interest to TOC activities. These systems are used to provide traveller information, for business intelligence, and to measure outcomes of TOC activity. Case study 1 (refer section 6.2.3 and appendix B) identified a potential issue (possibly associated with sampling) in the dataset used for the analysis. This could be investigated further, and work could extend to cover the general suitability of on-street data collection systems for establishing robust travel time measurements.
- It should be possible to identify areas in the New Zealand network with similar characteristics to the North Shore example (including potentially viable alternative routes) and identify locations where incident management systems may offer benefits. If infrastructure and new services are required, this could extend to analysis of the wider lifespan of these systems (refer case study 1, section 6.2.5).
- Wider application of this research to measurement of the TOC activities working in combination, or across a wider area (ie whole network) could identify further benefits, funding opportunities, efficiencies and improved targeting of TOC and RCA planning activities. This could extend to an assessment of the TOC's 'base level' of operations (eg day-to-day upkeep of real-time and ITS systems), although the added value from this exercise may be questionable.
- Possible case studies identified through discussion with the Steering Group and TOC staff did not include any schemes specifically targeting PT and/or pedestrians, although this was a noted issue in Steering Group discussions and an area covered by the research project. The framework could be tested against pedestrian and PT operations projects.

- There is an emphasis (from operations practitioners in New Zealand and identified in the literature review) on the use of before and after data measurement to assess the benefits of operations activities. This has a degree of associated risk (it requires the scheme to be implemented before it is assessed) and outcomes may not be clear (‘noise’ in on-road environment, parameters/measurements missed etc). This research can be applied to carry out a moderately extensive exercise evaluating the relative merits of the two approaches (modelling vs on-street data measurement). This could consider identifying when/where/what activities may be riskier to implement without pre-scheme assessment; whether modelling tools available have the capability to robustly measure the on-street outcomes from certain activities; and what margin of difference may exist between model estimates and on-street measurements outcomes (and why this might be and identification of risks with each approach).

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ITS International articles reviewed (refer appendix A1)

Cost saving multi-agency transportation and emergency management. (Apr 2010)

Reducing incident clear-up times, saving money (Oct 2011)

Integrating traffic systems improves management and control (Apr 2012)

Automatic speed enforcement in Finland (Jun 2010)

Wireless traffic management reduces costs and commute times (Feb 2010)

Signal optimisation reduces congestion, improves travel times (Apr 2011)

Adaptive control reduces travel time, cuts congestion (Aug 2011)

Benefits of traffic light synchronisation (Jun 2011)

Adaptive traffic control drives financial benefits (Oct 2009)

Cost benefits of LED traffic signals (Jun 2009)

Re-timing traffic signals delivers cost benefits (Apr 2009)

Real time traffic control aids travel time reduction (2012)

Report analyses multiple ITS projects to highlight costs and benefits (2015)

TfL expands SCOOT adaptive traffic management (2012)

SCATS study shows significant savings (Dec 2013)

Benefits of Florida's traffic signal retiming (Oct 2012)

Mounting benefits of dynamic tolling project Feb (2010)

Barcelona finds speed cameras save money and lives (2012)

Study finds speed cameras cut fatal accidents (Feb 2012)

Refurbishing ageing VMS with new technology (Dec 2011)

Upgrading Koblenz's traffic information system (Feb 2013)

Road space utilisation improves travel times, reduces costs (Jun 2010)

Dynamic lane closures cuts time, cost and congestion on motorway roadworks (Feb 2014)

Moveable barriers improve workzone safety, reduce costs (Apr 2011)

Workzone safety can be economically viable (Oct 2014)

Other ITS International articles

Scorecard scores. (July/Aug 2009)

Social media a one-stop shop for travel information. (Aug 2011)

Ramp metering delivers – again. (May/June 2011)

Impact of speed limits in Barcelona (Jan/Feb 2011)

UK average speed camera installation proving successful (Jan 2015)

Instant messaging for Manchester’s (Feb 2010)

Wireless traffic management reduces congestion and commute times (2010)

Adaptive traffic control drives financial benefits (Jan/Feb 2009)

Solar studs a cost-effective alternative street lighting (Sep/Oct 2009)

Cost benefits of LED traffic signals (May/Jun 2009)

Europe calls for guidance on evaluating project (Sep/Oct 2012)

ITS advancement lays beyond benefit-c analysis (May/Jun 2013)

The Canadian way (May/Jun 2009)

