The effectiveness of incident management on network reliability

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Contents

Executive summary

This report summarises research undertaken in New Zealand during 2006–07 to investigate how intelligent transport system (ITS) measures can be used to improve the transport network efficiency during traffic incidents. It was intended to be a scoping study only, to identify the key issues and the need for further investigation.

The overall aim of this long-term research was to:

- investigate the ability of ITS treatments such as adaptive signal control (eg, the Sydney Coordinated Adaptive Traffic System (SCATS)) and variable message signs (VMS) to detect and respond to serious traffic incidents
- determine the most appropriate traffic management strategies (in terms of overall network reliability) to apply when such incidents are detected.

The scoping study involved:

1. A literature review of techniques and software/systems currently used in New Zealand and elsewhere in the world to manage traffic congestion and respond to incidents
2. An exploratory study modelling incident detection and response in a New Zealand urban network (Auckland North Shore) using microsimulation.

The literature review found that:

- considerable research has been done in the areas of incident detection and management, ITS methods such as adaptive signal control (eg, SCATS) and network reliability measures. However, little work has been done to bring all three research areas together
- while automated incident detection techniques on traffic networks have become increasingly sophisticated, in practice there is still limited use (and trust) of them. However, there has been some success in using simple detection systems to monitor and treat isolated problems such as intersection approach queues
- motorway incident detection is often relatively well established, but there has been less attention on incident monitoring of arterial road networks. This is despite the fact that such incidents regularly affect the adjacent motorway networks and vice versa
- there is a lack of robust incident detection available at present in New Zealand. The Auckland Traffic Management Unit is expanding its data collection in order to improve its response to the traffic conditions and respond to incidents
- there is a lot of variability in the effectiveness of using driver information systems such as VMS to redirect road users away from incidents. However, it is possible to 'learn' the effectiveness of such treatments in a particular location using an expert system and cumulative treatment/effect data

- while overall network travel time is still a strong measure of network performance during incidents, other measures such as variability of travel times and time to recovery may be just as important for motorists and other parties
- SCATS was not originally developed as an incident management system and has a relatively limited ability to detect and treat significant incidents. However, its predominance here in New Zealand means that it has an important role to play in any such system
- modelling dynamically adaptive signal control systems using microsimulation enables a more realistic response to be produced (compared with fixed-time signal systems) when testing the effects of incidents on the network
- although microsimulation is a good tool for evaluating incident management strategies, using a model calibrated under ‘normal’ operating conditions may not be sufficient to properly test incident scenarios. It may be necessary to calibrate microsimulation models using data from real incident conditions (where driver behaviour may be different than under normal conditions).

The exploratory microsimulation modelling study found that:

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

Both the literature review and the preliminary modelling highlighted the need for more work to be undertaken in this area in New Zealand. The following are recommended for further investigation or action.

- Future modelling should build on this study by expanding the range of incident scenarios tested and treatment options applied.
- Consideration should be given to further expansion of the existing modelled network to include a wider range of alternative detour routes and to capture the impact of incidents over a wider network area.
- Field data should be collected to investigate how motorists respond during incidents and to confirm the accuracy of the simulation model findings under incident conditions. Suitable data could include:
    - SCATS traffic count/occupancy and signal phasing data
    - closed-circuit television (CCTV) images (queue lengths)

  - detector loop data (speed, occupancy); either existing installations or one-off
  - floating-car or number-plate data (travel times)
  - a survey of route choice during incidents, including drivers' response to VMS and other information regarding incidents.

- More widespread and robust means of incident detection should be considered in major New Zealand urban areas, on both motorway and arterial road networks. This includes more frequent mid-block detector loops (or alternative technology), expanded CCTV coverage and automated incident detection systems.
- The impact of different response times to the overall performance and recovery of the network during and after an incident should be investigated further.
- Further investigation is recommended into how drivers behave during incidents, particularly when provided with additional route information via VMS, radio reports, etc.
- Further investigation should be made into the ability of SCATS and other software tools to detect incidents automatically and to provide suitable guidance on appropriate treatment strategies. If necessary, develop improved capability for the tools to do these tasks.
- Investigation should be carried out into the ability of microsimulation to be linked directly to a live traffic situation, to enable 'on-the-fly' incident assessment, modelling and resolution.
- Monitoring should continue of ITS literature and practice worldwide for any newer technologies or congestion management treatments that may emerge and be applicable to the New Zealand context.

Abstract

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.

1. Introduction

This report summarises research undertaken in New Zealand during 2006–07 to investigate how intelligent transport systems (ITS) measures can be used to improve the transport network efficiency during traffic incidents. It was intended to be a scoping study only, to identify the key issues and the need for further investigation.

1.1 Purpose of the proposed research

As congestion on New Zealand roads increases, the network has less spare capacity for use during incidents. It is imperative that such capacity is used optimally.

The overall aim of this research in the long term was to:

- investigate the ability of ITS, such as adaptive signal control (eg Sydney Coordinated Adaptive Traffic System) (SCATS)) and variable message signs (VMS), to detect and respond to serious traffic incidents
- determine the most appropriate traffic management strategies (in terms of measures to be identified for overall network reliability) to apply when such incidents are detected.

1.2 Research tasks

The proposed research in this study involved:

1. a literature review of techniques and software/systems currently used in New Zealand and elsewhere in the world to manage traffic congestion and respond to incidents.
2. an exploratory study modelling incident detection and response in a New Zealand urban network using microsimulation.

The resulting findings enabled us to determine whether there was a need for more detailed investigation in this area.

The following sections detail the work undertaken. Following a review of the literature (section 2), a desired methodology for modelling was developed (section 3), and preliminary modelling undertaken (section 4). Conclusions and recommendations for further research follow (sections 5 and 6).

2. Background literature

A literature review was undertaken of techniques and software/systems currently used in New Zealand and elsewhere in the world to manage traffic congestion and respond to incidents. The aim was to examine what was currently being done within New Zealand to **identify** and **manage** incidents in congested networks and **monitor** the effectiveness of these strategies. This would assist in identifying the key problems for practitioners requiring resolution. It also aimed to determine the extent to which these issues had been investigated elsewhere in the world and whether any techniques/systems developed could be applied here in New Zealand.

2.1 Context

There is growing interest in non-infrastructure solutions for handling the effects of traffic congestion – by using intelligent transport systems (ITS) to monitor traffic conditions, detect any incidents, and implement appropriate remedies such as changed traffic signal plans or driver information signage. These techniques provide a cost-effective way to make better use of the existing road infrastructure, rather than simply providing additional road capacity. Overseas evidence to date has identified good benefits to both motorists and transport agencies (James 2006).

Car ownership levels are increasing and traffic congestion continues to grow in major urban centres in New Zealand. There is an increased awareness of the environmental effects of congestion and mitigation measures are needed. In order to address these trends, the efficiency of the existing transport network needs to be maximised. ITS applications in New Zealand are currently limited, but likely to become more important in the future.

Dynamic traffic signal control systems (eg, SCATS, developed by the New South Wales Roads and Traffic Authority) are used in every major city in New Zealand to optimise the timing of individual signalised intersections for the benefit of the network as a whole. While this is an effective method for handling the normal gradual changes in traffic flows within a network over time, it is not clear whether it can always respond optimally by default when a major traffic incident (eg, accident or blockage) or abnormal traffic demand (eg, travel to/from a major sports or cultural event) affects the network (particularly at peak congestion times). It may be that, in attempting to ‘fix’ a blockage, the flow-on effects to the rest of the network result in a worse overall network performance than from doing nothing.

Pre-determined incident management plans may be a way to improve the default handling of such situations; these would (for example) identify key alternative routes, provide signal priority along these corridors, and possibly provide driver guidance using dynamic signage and in-vehicle navigation systems. There is, therefore, a need to determine how effective they are and how they can be automatically implemented.

Traffic modelling provides a means to test these scenarios in an efficient manner without affecting real road users. Microsimulation is a form of traffic modelling whereby individual vehicles are simulated within the defined road network and driver decisions are made dynamically in response to conditions encountered throughout the network. Luk and Tay (2006) note that microsimulation models are particularly useful for 'complex, congested situations that are normally beyond the domain of analysis using conventional analytical or macroscopic modelling procedures'.