Appendix A: Literature review evaluations

A1 Core summary of international literature

#	Cat 1	Cat 2	ITS Article Title	Publ date	Scheme Title/Agency	Benefit Framework	BCR / Net
1	NM		Cost saving multi-agency transportation and emergency management	01-Apr-10	Houston TranStar (multi-jurisdiction transport & emergency management agency).	CBA	11.4
2	RTO	IM	Reducing incident clear-up times, saving money	01-Oct-11	Towing and recovery incentive programme (TRIP).	CBA	11
3	RTO	IM	Integrating traffic systems improves management and control	01-Apr-12	STREAMS Motorway traffic management and control system (Transmax). VicRoads, Aust.	CBA	>$1M per day
4	RTO	SE	Automatic speed enforcement in Finland	01-Jun-10	Ext. of automatic speed enforcement cameras. Finland.	CBA (partial)	c4.0
5	RTO	TC	Wireless traffic management reduces costs and commute times	01-Feb-10	Wireless traffic monitoring and management system. LA County Department of Public Works.	No formal CBA.	
6	RTO	TC	Signal optimisation reduces congestion, improves travel times	01-Apr-09	Traffic signal optimisation, Metro Nashville, Tennessee USA.	CBA	21
7	RTO	TC	Adaptive control reduces travel time, cuts congestion	01-Aug-11	Reduce arterial congestion (adaptive control software). San Diego County, USA	CBA	8
8	RTO	TC	Benefits of traffic light synchronisation	01-Jun-11	Alicia Parkway signal synch. (11 mile corridor, 41 signalised intersections). Orange County Tptn Authority, CA, USA	CBA	
9	RTO	TC	Adaptive traffic control drives financial benefits	01-Oct-09	Adaptive traffic control system (52 intersections). City of Cartagena, Columbia.	CBA	
10	RTO	TC	Cost benefits of LED traffic signals	01-Jun-09	Kentucky statewide replacement of incandescent traffic signals with LED modules. USA	CBA (financial only)	>5.0
11	RTO	TC	Re-timing traffic signals delivers cost benefits	01-Apr-09	Commentary on experience and benefits from re-timing traffic signals (no specific project covered). USA.	CBA (advocated)	
12	RTO	TC	Real time traffic control aids travel time reduction	01-Dec-12	Movement-based adaptive control improves intersection performance. TNO (Netherlands).	TT savings	

13	RTO	TC	TfL expands SCOOT adaptive traffic management	01-Dec-12	Modelling the impacts of SCOOT adaptive controls on intersection performance. London, UK.	Annual benefits	
14	RTO	TC	SCATS study shows significant savings	01-Dec-13	Quantification of the benefits of SCATS. Roads and Maritime Services, NSW, Australia	Annual benefits	
15	RTO	TC	Benefits of Florida's traffic signal retiming	01-Oct-12	Traffic signal retiming and installation of advanced monitoring. Lee County Dept of Tptn, Florida, USA.	CBA	>120
16	RTO	TO	Mounting benefits of dynamic tolling project	01-Feb-10	SR167 HOV to HOT lanes conversion pilot project.	No formal CBA.	
17	TI	SC	Barcelona finds speed cameras save money and lives	01-Feb-12	Speed cameras on Barcelona's beltways: cost benefit analysis. Agencia de Salut Publica de	CBA (partial)	c1.5
18	TI	SC	Study finds speed cameras cut fatal accidents	01-Feb-12	Speed camera deployment in Qatar. Supreme Council of Health, Qatar.	Accident reductions	
19	TI	VMS	Refurbishing ageing VMS with new technology	01-Dec-11	Variable message sign retrofitting programme. Virginia DoT, USA	Cost impacts	c$300kpa
20	TI	VMS?	Upgrading Koblenz's traffic information system	01-Feb-13	Koblenz traffic information system upgrade	No formal.	
21	TTM	DLC	Road space utilisation improves travel times, reduces costs	01-Jun-10	DRUM (Dynamic Roadspace Utilisation Manager) - dynamic lane closures during roadworks (based on RTI methods).	Cost reductions for roadworks	c4.5
22	TTM	DLC	Dynamic lane closures cuts time, cost and congestion on motorway roadworks	01-Feb-14	Application of DRUM to optimise lane closures for road works. Highways Agency, UK.	Cost reductions for roadworks	
23	TTM	DLC	Moveable barriers improve workzone safety, reduce costs	01-Apr-11	Use of movable barrier on reconstruction of route 3500 South, Salt Lake City,	CBA	c4.0
24	TTM	VMS	Workzone safety can be economically viable	01-Oct-14	Safelane project, 2012-14:Improvements to work-zone safety. EC project (4 countries, 8 partners).	Cost reductions for roadworks	

A2 International information: key economic outcomes

Ref #	Benefit Components Included	Evaluation Results	Impact Data Sources & Methods	Base Case Definition	Costing Basis
1	Road user time savings, reduced fuel consumption , reduced emissions (HC, CO, NOx)	BCR=11.4. Annual traveller benefits (2008): $308M, of which 77% time savings, 23% fuel savings. Oannual oerating costs of centre: $27Mpa.	Direct monitoring of travel times, etc before vs after (?–no information given).		Annual operating costs given appear to be total for new facility, without allowance for any functions (if any) previously
2	Travel time (incl incident duration), fuel consumption , emissions	BCR=11. Average duration of incidents involving large commercial vehicles reduced 269 to 106 mins; average incident costs reduced by 71%.	Direct monitoring of time between incident and reopening of blocked lanes	Before' time etc involved in clearing same category of incidents	No issues.
3	Travel time, TT reliability, accidents, GHG emissions.	On M1 Freeway, TT (peak periods) reduced by 42%; accidents reduced 30%, GHG reduced 11%, sustainable peak period flows increase >25%. . Economic benefits > $1M per day.	Direct monitoring of travel times and accidents	Direct observations of 'before' situation.	N/a
4	Accident benefits (fatalities/injuries), as a result of increased numbers of speed	Capex cUS$2.9M; opex c$3.2Mpa; accident benefits (prior estimation) c$15.2M, hence BCR c4.0. No account appears to be taken of travel time (dis) benefits from slow speeds.	Benefits (accident savings) based on a literature review etc, not post-monitoring results.	Direct observations of 'before' situation.	No issues.
5	Travel times (peak/commuter); local emissions.	Compared with alternative (existing/non-wireless technology), scheme capex was similar and substantial reductions in operating costs (ie PVC negative).	Direct monitoring of travel times, etc before vs after (?–no information given).	Base case assumed use of wired technology (similar to existing), so main difference option vs base was in cost terms, but also included significant traveller benefits.	No issues.