It should be noted that, like all traffic models, the usefulness of microsimulation is somewhat related to the ability to accurately model driver route-choice behaviour, especially where drivers do not have the capacity to receive and respond to information on congestion ahead on their (pre-incident) perceived optimal route.

There has been increasing interest worldwide into assessing various measures for mitigating the effects of traffic incidents. In the United Kingdom for example, the Department for Transport's Urban Traffic Management and Control programme is a long-term research and implementation effort to test new techniques for using ITS to manage urban areas (DfT 2006). One project of the programme (Gale and Spiers 2001) investigated the use of microsimulation modelling to determine the best choice of management plan following an incident on Birmingham's motorway network. It was, however, limited in its use of a fixed-time (non-dynamic) signal control system.

Similar applications of incident modelling using microsimulation have also been investigated in Australia (eg, Stazic et al 2004, Dia and Cottman 2004). Microsimulation of a SCATS-controlled traffic signal network to assess its performance has also been studied (Millar et al 2004, Zhang and Taylor 2006), but little research has investigated the combination of SCATS control and incident management.

The implications of transport network reliability have also been a field of growing interest, both internationally and in New Zealand (eg, Nicholson and Dantas 2004). Various studies have been undertaken to identify possible incident mitigation strategies and to determine how to objectively measure the network impacts of an incident.

2.2 Congestion

Congestion is becoming an increasingly large problem in New Zealand. Growth in major urban centres and an increase in car ownership levels have contributed to increased congestion. Auckland is the fastest growing region in New Zealand with 90% of New Zealand's population growth occurring in Auckland (ARC 2006). The cost of congestion on Auckland's motorways and state highways is estimated to be one billion dollars a year (Transit NZ 2006a). In Auckland, car ownership levels are quite high and have been increasing at about twice the rate of population growth in the region (ARC 2006).

Traffic congestion can be divided into two different types:

1. **'Recurring' congestion** occurs when there is regularly not enough capacity in the transportation system to meet the demand, for example during peak-hour periods of the day.
2. **'Non-recurring' congestion** is caused by a temporary and unexpected reduction in capacity due to incidents such as crashes, spills or weather; or a similarly unexpected temporary increase in 'typical' demand levels generated by unique, unusual or infrequent events such as sporting events, festivals, retail openings or sales.

It has been estimated that incidents (ie, non-recurring congestion) are responsible for half of the congestion on United States freeways (USDoT 2000).

Adding capacity to the transportation network, by building additional roadways or lanes, is often proposed as the main long-term means to resolve recurring congestion. Such treatments may also minimise the effects of non-recurring congestion. However, it is not necessarily the most appropriate solution to manage congestion, given the large cost often involved and the potential for induced traffic to negate any gains made.

A potentially cost-effective treatment of urban congestion is to increase the efficiency of the existing road network using ITS. Such solutions can ensure that the full capacity of the transportation system is used more often, generally at lower cost. However, there may still be the potential for such efficiencies to induce further traffic on the network.

2.3 Incidents

There are many different events that affect the normal or desired operation of the road network. Scottish Executive (2003) identifies the following events that can cause temporary reductions in road network capacity (relative to the demand):

- vehicle-based incidents, ranging from minor vehicle breakdowns to multiple injury accidents
- debris/obstructions on the road network
- maintenance activities
- recurrent congestion
- any combination of the above.

Another possibility is extreme weather events, such as heavy rain or hailstorms. For the purposes of this research, all of these could be considered 'incidents'. However, planned events (eg, maintenance, sports/cultural activities) or repeating events (eg, peak-period congestion) may be of less interest when they occur alone, because of the ability to plan ahead for them.

Many unplanned incidents of note tend to occur during peak periods when the network is already operating at or near capacity and any disruption in the traffic flow can have a significant effect (a similar incident in off-peak times may be easily absorbed by the available capacity). Incidents can, therefore, cause large variations in transportation network reliability. Cambridge Systematics (2005) cited examples of United States road corridors where the 95th percentile travel times were 50% higher than mean travel times in the pm peak period; yet for the same corridors earlier in the afternoon the 95th percentile was only 15–20% higher than the mean.

2.3.1 Incident management

Successful management of incidents on road networks requires two key elements:

1. Efficiently **detecting** incidents (including identifying their location and nature), preferably by automated means
2. Suitable options for **treating** incidents, both in terms of removing or fixing the entity that caused the incident (if possible) and managing vehicle flows during and after the incident.

Methods for incident detection could include, for example, calls from public (call boxes, cell phones), Police, highway patrols and automated incident detection systems (discussed below). Incident verification is required to determine the precise location and nature of the incident and is important to prevent responding to false alarms. Verification can be performed by on-site personnel, closed-circuit television (CCTV), or multiple incoming calls. The response to the incident will depend on the type of incident and any incident management plan that may be available to put in place.

2.3.2 Automated incident detection

Automated incident detection (AID) uses real-time traffic data and specific algorithms to identify incidents. Typically, a system will require some arrangement of traffic detectors spread around the road network (eg, inductive in-ground loops or overhead microwave detectors) connected to a central traffic monitoring centre where software can analyse the data and relay relevant information to human operators. Usually such monitoring systems also include a series of CCTV video cameras placed around the network and linked to the control centre to provide additional visual information for the operators.

Reductions in observed vehicle speeds are often used to trigger incident alarms. A good AID algorithm will have a low false alarm rate, a high detection rate and a fast time to detect the incident. However, a reduction in speed on the monitored network is not necessarily indicative of an incident and incidents tend to occur when the network is already heavily congested during the peak periods. This makes it difficult to detect incidents using simple algorithms.

Scottish Executive (2003) proposed two event monitoring processes to detect traffic events, using automated traffic counter sites:

1. The ‘network operator’ process compares the current speed (an average of a user-defined number of vehicles) to the historic average speed (over a user-defined number of days) for the current day of the week. When the speed drops below a user-

defined percentage (eg, 50%) of this average an alarm is raised and the traffic counter carries out an action such as informing the traffic monitoring centre or switching on a VMS. This process is useful in identifying deviations from the expected traffic delays for a particular situation.

2. The ‘public’ process allows a user to specify boundary events (eg, speed values that, when breached, cause an alarm to be raised). These boundaries could be based on a proportion of the prevailing speed limit (eg, 50%). This process is useful for identifying departures from the optimal (or acceptable) traffic flow situation; however, such departures may be quite common during peak periods.

While the former process is useful for network operators to be able to identify and respond to unexpected incidents, information from the latter process could be disseminated to the public (eg, via a map-based website) to show (in real time) areas of the arterial road network that were suffering delay. The latter would act as an informative pre-trip communication medium and form the basis for trip planning, whereas the former would enable network operators to assist travellers once on their way.

Williams and Guin (2007) provide a useful summary of the various algorithms devised over the years to detect incidents on traffic networks, the first going back to the 1970s (eg, Payne 1975). While early algorithms were largely based on simple speed or occupancy comparisons and classical traffic flow theory, more recently complex techniques have been tried such as neural networks (eg, Srinivasan et al 2004), fuzzy logic (eg, Yaguang and Anke 2006) and wavelet transformations (eg, Samant and Adeli 2000).

Incident detection algorithms for high-speed freeways are well established; however, on lower-speed urban arterials the problem is more complex (due to the greater density of intersections and other interruptions, and lower initial traffic speeds) and less researched. A methodology for arterial incident detection has been investigated (Zhang and Taylor 2006). This was done by researching lane-blocking incidents (including the entire link being blocked) between two adjacent intersections on an arterial network. Due to a lack of real incident data on the arterial network, incidents were modelled using Q-Paramics software. Additional detectors were required on the upstream link to monitor volume, occupancy and upstream turning volumes.

Evans (2006) describes work that has been done on various state highway intersections in the Auckland region to address isolated congestion problems by signal intervention triggered by (inductive loop) queue detectors in strategic locations. Considerable success was achieved in addressing some localised problems with interventions such as:

- using a queue detector approaching a Give Way controlled left-turn slip lane at a signalised intersection to modify the signal operation to provide some protection for the left turn when significant queues form
- using a queue detector to locate queues on a low-priority approach to a roundabout or priority intersection to trigger traffic signals nearby that create gaps in the major flow and provide a measure of relief to the low-priority flow

- systems that detect queues downstream of a signalised intersection and trigger a switch from network-wide (master) signal control to an isolated fixed-time operation to better handle approach time sharing until the queues downstream disperse.