6	Travel time reductions, fuel savings, local air emissions.	Total cost (consultancy contract value) cUS$0.75M. First-year benefits $15.4M (travel time savings 96%, fuel savings 4%, emission reductions 0.2%), resulting in one year BCR = 21. Over the seven corridors affected, TT reductions were 20%, fuel use reductions 6% and pollutant reductions 1-3%. Based on a typical useful life for signal timing plans of three years, BCR over this period would be c60.	Direct monitoring of travel times, etc before vs after (but exclude evenings and weekends). Method used for assessing fuel and pollutant reductions unclear.	Direct observations of 'before' situation.	Costs would appear to be understated, as only cover direct costs for consultancy work.
7	TT savings, reduced fuel consumption, reduced local emissions (PM10, NOx, HC), reduced CO2.	BCR=8. Main benefit components: TT savings (PM peak 46% reduction in delay time in peak direction, minimal change in reverse direction), fuel savings, local emissions, CO2. Accident savings mentioned, but not quantified. Noted that significant health benefits of reducing local gas emissions (but not fully quantified).	Direct monitoring of travel times, etc before vs after (little information given). No info on other impacts.	Used existing situation, after initial phase of coordinating signal timings on a fixed planned basis.	No details given.
8	TT savings/average speeds, number of stops, GHG emissions.	No BCR calculated. TT reduction ave 11% (3 peak periods), number of stops reduced 33%, fuel savings 0.4 million gallons pa, GHG reduced 7%.	Direct monitoring of travel times, etc before vs after (3 peak periods only). No info on other impacts.	Direct observations of 'before' situation.	
9	O&M savings, reduced fuel consumption, TT savings (?).	Payback period of c3 years stated, without taking account of other savings, such as environmental impacts, traffic light down-time, accident rates and others. Quantified annual benefits given as US$1.47Mpa, of which fuel savings stated to be US$1.34Mpa, remainder O&M savings. It is stated that TT savings have been considerable, but not clear on the quantification in the evaluation.	Direct monitoring of travel times, etc before vs after (initial after surveys 8 mths from implementation). No info on other impacts.	Direct observations of 'before' situation.	No issues.
10	Maintenance savings, energy savings.	Total cost US$10M. Annual savings $7Mpa re LED module replacement; $1.6Mpa (82%) energy savings. Financial BCR >5.0.	Direct monitoring of costs, before and after.	Before situation, and associated costs.	No issues – all financial costs.
11	Comments that main benefits relate to reducing congestion/improving travel times, while also improving air quality and reducing fuel	No results given. Supports ITE recommendation that signal settings should be retimed every 3 years as a matter of course.	Not stated.	Before situation – travel times etc.	Not addressed.

12	TT savings	TT delays at intersections resulting from application of movement-based real-time adaptive control system (taking account of predicted arrivals) vs system based on historical information only. Results based on modelling only, gave c. 20% TT reduction over five intersections modelled.	Model (calibrated?) of intersection performance, based on control algorithms.	Modelled situation with traffic actuated control system.	No costings involved.
13	Changes in intersection delays and number of stops; associated reductions in PM10, NOx and GHG emissions.	Application of microsimulation modelling to c600 intersections gave average reductions in delays of 13%, in vehicle stops of 5%. Application to a limited sample gave reductions in PM10 of 1-6%, in NOx of 3-9% and in GHG of 3-8%.	Model (calibrated) of intersection performance, based on microsimulation techniques.	Generally based on current intersection performance data.	No costings involved.
14	Changes in travel times, number of traffic stops, reductions in PM10, NOx, CO2.	Modelling study to compare SCATS 'Masterlink' system (fully adaptive) with SCATS 'Fallback' option (semi-fixed time system), on a major route into Sydney. Extrapolated results to some 2800 intersections in metropolitan Sydney, givng: 25% increase in speed, 23% decrease in stops/km,, PM10 reduction 21%, NOx reduction 16%, CO2 reduction	Model (calibrated) of intersection performance, based on microsimulation techniques.	Modelled situation with a simpler (non-adaptive) SCATS mode of operation.	No costings involved.
15	Changes in travel times, fuel consumption, emissions.	Benefits estimated at $17.3Mpa, comprising time savings (88% of total, 23% reduction in delays), fuel savings (11% of total), emission reductions (0.7% of total). With costs of $0.36M, indicates BCR >120 assuming a three year effective life.	Direct monitoring of travel times, before and after.	Direct observations of 'before' situation.	Costs cover consultancy contract only – thus understated.
16	Evaln focused on opex, toll revenue, route efficiency (throughput, TT reliability)	HOV traffic not adversely affected. Total route traffic throughput increased. New users of HOTlane saved 7-8 mins per peak period, with average toll of $1.00. Traffic speeds were somewhat higher and more consistent on untolled lanes.	Direct monitoring of travel times, traffic volumes etc before vs after.	Direct observations of 'before' situation.	No issues.
17	Public cost savings (hard $) from reduced accidents; traveller benefits (soft $) from reduced accidents.	Over two year period, estimated reduction 364 accidents/507 personal injuries. Scheme costs E14.5M (incl O&M costs over 10 years). Public savings E0.83M (hospital, property, direct productivity costs); traveller benefits E20.51M (' soft'benefits). No account taken of any increases in travel times. BCR c1.5 over 10 year life. (Some doubt re interpretation of results.)	Direct monitoring of accident records.	No sign that analysis has allowed for any underlying accident trends.	No issues on cost side.

18	Injury & death rates per capita.	Before period (2000-2006) injury & death rate 199/M persons; after period (2007-2010) rate 147/M persons.	Direct monitoring of accident records.	No sign that analysis has allowed for any underlying accident trends.	No attempt made at costing accidents.
19	Capital costs. Op cost savings for maintenance and electricity.	Capital costs related to retrofitting new technology to existing signs (c$100k per sign), compared with costs for new signs (c$300k). Operational cost savings (mtce/electricity() estimated at c$300kpa.	Cost estimates	Base case taken as costs for new signs, given that existing signs were near end of economic life.	No issues (given base case definition).
20	Use of local website giving real tiume trafficx information.	Scheme costs E126k. Benefits -30% increase in use of website on local traffic conditions in reaL time. (No estimates of changes in traffic conditions given.)	Monitoring of website usage.	Before' web site usage.	No major issues.
21	Reductions in road work contractor costs, as a result of increased working times. (Appears to assume that traffic flows will be unaffected)	M25/M27 trial: deployment cost US$75k, roadworks cost savings $385k, giving financial BCR c4.5. Other benefits seen as: elimination of queueing during the construction programme; and use of daytime working at weekends (including allowing noisier activities to be completed during daytime).	No great issues – only costs are measured.	Effects of DRUM on available working times were assessed relative to times available under old 'Lane Prohibition Plan' system, designed to minimise congestion resulting from lane closures.	
22	Refer ref #21.	M25 (pilot): two year construction period reduced by six months, saving US$1.93M. M61: construction period reduced by four weeks, saving $0.41M.	No great issues – only costs are measured.	Refer item 21.	No issues.
23	Main analysis-user delay costs, accident savings. Additional analyses-reduced air emissions, benefits to businesses of early scheme completion.	Total cost cUS$0.6M (movable barrier technology). Main analysis-benefits (time delays, accidents) c$2.4Mpa, giving BCR c4.0. Additional analyses included benefits of earlier project completion to users and businesses, reduced contract costsand reduced air emissions – total BCR >10.	Direct monitoring of travel times, etc before vs after (little information given).	Base case related to phase 1 system of traffic management for the project, requiring four lanes to be available for traffic rather than three lanes (with centre lane reversible).	Appear to be no major issues.
24	Principally cost savings in management of roadworks; also some safety improvement	New vs conventional overhead hazard warning system: cost reduction c 90%. Smart batteries to replace disposable batteries in illuminated traffic cones: payback period <18 months.	No great issues – evaluations cover costs and effective lives only.	Base case represents prior technology being considered for replacement/ enhancement.	No issues.

A3 New Zealand research projects

Authors	Report title/ number/date	Abstract
Raine J, A Withill and M Morecock Eddy (URS Ltd)	Literature review of the costs and benefits of traveller information projects. RR 548. May 2014.	NZTA selected URS NZ Ltd to conduct a literature review to find available cost and benefit information for traveller information systems (TIS) and associated products. The outcome of this literature review will be used as reference material for current traveller information projects and as the basis for future New Zealand TIS projects. This study aims to begin to fill the knowledge gap in the field of TIS and provide detailed information on the costs and benefits associated with the use of TIS. TIS have been accredited with providing various direct and indirect benefits to the end user during day-to-day journeys and on key transport routes during the pre-trip and en route travel stages. The claim is that TIS increases travel efficiency by better utilising the existing transportation network. The end users of TIS are essentially anyone who needs to travel – no matter what the mode. This includes pedestrians, cyclists, public transport users and drivers: travellers, motorbike riders, motorists, freight operators, commuters, drivers of emergency vehicles and all other drivers. Many governmental organisations as well as transport operators provide TIS which implies there is some perceived merit to the expenditure. Literature was investigated from New Zealand and around the globe during the course of this project.
Chang J, G Rive, J Thomas, C Morahan and C Crooks (Opus International Consultants)	Customers' requirements of multimodal travel information systems. RR 540. December 2013.	The purpose of this research was two-fold: 1) to provide evidence-based recommendations that identify the Transport Agency's customers' key information needs, and 2) to provide best-practice guidance on ways the Transport Agency can best offer and 'push' the delivery of multimodal travel information that is tailored to individuals. This research was carried out in three stages: • Literature and best-practice review of current travel information provision, both in New Zealand and internationally • Focus groups/structured interviews to examine key traveller information needs and to conduct a practical assessment of the usefulness for the New Zealand context of the various delivery systems • Online interactive survey to provide a quantitative assessment and priority ranking of travellers' information needs. This report describes the above work and provides recommendations for potential future actions.
Land Transport New Zealand	Effectiveness of incident management on network reliability, RR 346. June 2008.	This report summarises preliminary research undertaken in New Zealand during 2006-07 to investigate the ability of intelligent transport system (ITS) treatments, such as adaptive signal control (eg, SCATS) and variable message signs (VMS), to detect and respond to serious traffic incidents, and to determine the most appropriate traffic management strategies (in terms of overall network reliability) to apply when such incidents are detected. The study involved a literature review of techniques and software/systems currently used to manage traffic congestion and respond to incidents, and an exploratory microsimulation study modelling incident detection and response in an urban network. The research found few attempts to bring together research in the three areas of incident detection/management, ITS methods such as adaptive signal control, and network reliability measures. There is also a lack of robust incident detection available at present in New Zealand. Preliminary modelling found that SCATS can be modified to better meet additional demand due to diversions after an incident, and modelling can help to identify which particular journey paths benefit most from such incident management interventions. The findings highlighted the need for more work to be undertaken in this area in New Zealand