The queue detection uses a standard 4.5 m long in-ground inductance loop with a 2.5 second delay before being triggered by passing vehicles. This combination appeared to optimise realistic queue detection; free-flowing longer heavy vehicles could clear the loops easily within this time while the 2.5 s activation appeared to quickly identify queue build-up over the detection area.

Other forms of detection technology are available, subject to practical considerations. For example, image processing of video to detect passing vehicles (eg, via the Autoscope series of products, developed by Image Sensing Systems Inc; and the Traficon video detection system, developed in Belgium) has been used in some locations (including previously Ngauranga Gorge in Wellington). Versavel (1999) claims that incident detection via Traficon video cameras has a higher and faster detection rate and fewer false alarms than loop-based algorithms. Wang et al (2005) notes that such systems have an advantage in not requiring in-road installation (which can be quite disruptive on busy roads), but the converse is that they generally require some overhead location (eg, gantries) and this can become more difficult to find if monitoring repeatedly along a motorway.

Williams and Guin (2007) undertook a survey of AID use by traffic management centres (TMCs) across the United States. From 32 TMCs, they found a lot of concern with the level of performance with existing AID algorithms, with 81% stating that even if reliable and accurate AID algorithms were widely available in the future, they would not completely replace other methods (such as mobile phone calls or operator visual detection) but, rather, would serve as a complement to these. While 53% of the TMCs had an AID algorithm integrated into their system, less than half had the detection algorithm fully or partly functional, with others choosing to disable or ignore their AID. Coupled with the finding that 70% of respondents considered their current incident detection capabilities to be insufficient, this underscores the need for further AID algorithm research.

2.3.3 Incident treatment

The aim of most successful incident treatments should ideally be to return the road network to ‘normal’ operating conditions as quickly as possible. In some cases, a proposed treatment may attempt to prevent the incident from happening in the first place or mitigate its size or duration (eg, prevent it escalating to a major catastrophe).

ITS solutions provide an important tool for treating incidents in an efficient and relatively low-cost manner. Some of the key elements are discussed below (not all of them are directly relevant to incident management, but may have an effect on the likelihood of incidents occurring in the first place).

Advanced traffic management systems (ATMS) include:

- real-time automatic incident detection, as discussed above in section 2.3.2
- adaptive signal control, which dynamically adjusts the signal times available for each phase based on observed demands and network optimisation considerations
- traffic signal pre-emption for public transport or emergency vehicles
- dynamically varying speed limits
- variable lane direction use (‘tidal flow’) or temporary shoulder use
- ramp metering limiting access to motorway on-ramps
- automatic tolling or road pricing, to discourage motor vehicle use.

Advanced traveller information systems (ATIS) include:

- dissemination of real-time traffic information in the form of radio traffic reports, traffic websites etc
- variable message signs (VMS) to inform motorists of incidents, road conditions, congestion, road works, suggested detours etc
- in-vehicle navigation systems, which provide drivers with continuous detailed information (using GPS location) on how to get to a desired destination.

While VMS can be effective, if motorists have local knowledge they will often ignore the VMS suggested routing and select their own perceived optimal route. Motorists are often unwilling to change routes during an incident if they are unsure of the reliability of alternate routes. Traffic diversion rates for VMS routing can range from 5% to 80% with the most important factor affecting the decision to divert being network familiarity (Hidas 2001).

Recent local research on the use of ITS in New Zealand (James 2006) identified ‘adaptive signal control’ and ‘incident detection’ among the top four ITS treatments (out of 48) in terms of contributing to the objectives of the *New Zealand Transport Strategy* (MoT 2002).

Although many ITS treatments such as adaptive traffic signals are able by default to handle changes in traffic due to incidents, pre-determined incident management plans may be a way to improve the default handling of such situations. Once a particular incident is detected, a specific plan to deal with it would be identified and implemented, either automatically or via human intervention. These plans would (for example):

- identify key alternative routes to re-route traffic to (either existing traffic already affected by the incident or subsequent traffic approaching the affected area)
- provide signal priority either along the incident-affected corridors or along the alternative routes
- possibly provide driver guidance using dynamic signage and in-vehicle navigation systems to warn of the incident and suggest alternative routes.

Because of the unpredictable nature of many incidents, however, it is difficult (if not impossible) to identify a specific plan that exactly addresses each and every possible incident. Instead, common coping strategies may need to be identified and coupled with incident-specific traffic data to tailor a suitable solution.

Expert systems are one potential tool to help assist in the incident treatment decision-making process. Whyte (1997) explains how such a system has been used in Scotland to determine suitable VMS legends and strategies when an incident is detected. A simulation model is used to forecast two hours ahead the likely effects on the network due to the incident (to be of use, clearly this has to simulate at much faster than real-time speed). Using the results obtained from the traffic model, the system searches for the best guidance message to be displayed on the VMS. It assesses each sign upstream of the incident in isolation, checking that at least one origin-destination route, passing the VMS, complies with the following:

- the origin-destination pair is classed as a main destination
- its normal route will pass through the incident
- its flow is greater than a minimum threshold
- there is an alternative route available (journey time difference to be greater than a set threshold)
- there is available capacity on the identified diversion route.

At the end of this procedure, the best signing strategy is identified (based on minimising journey times) and the process is repeated every six minutes, taking account of the VMS obedience rates and traffic flows obtained from the last signing strategy implemented. Over time, the expert system learns what effect each legend has on the traffic diversion rates obtained.

From preliminary testing of three scenarios, Whyte (1997) found that the expert system saved between 17–52% of the predicted additional vehicle-hours, compared with no VMS being implemented.

2.4 Performance measures

The effectiveness of an incident management plan is dependent on the response time to incidents and what response is actually applied. The impact the incident has on the traffic network is also dependent on the location, type and severity of the incident as well as the level of congestion on the network at the time of the incident. If the network is operating near capacity, any reduction in capacity caused by an incident can have a large impact on the network.

Figure 2.1 below (adapted from FHWA 2000) illustrates how an incident typically affects vehicle delays. The normal traffic flow is constrained by the incident, thus causing delays and usually queuing. Once the incident has ended or been treated, the route will run at capacity for some time to dissipate the built-up traffic. How long this will take will depend somewhat on whether the normal demand flow continues to arrive or some of the subsequent demand is diverted to other routes or times (determining this reduced demand is an interesting modelling exercise in its own right).

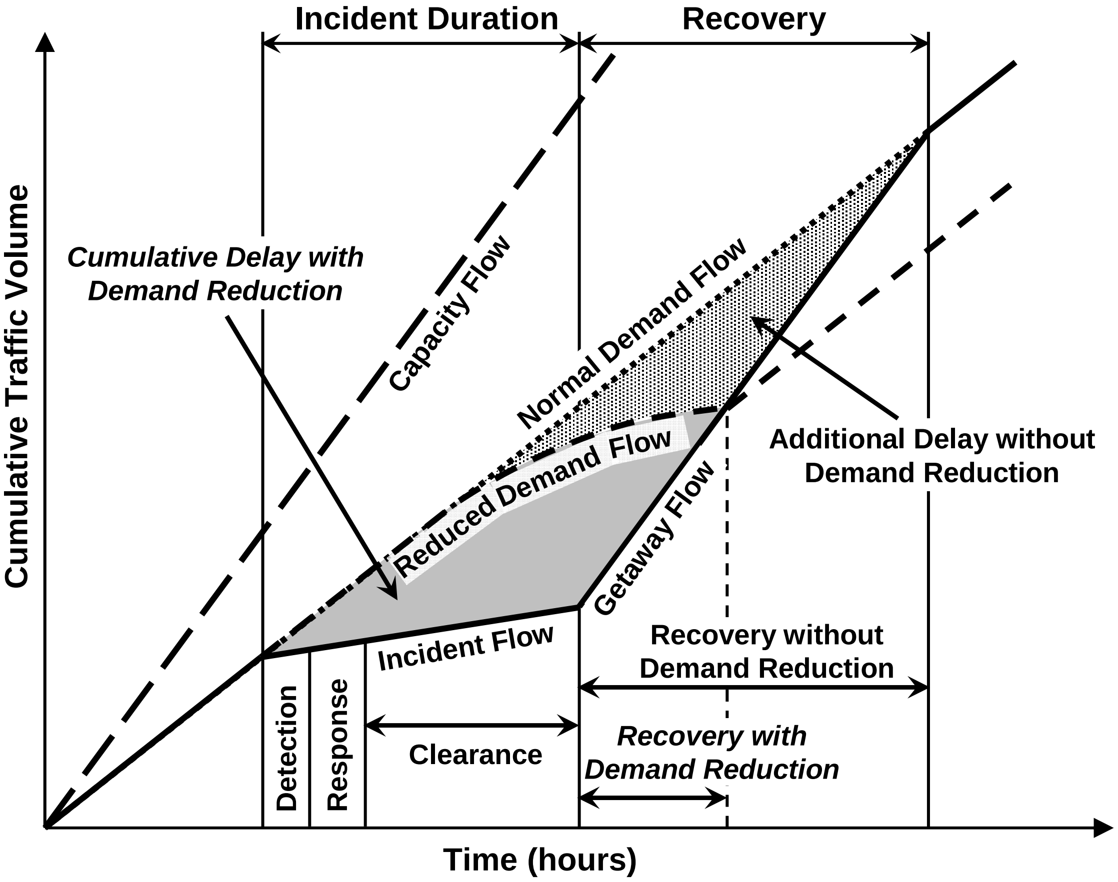

Figure 2.1 Delay caused by incidents (adapted from FHWA 2000).

The network performance during an incident can be determined by looking at measures such as the:

- change in vehicle travel times
- amount of re-routing that takes place
- level of service (volume/capacity ratios) at key locations of the network
- time for the network to recover.

Such measures can be assessed at both a network-wide and route-specific level. It may be that, in attempting to fix an incident locally, the flow-on effects to the rest of the network result in a worse overall network performance than from doing nothing. The performance of certain key routes or intersections may also be deemed more important and the performance measures at such locations may need to be weighted accordingly.

While overall network travel time is relatively straightforward to obtain from modelling, it may not be a sufficient measure. Variability of travel times is often viewed just as importantly as average times by motorists (Ensor 2004).

The Austroads travel time performance programme is implemented by Transit New Zealand (Transit NZ) and local councils to monitor the performance of the transportation network in Auckland, Tauranga, Wellington and Christchurch (Brown et al 2006). Traffic congestion levels are measured using travel time data. A congestion indicator has been developed that is a function of the measured travel time versus free flow (uncongested) travel time. The highest congestion indicator on urban state highways in New Zealand currently occurs in Auckland during the pm peak period; Auckland also has the highest degree of travel time variability in New Zealand (also during the pm peak).

Scottish Executive (2005) lists a number of network performance indicators (both at a nation-wide and a local route level) used to monitor congested arterial routes:

- **additional travel time per annum** attributable to traffic congestion (ie, compared with the same trip made under free-flow speed conditions)
- **average time lost per vehicle kilometre** (the above measure divided by the amount of traffic, averaged over the year)
- **cost of trunk road congestion per annum** (based on the additional travel time and economic value-of-time figures)
- **journey time reliability** (based on proportion of trips taking >115% of the average journey time for that same period)
- **congestion bands** (where the average speed drop compared with free-flow speed is banded into ‘mild’, ‘serious’, and ‘severe’ categories)
- **annual average daily congestion index** (the ratio of the free flow speed to the actual speed averaged over the whole day).

How well these kinds of measures would first detect and then assess the performance of incident management treatments would depend somewhat on the level of existing congestion and the relative impact on this of incidents. If, for example, incidents could be absorbed largely within existing capacity, there might be some increase in additional travel time, but very little change in the amount of severe congestion or proportion of trips taking >115% of the average journey time.

The application of the performance measures will affect the choice of metric used. For example, an evaluation of a proposed new network management treatment may require a cost-benefit analysis to justify funding; hence economic costs of incidents will be important. For day-to-day operational performance assessment, more immediate measures of overall travel time lost each day may be useful. Meanwhile, obtaining a suitable indicator of the perceived level of satisfaction by the general motoring public may require some kind of journey time reliability measure.

The choice of performance measures to use will also depend on what can be readily extracted from either the real-world detectors or (in the case of test modelling) the software package being used. For long-term operational monitoring of performance, the ongoing means to do this has to be cost-effective with a minimum of effort.

The performance of the network from the point of view of the road user is another important perspective to consider, even if the perceived performance doesn't always match the true performance by more objective measures. Scottish Executive (2001) noted that market research carried out for their national road monitoring system suggested that drivers favoured delay information (ie, that imposed by roadworks or an incident over any usual delay) more highly than overall journey time information.

2.4.1 Network reliability

Good incident management strategies can provide more reliability to the network in terms of travel time. This may be important from a road user perspective; Ensor (2004) found that Auckland motorists viewed the importance of travel time variability similarly to reducing average travel time.

FHWA (2006) notes that while traffic congestion is often communicated only in terms of simple averages, most travellers experience their travel times varying greatly from day to day and remember those few bad days where they suffered unexpected delays. Figure 2.2 illustrates this concept.

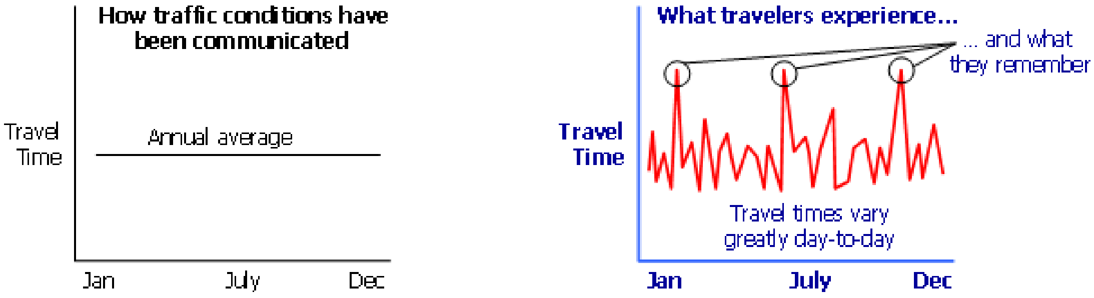

Figure 2.2 Average versus perceived congestion (from FHWA 2006).

Commuters who travel on a route with significant travel time variability must plan for this variability if they want to arrive nearly always on time. Using the average travel time will not suffice; a time cushion or buffer must be allowed for.

Such benefits of improved reliability may be quite noticeable when attempting to quantify the benefits of an incident management treatment. The improvement in average travel time may be rather modest; however, reliability measures may show a much greater improvement in reducing the worst few days of unexpected delay. Figure 2.3 demonstrates a hypothetical example of this effect.

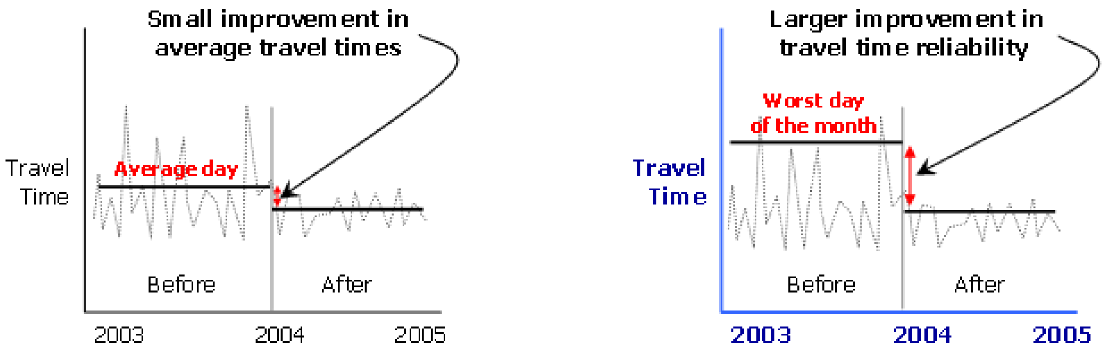

Figure 2.3 Effects on reliability of network improvement (from FHWA 2006).

Taking these issues into consideration, it may be that additional measures of network reliability need to be determined, such as the 95th percentile travel time or the average 'buffer time' (ie, the extra time that most travellers add to their average travel time when planning trips to try to ensure on-time arrival).