James R (Hyder Consulting Ltd)	Intelligent Transport Systems: What Contributes Best to the NZTS Objectives? RR 302. 2006.	The purpose of this study has been to document international experience on the benefits gained from the implementation of ITS, and to compare these benefits with the key outcomes sought in the New Zealand Transport Strategy (NZTS) and Land Transport Management Act (LTMA). The New Zealand Transport Strategy (NZTS) sets out the Government's overall vision for Transport and is underpinned by series of principles and objectives. The report provides guidance on the ways in which different ITS initiatives can contribute to these objectives. Using a matrix structure, each application has been assessed, in terms of the types of benefits produced, considering each benefit area in the context of the scale of overall benefits. Following this matrix based assessment each application is summarised, setting out the types and scale of benefits produced by different ITS applications, potential problem areas and conditions in which they are best applied. The conclusions identify the systems or groups of systems that have the greatest potential to provide benefits in the context of the NZTS and LTMA objectives. The highest rated applications include a strong focus on travel demand monitoring, management and control, as well as the early detection and management of specific problems, monitoring road weather conditions, prediction of adverse conditions, informing drivers and assisting in more effective response and treatment.
Dalziell EP, AJ Nicholson & DJ Wilkinson (University of Canterbury)	Risk Assessment Methods in Road Network Evaluation. RR 148. 1999.	This study investigates hazards that have the potential to close the Desert Road, which traverses for some 60 km the Central Volcanic Plateau of the North Island, New Zealand, at c.1000 m altitude. It is part of New Zealand's major north-south link, State Highway 1, and it provides a case study for the application of risk assessment methodology to the evaluation of road networks in New Zealand. The hazards investigated comprise snow and ice, volcanic eruptions and lahars, seismic events, and traffic accidents. A stochastic model is developed for each of the hazards to determine the probability of the hazard occurring and the resulting road closure duration. The vulnerability of alternative routes through the Central North Island, to these hazards is also evaluated. A traffic assignment model (SATURN) is used to predict the disruption caused by closures of the Desert Road and its alternative routes, and quantifying the economic cost of closures to the New Zealand economy. Monte Carlo simulation is used to find the probability distribution of the average annual cost of closures caused by each hazard. Decision-analysis software, which can be used to determine the spending portfolio for mitigation options that will optimise the risk reduction attained for a given expenditure, is also described.

Report title/ number/date	Summary of relevant aspects
Literature review of the costs and benefits of traveller information projects. RR 548. May 2014.	* TIS were categorised into urban v rural, pre-journey v en route.
	* Benefits were considered under five headings (largely consistent with EEM): travel time savings, VOC, crash costs, vehicle emissions, and customer satisfaction (this being outside the EEM benefits framework).
	* While TIS costs can be established quite readily, there are major difficulties in establishing benefits – very little objective and relevant information is available internationally on the financial and economic benefits. There were particular Information gaps relating to TIS in rural situations, and nothing specific to services in NZ.
	* Review of the literature relating to benefit estimates from TIS measures in each of the benefit categories showed very little 'hard' evidence internationally. A table (6.8) summarises the (limited) evidence on benefits against the following aspects: improved travel efficiency, improved road safety, improved PT services, improved freight management, improved freight fleet management, enhanced security, reduced environmental impacts, improved road traffic planning & operations, improved revenue generation, decreased traffic violations, and user acceptance.
	* A table (6.1) categorises the types of TIS benefits by the five benefit headings by the four TIS categories (pre-trip v en route, urban v rural).
	* One conclusion is that *"the evaluations of TIS show that these systems are well received by those that use them (suggesting that the benefits are likely to be significant). Benefits are found in the form of improved on-time reliability, better trip planning and reduced early and late arrivals".*
Customers' requirements of multimodal travel information systems. RR 540. December 2013.	* The main focus of this report was on multi--modal travel information and how this influences traveller behaviour.
	* The international literature review identified very limited research on willingness to pay for transport/travel information systems.
	* It was generally found that willingness to pay was low (in part reflecting that people are used to obtaining free information on the Internet).
	* Quite a number of market research studies have investigated willingness to pay of PT users for real-time information (at stops and via other means).
	* One of the key conclusions of the report was: *"Research indicated that providing additional information to travellers would allow them to make travel choices (eg regarding transport mode choice and travel time) that would enhance their travel experience. Further benefits could include:* *• improvements to road network performance and safety by spreading demand throughout the day and onto different routes – eg fewer cars circulating as drivers look for parking* *• increased safety, as appropriate rest stops for long car journeys and freight movements could be planned* *• reduced customer frustration around congestion and delays* *• improved accessibility for people with different abilities"*

Intelligent Transport Systems: What Contributes Best to the NZTS Objectives? RR 302. 2006.	* This report rates 14 ITS applications in terms of their contributions to each of the following 10 objectives/issues (and their sub-components): economic development, safety and personal security, access and mobility, public health, sustainability, energy efficiency, integration, responsiveness, affordability and cost effectiveness, and implementation risk.
	* The main benefit categories relating to each ITS application are listed, comments are provided on potential problems, and application types/situations are listed.
	* Where 'hard' evidence is available (in NZ or internationally) on the effects of specific application types, this is summarised for example applications, including information on benefits and costs. (This could provide a useful starting point if NZTA wishes to develop/maintain a database on the costs and benefits of ITS applications internationally.)
Risk Assessment Methods in Road Network Evaluation. RR 148. 1999.	* This report (7.5) applies SATURN to estimate the traffic behaviour effects of temporary closure of the Desert Road section of SH1. Modelling includes allowance for the effects of closure on the travel costs of the trips involved, and applies an elasticity to adjust the number of trips made according to the difference in travel costs using the alternative route. The SATURN analyses relate to a 'steady state' situation (with/without the road link in question) and do not allow for the initial effect on motorists 'caught' at the time of closure.
	* The report (7.6) outlines the basis, using PEM (now EEM), for estimating economic costs due to road closure, including application of the SATURN outputs. It also sets out (8.4) methods used to assess the economic costs and benefits associated with several mitigation options: these options include the provision of VMS, although noting that the benefits from this measure are very difficult to estimate.
	* We note that the economic methodology appears to assume that, should the route be closed for any reason, the intended journey either continues to be made (via an alternative route) or is no longer made. There appears to be no consideration of the option of making the journey later, which would tend to reduce the estimated disbenefits of closure.

Appendix B: Measured data and transport modelling

B1 Types of data

B1.1 Overview

A range of data is currently collected and available to provide users, managers and operators with information relating to transport system operation and performance. The sources, sampling and fidelity of these datasets is consistently increasing as modern data collection techniques become viable and are implemented on-road (eg Bluetooth and wifi monitors, GPS datasets, automated count methods). In the current transport environment the development, deployment, application, and variety of data collection techniques and systems are progressing rapidly. Broadly the types of on-road observed transport system data available can be classified as follows. A more comprehensive list of data systems and their current availability/access (as obtained by the authors) is provided in section B1.2.

1 Journey time and volume sample data from modern 'in-situ' detection systems (Bluetooth, wifi and similar).

2 Journey time or speed data from GPS systems, fleet tracking and similar GIS databanks (polling of GPS data from in-vehicle/mobile devices, fleet tracking devices and systems etc).

3 Journey time data from a bespoke data collection exercises (modern detection systems or historic techniques).

4 Speed and performance estimate data from loop systems (motorway, SCATS systems, TMS etc).

5 Volume (counts or estimates) from loop systems (motorway, SCATS, TMS etc).

6 Travel volume data, historically collected, or bespoke exercises.

7 Travel pattern data, from regional planning sources/systems or bespoke exercises.

A point to note; evaluations of the benefit of an operations activity are focused on reviewing outcomes before and after the activity has been carried out (the state of the network with and without the activity). The ability to carry out the activity may have its own unique data requirements. The data requirements of *evaluating* the activity are generally not equivalent to the data requirements of *carrying out* the activity. For example, an incident identification and management system may require monitoring of a variety of transport system data in real time or near real time. Evaluating the benefits of this activity may not require the same sets of system data and generally does not require any real-time component.

B1.2 List of data collection systems and availability

This list covers the systems that the authors are aware of and were notified of via conversations with practitioners (notably the regional TOCs) and it is unlikely to be complete and should not be considered completely comprehensive.

- Bluetooth journey time data: Fixed detection systems currently in place in Christchurch, Wellington, through the Waikato region and parts of the Auckland network.
- Network wide GPS and fleet tracking sample data: Sampled GPS/GIS fleet tracking link (road section) data and/or travel pattern data from a number of systems/sources such as the Transport Agency journey performance measurement tool (sourced from TomTom data), NIS and eRUC systems.

- Cell trace tracking sample data: Trace data from tracking mobile phone locations via cellular towers.
- SCATS added-value real-time network analysis and optimisation software: Advanced Real-time Traffic Information System (ARTIS) and Travel-time Reporting and Integrated Performance System (TRIPS): Monitoring of arterial road network performance and estimation of route travel time from SCATS detector data. ARTIS is in greater use in Auckland, as described by Ensor et al (2008), and TRIPs in Tauranga.
- Mobile detector journey time data: Wifi, Bluetooth, automatic number plate recognition (and similar) systems can be deployed for site-specific surveys. Survey capability exists largely throughout New Zealand with the potential exception of remote rural areas.
- Floating car journey: Bespoke journey time collection method can be used as a fall-back method to save cost, complexity, or in remote locations.
- NZ Transport Agency TMS loop data: Permanent count sites record constantly and data is available promptly. Data is sampled periodically at other non-permanent sites. Available at locations throughout the state highway system.
- SCATS loop data: Estimates of traffic volume, loop occupancy and speed. Available in majority of urban areas.
- Other motorway loop data: Estimates or records of volume, occupancy and speed. Concentrated on the Auckland Motorway system (eg the ramp metering system loop data).
- Historical records of traffic volumes: Loop counts on links and turning movements at intersections (manual counts or more commonly via video survey collection or modern detection systems). Generally held and available by the local RCA.
- Count/volume sample/travel pattern data via video: Use of video to track/sample pedestrian and vehicle movements either through fixed existing cameras, or deployment of mounted cameras. Limited examples to date.
- Regional planning data: Regional transport models, land-use and planning data, other system-wide GIS data held by RCAs and operators (eg bus stop and route data, service locations/provisions).
- Travel pattern data: Bespoke collection exercises such as intercept surveys, roadside interviews, household surveys, origin-destination sample surveys.
- Other detection/GPS system data: Bus system GPS data, microwave detection, infra-red detection, counting/sampling from video (eg fixed cameras), parking sensors, mobile device data etc. Current availability/access/deployment of these systems and data is either limited (eg new detection devices), not significantly beneficial to operations activities (eg bus data), or has unknown elements such as the access/form of data outputs and privacy issues (eg parking sensors, mobile device data).