2.5 Software

Both operational (day-to-day) management and longer-term planning of incident detection and treatment is greatly assisted these days by various software tools to manage network flows (eg, by adjusting signal timings) and predict the likely effects of any changes made. The following discussion outlines some of the key tools available.

2.5.1 SCATS

Traditionally, traffic signals were operated on fixed-time cycles (during peak times at least), whereby a constant green time was repeatedly given to a particular phase. However, this failed to account for any variations in traffic flows, both normal and unusual variations. Similarly, such systems could not account for any wider network effects of changes to individual intersection timings. Nowadays, dynamic traffic signal control systems are used in every major city in New Zealand to optimise the timing of individual signalised intersections for the benefit of the network as a whole.

SCATS was developed in the 1970s by the Roads and Traffic Authority (RTA) of New South Wales, Australia, as a traffic adaptive system to coordinate the traffic signals on Sydney's main arterial routes. SCATS is now used extensively in Australia and New Zealand and is also used in Asia and North America. Nineteen local authorities in New Zealand use SCATS and 90% of all signals in New Zealand are under SCATS control (Sissons 2006).

Traffic operation in SCATS is optimised by changing the green-time splits, offsets and cycle lengths (Lowrie 1982). Vehicle detectors on the intersection entries are used by a network of computers to determine the appropriate timings. The main computer runs the Central Monitoring System, which manages the regional computers, performs the collection of SCATS data, develops and generates the intersection personality data, and runs the analysis programs. The regional computers determine the overall strategy used by the local signal controllers at each intersection (see Figure 2.4).

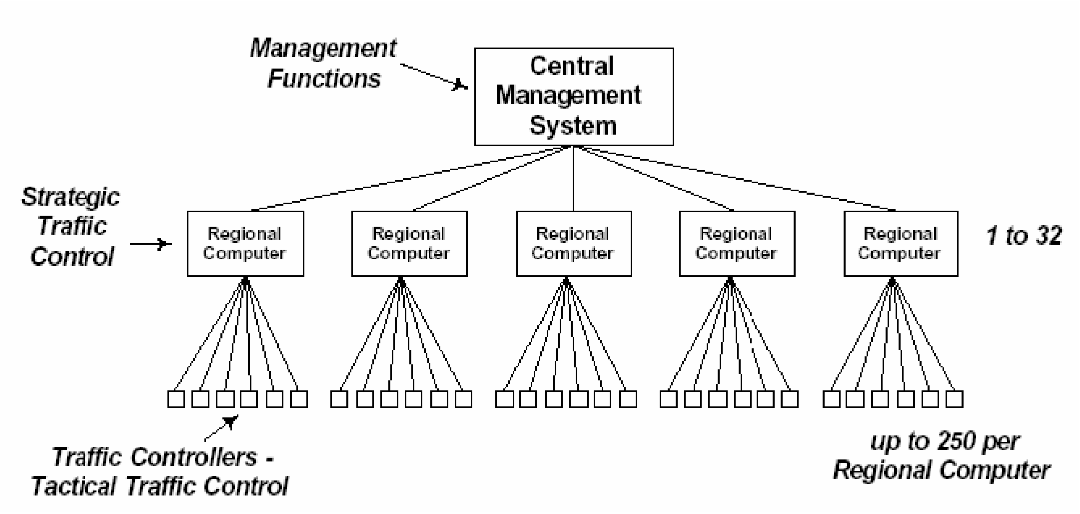

Figure 2.4 SCATS network computer control.

RTA (1997) describes the optimisation process in more detail. The intersections in the SCATS-controlled network are divided into systems and subsystems. The cycle time, phasing, green splits and offsets are constantly monitored and adjusted at the subsystem level. Adjacent compatible subsystems can be linked to improve coordination. Vehicle detectors are located at the stop line at each intersection, ie, where vehicles enter the intersection or wait to go through. The average maximum flow rate is determined for each measured approach as a moving average of the daily maximums. Thus the saturation flow for each location is self-calibrating to reflect local conditions. The SCATS degree of saturation is defined as the ratio of green time used by vehicles (at the saturation flow rate) to the available green time. At the subsystem level, splits and cycle lengths are monitored and adjusted to obtain an appropriate equal degree of saturation for each phase to maximise network efficiency in terms of delay.

The benefits of SCATS signal control versus fixed time and isolated vehicle actuated control are demonstrated in the literature. The results demonstrate significant traffic benefits can be obtained from SCATS. As traffic demand increases, the benefits of SCATS control also increase, in terms of reduced delay and stops, compared with fixed and actuated control (Wilson et al 2006). SCATS also provides more consistent delay with varying demand as the system adapts to the demand changes. Delay is also distributed more evenly across all approaches; however, under certain circumstances the total intersection delay may increase (Wolshon and Taylor 1999). Benefits can also be measured in terms of improvements in stops, delay and travel time versus fixed time, especially when demand increases or when demand varies. This is an advantage when the network experiences changes in demand due to incidents, or daily/seasonal variation (Chu and Recker 2004).

2.5.2 SCOOT

Split Cycle and Offset Optimisation Technique (SCOOT) is an adaptive signal control system developed by Transport Research Laboratory (United Kingdom). It is similar to

SCATS, but relies on upstream detectors, rather than stop line detectors, to determine the traffic demand in the system. SCOOT adapts to the traffic by adjusting cycle length and phase splits in small increments (Ozbay et al 2006). The SCOOT system also includes the Automatic SCOOT Traffic Information Database (ASTRID) which is an historic database of traffic information collected by the SCOOT detectors. It also includes INteGRated Incident Detection (INGRID) that detects changes in traffic demand to determine if there is an incident on the network (Ash 1997). INGRID uses the ASTRID data and applies algorithms that analyse the flow and occupancy data to determine if the traffic data is different than expected. Occupancy data is analysed upstream and downstream to determine where queuing is taking place in the network. The number of detectors upstream and downstream affected by the incident as well as the duration of the incident determine the confidence in and estimated severity of the incident.

SCOOT is used for signal control in Toronto. Toronto also has an automated incident detection system on the motorways. Although Toronto has access to the INGRID feature through SCOOT, resources are not in place to implement an effective incident detection and management plan on the arterial network.

A study in the Greater Toronto Area investigated the Brock Road Incident Management System (Loane and Mackay 2004). Brock Road is an arterial corridor that is affected by incidents on the adjacent Highway 401, which is the major east/west commuter route in Toronto. The system includes ATMS with responsive control, ATIS and AID at selected sites in the corridor. One of the goals of this ongoing study is to develop traffic responsive plans to mitigate the impact of incidents on the motorway to the arterial network. Modelling was done of various incident scenarios on the motorway to determine the impact and to develop various mitigation measures including upgraded responsive control algorithms, improved local detection and automated incident detection on the motorway.

Other adaptive signal control systems are available around the world (eg, MOVA, OPAC); however, not all of them manage signals on a network-wide basis. Martin et al (2003) provide a reasonable overview of the relative capabilities and merits of different systems. Because of the predominance of SCATS use in New Zealand, further discussion and analysis in this study will be based around SCATS; however, many of the principles would be equally applicable using other systems.

2.5.3 Paramics

Much of the development of traffic models in recent times has focused on (often complex) urban and motorway networks. In the past, computing power has limited the ability to model these networks in great detail, resulting in macro-simulation packages that rely largely on speed-flow curves or macro-flow profiles to determine link flows and efficiencies eg, SATURN by WS Atkins (United Kingdom). Now a number of software tools have been developed to take advantage of microsimulation techniques and one such tool is Paramics, produced by SIAS Ltd (Scotland)[1].

Paramics simulates the individual vehicles that make up traffic flow and congestion, and presents its output as a real-time visual display for traffic management and road network design. Paramics microsimulation is concerned with modelling individual vehicles for the duration of their journey through a network, with the route that a driver chooses not being predetermined, but depending on the network situation being encountered. The conditions in the model vary with time and drivers adapt their behaviour (eg, route choice) in response to this. Thus a Paramics model is not a traditional network equilibrium model, but a dynamic model.

One of the strengths of this microsimulation is that it can show an easily understood graphical display of real-time traffic flow on a computer screen. Although measurement and validation of network statistics will still be required to confirm the model's accuracy, major problems can be quickly identified using the maxim ‘if it looks wrong, it probably is wrong’. This approach should help to minimise coding errors, as opposed to the traditional model analysis by abstract accumulation of numerical data and related plots. The visual display also enhances the perceived validity of such models with both transport professionals and lay people alike.

Paramics has been developed over more than 15 years by UK traffic and transportation engineers. The name Paramics (‘**Par**allel **mic**ro**s**imulation’) is a legacy of its initial focus on running complex simulations on parallel processors. Earlier versions were only available for Unix systems, such as Linux PCs and Solaris servers, but the software has been mainly supported on Windows PC versions only for the last few years. Figure 2.5 shows an example of 3D visual modelling within Paramics (models can also be viewed in 2D or batch-run without visualisation).

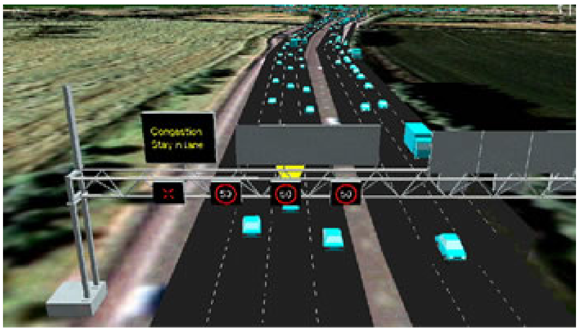

Figure 2.5 Paramics simulation

Three interacting models applied at the same time govern the movement of individual vehicles in a Paramics model; car following, gap acceptance and lane changing. In addition, drivers have certain behavioural characteristics randomly assigned to them – ‘aggression’ and ‘awareness’. These factors represent the characteristics of drivers that

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[1] It should be noted that, due to the original joint Paramics developers SIAS and Quadstone going their separate ways a few years ago, there are actually two versions of Paramics commercially available; Q-Paramics and S-Paramics. The latter is being used in this study.

result in their different performances with regard to gap acceptance, car following and lane changing. Top speed, headway and lane usage are also influenced by these factors. Some simple vehicle dynamics are also taken into account, such as size, weight (eg, for tonnage restrictions), acceleration and deceleration.

The road network is coded into the software in considerable detail and the success of the modelling depends somewhat on the accuracy of the road layout description. Unlike macroscopic network models, neither travel times nor intersection capacities are entered into the model. The input data includes details of nodes, links and a large number of other details describing the network, such as number of lanes, parking or bus lanes, bus stop positions, traffic signal data, movement definitions and priorities at intersections etc.

The most recent versions of Paramics have been able to simulate area-wide traffic control operations, using real-time urban traffic control (UTC) systems linked to a model of simulated traffic flows. Adaptive traffic control systems such as SCOOT or SCATS can be linked to Paramics, enabling the dynamic exchange of data between an external traffic control system and the simulated loops and traffic signals within the microsimulation model. In this way Paramics models can include signal operations optimised to variable traffic conditions and provide an ideal facility for testing UTC systems prior to installation.

Incidents can be modelled in Paramics using the incident editor (SIAS 2005). During a modelled incident, vehicles will slow down and/or stop for the duration of the modelled incident. The information input into Paramics to model an incident include: the duration of the incident, the speed of the vehicles (zero for stopped), turn delay experienced by affected vehicles (seconds), lane(s) affected and the incident rate (the percentage of vehicles using the specified lane that will incur the incident). If ‘feedback’ is turned on, vehicles will re-route to avoid additional delay caused by the incident.

ITS measures can also be modelled including VMS signs and transmitters (vehicles receive information about the incident when they are in a defined area). The incident information can include speed restrictions, lane restrictions, delay warnings, diversion routing and car-park availability advice. Drivers’ aggression, awareness and headways (for a specified area such as a ramp) can also be modified during the incident. The ITS messages can be applied to all vehicles, or to specific vehicle types.

Apart from Paramics, a number of similar network microsimulation packages have also been developed in recent years, such as AIMSUN (TSS, Spain), VISSIM (PTV, Germany), and DRACULA (ITS Leeds and WS Atkins, United Kingdom). While some of these models have had limited use in New Zealand over recent years (and in some cases have particular advantages over Paramics), the predominant microsimulation modelling to date in New Zealand has been with Paramics.

The University of New South Wales has developed a microsimulation model called SITRAS that can be used to model incidents on urban road networks. This is used to evaluate various incident management strategies for various types of incidents. It can also be used to determine the demand for various detour routes (Hidas 2001).

2.5.4 Modelling incidents with SCATS

SCATS was not originally developed as an incident management system (and certainly not a motorway management system), and this seems to be reflected in its relatively limited ability to detect and treat significant incidents. However, increasingly attempts are being made to use it as such a system.

Martin et al (2003) note that because SCATS measures the degree of saturation based on detector occupancy, rather than the actual volume departing from the intersection, the detector cannot differentiate between a high-flow rate (high occupancy and large number of vehicles departing from the intersection) and intersection blockage (high occupancy but low number of vehicles departing from the intersection). Hence, SCATS cannot easily respond to congestion when the queue from one intersection completely fills the link and blocks the upstream intersection.

A key issue is the fact that SCATS is traditionally based around stop-line detectors (as opposed to SCOOT's upstream detectors), making it harder to detect the presence of large queues upstream of the intersection. However, it is possible to install additional detectors upstream to help address common congestion issues, and this has been done in some locations in Auckland (Evans 2006).

Royce et al (2006) also notes that certain intersection lane configurations do not help SCATS to determine the most optimal phasing:

> Short lanes can affect lane use at intersection limit lines. The traffic flow on short lanes can be less (because of blockage), and therefore the SCATS degree of saturation can be less than otherwise would be if the lanes were used fully. SCATS therefore may allocate less green signal time to the approach than it needs to, since the degree of saturation would appear to be lower. For SCATS to operate correctly, the short lane must be long enough to always discharge at the maximum rate.

Lane utilisation is averaged in SCATS. Actual lane utilisation in many intersections can be poor, thus producing unused capacity, but the critical lane is not identified in SCATS. Tools such as LNSAT can be used to predict lane usage.

A study in Michigan attempted to use real SCATS data from SCATS-controlled intersections along with Police reports of traffic incidents and correlate them to determine how SCATS currently handles incidents (Taylor and Abdel-Rahim 1998). However, it became too difficult to match up the exact time of the incidents on the network. Instead, incidents were modelled in NETSIM and various incident management strategies were evaluated on a theoretical grid network. The strategies tested included signal control strategies, vehicle routing strategies and a combination of both. The signal strategies involved adjusting the signal timings to meter traffic at intersections upstream of the incident to avoid queuing. As the traffic demand increased, the effectiveness of these strategies also increased. The metering of traffic was effective, but only if there was sufficient storage to handle the queued vehicles.

The latest versions of SCATS now have an ‘unusual congestion monitor’ to try to identify abnormal situations. The RTA have also written a SCATS History Reader, to help use historical traffic data for testing the effects of incidents and treatments, and the University of South Australia has developed an automated procedure for analysing historical SCATS data (Taylor pers comm). Transit NZ has also had discussions with VicRoads and RTA who are using the Advanced Real-time Traffic Information System (ARTIS) software to dynamically assess network performance; a pilot of 100 junctions in Auckland is planned (Whyte pers comm).

2.5.5 Adaptive signal control and microsimulation

The effects of proposed ITS measures such as adaptive signal control and incident management strategies can be difficult to predict and evaluate using traffic flow theories, but can be modelled using microsimulation models such as Paramics. The modelled routes taken during incidents may depend on the base calibration formulation of the model. The changes in driver behaviour during an incident may not necessarily be well captured by the base calibration and it is probably necessary to investigate calibrating a model to incident conditions.

By default, fixed signal phase times are specified in most microsimulation models. It is common practice to model SCATS-controlled intersections in microsimulation models by using the average timings from SCATS. For forecast scenarios, the timings, phasing and offsets can be optimised in an external package such as TRANSYT for input into a microsimulation model, whereas the future intersections are actually likely to be controlled by SCATS. It is difficult to effectively model SCATS-controlled signals using fixed-time signal plans (Zhang and Taylor 2006). This problem can be compounded when modelling incidents, as fixed-time signals are unable to react to the change in demand resulting from incidents. Therefore, linking a microsimulation model directly to SCATS, instead of using fixed-time or actuated control, produces more consistent, stable, reliable and realistic results (Sissons 2006).