B2 Types of transport models

B2.1 Overview

Modern transport modelling techniques have increasing functional and performance capabilities. The range of evaluations, analysis styles and performance measures, and types of transport interventions which models are used to assess have widened and diversified over the last 10 years. Broadly there are two types of transport models:

- Regional (or demand) models: Regional models include representation of land-use activities, demographics etc. They are commonly developed to assess the strategic impacts of land-use changes, larger scale transport and PT projects, and the effects of policy changes on wider regions.

  (Definition is from NZ Transport Agency (2014d))

- Operational models: Models which have a focus on predicting and evaluating the operation of the network (journey times, queues, speeds etc).

B2.2 New Zealand model availability and suitability

The focus and structure of the regional models across the main New Zealand urban centres and wider regions as described above means they are unlikely to be ideally suited for evaluating the impacts and benefits of operations activities. This does not prevent these models having a use/application in this field, eg in establishing wider effects of a significant road closure, and they are regularly used in conjunction with operational models (providing information on existing traffic patterns, land-use, forecasting etc).

Operational models are more likely to be the focus of an assessment of operations activity benefits and are likely to be better suited for this task. Broadly, there are four types of operational models which have been used historically and are currently wide-spread in New Zealand:

- Intersection: Isolated intersection modelling assessment tools, commonly used software is SIDRA (deterministic).
- Small network/short corridor models: Tools capable of covering shorter corridors and smaller networks, but with limited abilities to replicate route choice and assessment of system-wide effects. Commonly used software are LinSIG and TRANSYT (deterministic).
- Equilibrium (or iterative assignment) network models: Network-wide traffic assignment tools based on deterministic methods (outcomes are based on set relationships (non-probabilistic)). Main example in use in New Zealand is the SATURN software which uses an equilibrium assignment, ie all trips will look for the lowest cost route through the network and ‘equilibrium’ is achieved when the delays/travel costs on all paths are balanced. (It is arguable that the regional planning models can also fulfil this role to some degree and in New Zealand software includes EMME, CUBE and TRACKS).
- Microsimulation-style network models: Modelling of individual trips through the network generally includes dynamic (varying by small time slice) assignment and a stochastic basis (outcomes are based on probability (non-deterministic)). Commonly used software includes AIMSUN, Paramics and VISSIM.

Section 4.2 discusses the suitability of these model techniques for carrying out evaluations of operations activities.

Similar to comments relating to data systems above, modelling tools used to *carry out* the operations tasks (eg optimisation tools) may not be well suited to *evaluating* the benefits and outcomes of that activity. For example, intersection modelling tools (SIDRA) and smaller network tools (LinSIG, TRANSYT) may be used to carry out localised intersection evaluations, design checks and optimisation calculations but they have limited capability in establishing system-wide benefits and effects.

B2.3 Additional capabilities of microsimulation models

Microsimulation models represent individual vehicle trips through the network. The models have the ability to detect vehicles via loops/detectors placed in the network in the same manner as on-street loops. This provides the ability to link the model with operational systems: ITS control systems (ramp metering, speed management etc), traffic signal control systems (SCATS, VA etc) and 'in-vehicle' control systems (linked car systems, adaptive cruise control etc).

This provides additional capabilities of these model forms over other model types, use of observed data, and over-and-above 'typical' evaluations of operations activities. These capabilities provide the mechanism to carry out a range of investigations, examples include:

- System investigation: Investigation and testing of the operation of control system, strategies, techniques, parameters etc within a controlled environment and without affecting on-road conditions and transport users, eg trialling different approaches to network signal strategies.
- System and variable optimisation (pre-installation or refinement/testing of existing installation): Carrying out a level of investigation/optimisation into systems before installation to improve efficiency in system installation and arrive at optimal on-road settings more quickly, eg testing loop locations, parameter effectiveness and strategies for controlled motorway installation.
- Comparative system assessment: Comparison of one ITS system with another, eg benefits of different ramp metering algorithms, signal control algorithms.
- Predictive rather than deterministic approach: Strategies and their effectiveness can be evaluated through more direct manipulation of the control system, eg the effect and outcomes of actual system alterations can be more directly established rather than carrying out an optimisation calculation in an external tool, putting that strategy into the controlling system as a separate step and implementing on-road with a degree of uncertainty over actual outcomes.

As noted, these forms of assessment are over-and-above 'typical' evaluations of operations benefits. The benefits of these approaches are worth considering, particularly in carrying out investigations without effecting the on-road environment, but are not considered a core requirement in applying this framework and more generally evaluating the benefits of operations activities.

Appendix C: Transport model incident evaluation example

C1 Application of transport models to measure incident impacts, northern Christchurch

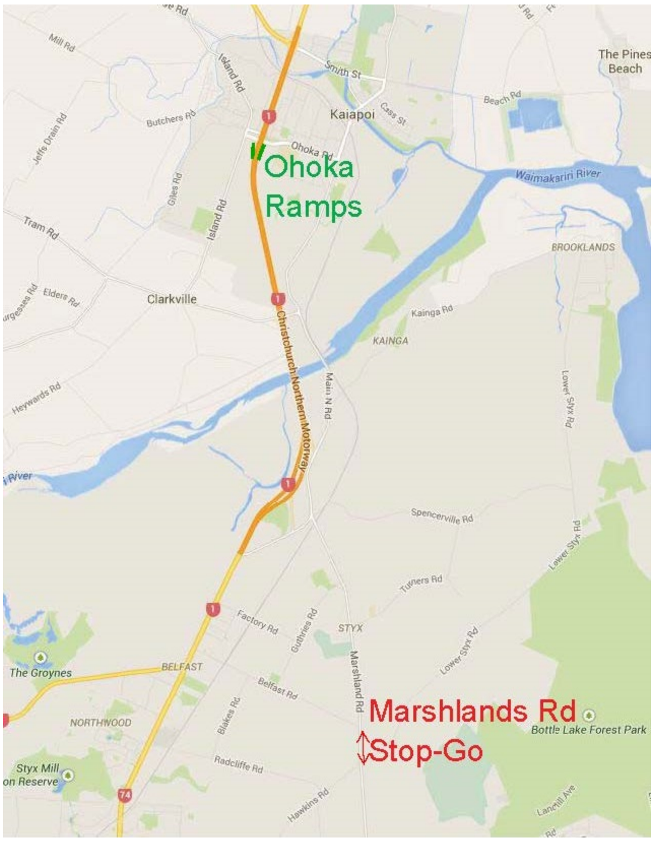
This appendix presents a brief investigation of alternative modelling methods for measuring the effects of an incident. Although it is akin to a 'light' case study, the focus is on the comparative results between the modelling methods. This is not directly linked with case study 3 (Pineacres intersection), although the microsimulation model developed for the testing in this appendix was also used for the Pineacres case study.

On Monday 20 October 2014 during the morning commuter peak period two incidents occurred in the northern area of the Christchurch network which generated levels of congestion over-and-above 'typical' Monday conditions:

- stop-go traffic management on Marshlands Rd around Lower Styx Rd (continued from overnight activities which were not completed in time).
- reports of animals on Ohoka Rd, affecting access to/from the northern motorway.

The locations of the incidents and the wider study area are shown in figure C.1.

Figure C1 Northern Christchurch incident study area



This area of the network is well covered by the Bluetooth journey time data system and Transport Agency permanent traffic count sites. This data enabled measurement of the actual volume of traffic affected and the delays they experienced. A summary of the incident, data and process used to evaluate the approximate economic magnitude of the incidents is described below:

- The impact was measured from 05:00–10:00am.
- Data from all the Bluetooth links was investigated, in both directions of travel, through the area (Belfast/Marshland to Pineacres).
- The average journey time across seven Mondays in August and September was used to reference the 'typical' conditions/congestion levels.
- The TMS count data was used to a) determine the traffic volumes in key locations and b) factor up the BT volume sample from around a 10% sample on other links.
- The travel time change was measured as the recorded travel times on Monday 20th, minus the 'typical' travel times from the average of seven historical Mondays.
- The traffic volumes were assessed for both the 'typical' and 'Monday 20th' days (economic 'rule of half' applied to demand differences).
- The 2013 EEM morning commuter peak value of time was used to convert travel time impact per vehicle to monetary values.

The economic impact of this incident was evaluated from this data and measured as roughly $42,000. This is a conservative estimate (ie low). The analysis does not include every trip in the network that would have been affected and only includes travel time impacts.

Christchurch has two network wide transport/traffic models:

- Christchurch Assignment and Simulation Traffic (CAST) Model, a SATURN traffic assignment model
- Christchurch Transportation Model (CTM), a CUBE four-stage regional planning model.

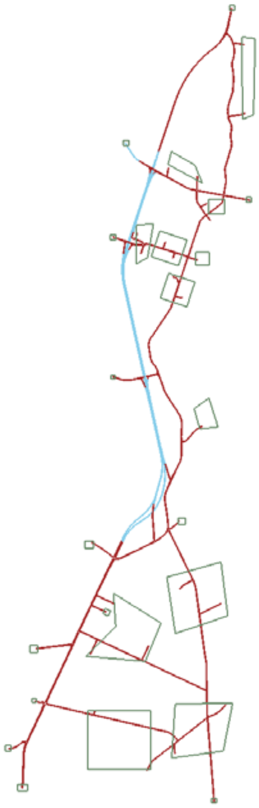
The incident described above was replicated in versions 2013/2014 versions of the two models and the value of time economic savings calculated:

- CAST value of time impacts: $5,000–$6,000
- CTM value of time impacts: $13,000–$17,000

Considering the conservative nature of the estimate using the observed traffic data (sample of strategic trips only), the CAST SATURN traffic model impact estimate is a factor of 7 to 10 lower than observed and the CTM regional model impact estimate a factor of 2 to 4 lower.

A Paramics microsimulation model was developed of the area covering the 5:00am–11:00am time period. The model was developed to a relatively high level, with a coarse zone system and representation of the strategic road hierarchy only. The base model was developed to represent typical 2014 conditions. Checks of the traffic demand and travel times were focused on the two main north–south corridors and the northern motorway in particular. The model area and zone system are shown in figure C2.

Figure C2 Northern Christchurch incident model



The model was run with the two incidents noted above and the economic disbenefit of the event calculated as $59,900. Compared with the real-world measured estimate of disbenefits ($42,000), the microsimulation model evaluation appears to be a) of the correct order of a magnitude (equilibrium-style modelling was an order of magnitude low) and b) a robust estimate of the actual impacts. The microsimulation model includes some effects of shorter trips crossing the main corridors, knock-on effects through adjacent intersections etc, whereas the measured data only sampled trips recorded between the Bluetooth detectors (the main north-south routes only).

This example provides direct evidence that microsimulation models are generally suitable for assessing operations-style activities, whereas traditional 'strategic' models which aggregate traffic flow are typically not suitable.