Incorporating SCATS signal control rather than fixed-time signals in a model can better replicate the existing conditions as well as future conditions and test scenarios for incident management modelling. As traffic networks become congested, the demand can exceed the capacity of the network. Microsimulation models output information only for the vehicles that were loaded onto the network during the simulation period. This does not account for the unmet demand that was unable to be loaded onto the network due to capacity constraints. Post-processing of the output can be done to account for the vehicles that basically remained queued in the zones (Sissons 2006), although it may be be difficult to identify how many of these trips in reality would be postponed or cancelled.

The RTA has worked with developers of microsimulation tools to develop interfaces between SCATS and microsimulation models including Q-Paramics, S-Paramics, AIMSUN and VISSIM (Lowrie 2006). Baseplus in Christchurch has recently developed baseplusFUSE to link SCATS to S-Paramics (Transit NZ 2006b).

In normal on-street applications, SCATS uses information from vehicle detectors, pre-determined operation boundaries and historical data to determine cycle times, phase splits, phase sequences and coordination offsets. BaseplusFUSE enables the actual on-street operation of SCATS-controlled intersections to be replicated in S-Paramics. It is relatively simple to code intersections in S-Paramics to be linked to SCATS through Fuse. Allowed and banned movements and vehicle detector locations are coded in S-Paramics and the signal 'personalities' are dropped into WinTraff, which emulates the signal controllers. S-Paramics, WinTraff and SCATSim (software that replicates SCATS when connected to a traffic model) can all be run on the same computer (see Figure 2.6).

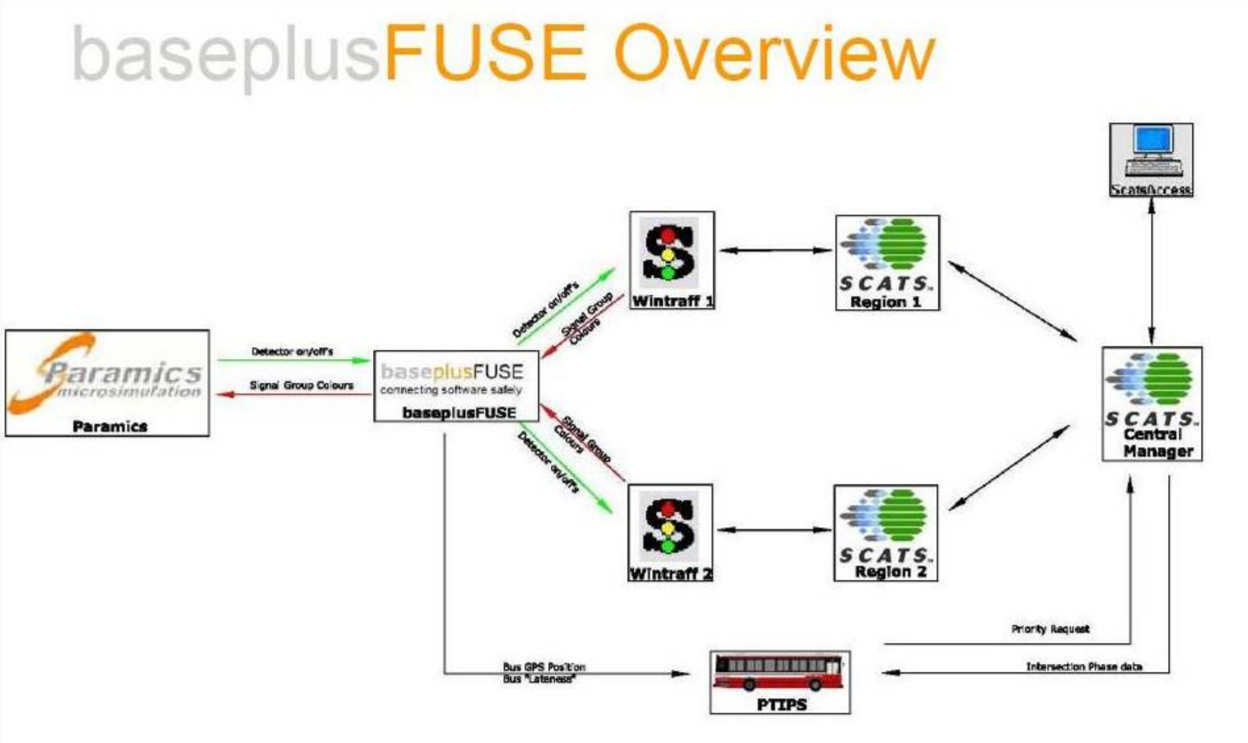

Figure 2.6 baseplusFUSE, Paramics and SCATS.

Theoretically, microsimulation models could be linked directly to a live traffic situation, to enable 'on-the-fly' assessment of incidents, modelling and performance evaluation of possible treatment measures (or of no treatment) and resolution of an appropriate strategy. The key to this would be faster-than-real-time modelling speed (and possibly parallel systems testing different scenarios), so that evaluation could be done in a timely manner to give useful information.

2.6 New Zealand and the international context

In New Zealand the most complex congestion management systems are currently operated by the Auckland and Wellington Traffic Management Units (TMUs), overseen by Transit NZ. Because of the larger, more congested network covered by the Auckland TMU, and its proximity to our key researcher, most of the investigations in this report are based on the Auckland situation.

2.6.1 Incident management in Auckland

The TMU draft regional CCTV and VMS strategy outlines the short, medium- and long-term implementation of VMS and CCTV on arterial roads in the Auckland region (Transit NZ 2006b). One of the purposes of this system is to create an efficient system of incident management. One of the benefits is that it will provide notification of incidents as well as alternate routes.

There are currently over 100 CCTV installations in the Auckland region. They are used for incident management on the motorways and traffic signal management on the arterials. Currently CCTV cameras are only installed at a few hot spots on the arterial network. There are 11 permanent VMS on Auckland's motorways used for incident management and motorway operations and six portable VMS used for incident and special event management. Figure 2.7 shows an example of one such VMS, approaching the moveable lane barriers on the Auckland Harbour bridge.

Figure 2.7 Example of variable message sign on Auckland Motorway network.

The Auckland TMU was established by Transit NZ in 2003 to provide Auckland with integrated traffic management for the region. The TMU released the *Auckland incident management strategy* in January 2005 (Transit NZ 2005). The strategy is applied to all roads on the primary network, defined as 'all regional and district arterials, plus all roads with traffic signals which, if closed as a result of an incident, will result in severe congestion on alternate routes'. The benefits of improved incident management include more reliable travel time on the transportation network, resulting in reduced transportation costs and improved traveller information. One of the issues outlined with the current transportation system includes capacity problems on detour routes, particularly during the peak periods that may be unable to cope with the increased demand resulting from diverted traffic.

Auckland Traffic and Transport Operation Monitoring Service (ATTOMS) is Transit NZ's Auckland Traffic Management Centre and manages Auckland's motorways and traffic signal operation on key regional arterial roads. ATTOMS includes a control centre operating 24 hours a day that operates Auckland's Advanced Traffic Management System (ATMS) and Advanced Traffic Information System (ATIS). Operators at ATTOMS monitor

CCTV cameras and control VMS in order to manage incidents and events on the motorway network. ATTOMS also operates the traffic signal system for the Auckland region, which is controlled by SCATS. Trained SCATS operators monitor and adjust, as necessary, the signal system. Figure 2.8 shows the view inside the ATTOMS centre.

Figure 2.8 ATTOMS Control Centre.

ATTOMS has extensive CCTV coverage of Auckland's motorways and is able to quickly detect and verify incidents, and works closely with the Police to provide suitable responses. Another major source of incident detection is calls from the general public as well as from the Police. These calls can be verified using CCTV. On some central parts of the motorway network, there are loop detectors located at 500 m spacings that collect speed and occupancy data. The detectors were used as part of an AID system, but this system is not currently in use. As Auckland's traffic network expands, extensions to the existing traffic management systems will be deployed, including robust AID capabilities. Figure 2.9 shows an example of the range of visual and numerical data that can be viewed remotely to help monitor traffic flows.

ID	TimeStamp	Event Type	Source
1601822	1/02/2001 07:41:08	SPEED_ALARM	VIPD5bZone4
1601821	1/02/2001 07:41:05	SPEED_ALARM	VIPD5bZone2
1601820	1/02/2001 07:37:16	SPEED_VARIATION	FCCTV11TDZone2
1601818	1/02/2001 07:36:43	STOPPED_VEHIC	FCCTV11IncidentZ
1601809	1/02/2001 07:13:52	SPEED_ALARM	VIPD5bZone2

Figure 2.9 Example of TMU monitoring data (Wellington Motorway network).

Detour plans are in place to manage incidents on Auckland's motorways. The detour plans include a listing of all of the signalised intersections on each detour route as well as the phase affected by the detour. The SCATS operators can then provide additional green time as required during the detour. As the CCTV coverage on the arterial network is limited, the SCATS operators generally rely on information they receive from the incident response unit (generally the Police) as well as the SCATS detector information to determine manual adjustments.

2.6.2 Incident monitoring in New South Wales, Australia

The Roads and Traffic Authority of New South Wales (RTA) has a Transport Management Centre that is the command and control centre for the operational management of the NSW road network (RTA 2005). The Transport Operations Planning Section has developed formal response plans for certain sections of the roadway. The plan may contain information on alternate routes. The network operation officers monitor the effectiveness of the traffic signal system controlled by SCATS. The system is continually tuned using advanced traffic modelling techniques and then adapts to changing traffic demand.

The Transport Operations Room monitors and manages incidents on the network using over 400 CCTV cameras and 54 VMS. There are over 2800 SCATS-controlled intersections in the traffic network.

The Incident Management System stores incident response plans that are matched to the incident data to give the operator a choice of response plans (local, tactical or strategic response plan). The type of response chosen will depend on the extent of the area affected (eg, viable diversion routes). Incident detection algorithms use speed, flow and occupancy data obtained from loop detectors spaced at 500 m on the motorways. SCATS detectors at intersections are used to detect unusual traffic flow and alert the Incident Management System. Incidents are also detected manually from Police, media and calls from the public.

2.6.3 United States incident management and adaptive signal control

In the United States, it is estimated that over half of all freeway congestion is caused by incidents (USDoT 2000). Most incident management strategies are focused on freeway incidents and the integration of the arterial network signal control with incident management is not common practice. However, route diversion is an effective incident management strategy and coordinated arterial signal control during incidents should be part of an effective incident management programme.

The Federal Highway Administration (FHWA) developed a framework for implementing adaptive signal control strategies in 1992 called Real-time Traffic Adaptive Control System (RT-TRACS). This included the development of Optimized Policies for Adaptive Control (OPAC) (Gartner et al 2001). The City of South Lyon, Michigan has installed SCATS-controlled signals as part of the Faster and Safer Travel-Traffic Routing and Advanced Controls (FAST-TRAC) programme. This programme has proved to be quite effective. Although much research has been done to evaluate various adaptive control strategies, their use is still quite limited in the United States (Fehon 2005).

2.6.4 Scottish traffic monitoring

Traffic Scotland enables the collection and distribution of real-time traffic information relating to incidents and events currently taking place on the Scottish trunk (arterial) road network (Scotland Transport 2007). This is known as the National Driver Information and Control System (NADICS).

Road users on Scotland's trunk roads are provided with information about road conditions with the aim of ensuring that best use is made of the existing Scottish trunk road network and to improve the safety and the efficiency of the network. By displaying messages on VMS, drivers are given advance warning of problems on the Scottish trunk road network. These may include roadworks, accidents, events, bad weather conditions and road closures.

On part of the trunk road network, overhead lane signalling improves road safety by telling drivers of lane closures and speed restrictions. This information can help drivers make the best response – from slowing down and changing lanes, through to selecting the best alternative route. When there are no known traffic incidents, safety messages are displayed.

Traffic Scotland is operated from the National Network Control Centre (NNCC), which is a 24-hour driver information and traffic control centre. From the NNCC, the trunk road network traffic conditions are monitored, using loops in the road and closed circuit television cameras.

The Police, from their own control rooms, are responsible for setting localised VMS and lane control signals during the initial stages of a traffic incident. The setting of strategic signing across the Scottish trunk road network is the role of the NNCC. The Police also answer and handle all telephone calls from the motorway emergency telephones. Trunk road maintenance operators, who are responsible for maintaining the trunk road network, advise the NNCC of roadworks planned and currently underway.

When traffic disruption is detected, the incident details are entered into Traffic Scotland's central computer system either manually or automatically. When the response to the incident is assessed, appropriate messages on VMS and/or control signalling are set. Traffic Scotland is able to assess the impact of various types of incidents and quickly react with the most appropriate response. Appropriate information is also passed on to the media and motoring organisations for radio broadcast.

Depending on the type of incident, two types of responses can be displayed to the road users:

- **Strategic response:** VMS located at key points in the Scottish trunk road network advise drivers of incidents and delays that lie ahead. This allows drivers to adjust their journey as they travel between the major urban areas.
- **Local response:** VMS and regularly spaced overhead lane signals on urban motorways provide warning and information to drivers concerning local traffic incidents, roadworks and delays. Automatic traffic detectors and closed circuit television allow rapid detection and response to traffic problems.

In addition to VMS and overhead lane signals, real-time information is distributed using the Traffic Scotland website and associated WAP and PDA services.

A similar system, Motorway Incident Detection and Automatic Signalling (MIDAS), has been implemented on the United Kingdom motorway network since 1995 (Morris and Negus 1997). This system is also more advanced in active traffic management control philosophies (eg, hard-shoulder running, mandatory speed signs).

2.7 Implications of literature findings

The literature review from the current project indicates a lack of combined research in this area, both in New Zealand and elsewhere. Research has been done in the areas of incident detection and management, ITS methods such as adaptive signal control (eg, SCATS) and network reliability measures. However, little research has been done to bring these three research areas together.

While the Auckland and Wellington TMUs make use of the SCATS system and incident monitoring tools, there is no automated means of combining the two and it is not clear what the relative effectiveness of existing incident management methods are. There is also no published data on the frequency, impacts and other characteristics of incidents in New Zealand; some analysis of ATTOMS data may be necessary to determine the scale of the problem in Auckland at least.

Elsewhere in the world, the Scottish NADICS system is worthy of further investigation, particularly in terms of its system organisation and VMS strategies. Closer to home, Australian state systems provide good practical experience of incorporating SCATS systems into wider network management and incident detection programmes. While the United States has traditionally been to the fore in terms of freeway management systems, the relative lack of use of adaptive traffic signal systems hinders their usefulness in the New Zealand context.

While major motorway networks are now increasingly being set up to detect incidents, the detection of incidents on lesser arterial road networks is currently fairly limited. However, incidents on one part of the network (motorway or arterials) show no such distinction in terms of their effects across other parts of the network. It would seem a sensible strategy, therefore, to enable more integrated incident management systems (both at the hardware and personnel levels) that considered the entire arterial road network.

Adaptive signal control systems such as SCATS have clearly proven their worth under typical operating conditions, although that still relies on them being set up properly to produce optimal timing patterns. It is less clear how well they work under abnormal incident conditions, and how much they need to be modified under these circumstances to best manage the effects and return the network to normal as efficiently as possible. Some key questions to investigate include:

- Is normal SCATS operation actually OK without intervention during incidents? (probably not in many cases)
- How much benefit is there in just optimising normal SCATS operation so that it is more efficiently run? For example, in Christchurch, intersections are reviewed on a five-yearly basis using updated count data and other information (crashes, network changes, etc).
- How beneficial is it to produce relatively generic alternative SCATS plans that can be quickly implemented should an appropriate incident be detected?

It is notable that the competing SCOOT system seems to be more capable in incident detection, partly due to greater software development in this area and partly due to its upstream traffic detector architecture. The latter issue can, however, be addressed in SCATS by employing greater use of upstream queue detectors in addition to the stop-line detectors.

A basic problem in assessing the effectiveness of real-world applications of incident management is that such interventions cannot be objectively measured in a comparative manner by whatever metric (eg, additional journey delays, time to restore the network to normal operation). While these measures can be monitored, the precise conditions of a real-world incident are highly variable and unable to be replicated to allow straightforward before-after comparisons. Trend analysis of multiple incidents may be able to provide some comparative assessment but, otherwise, traffic simulation is the *only* means to precisely replicate traffic incident conditions.

Microsimulation is thus a good tool for evaluating incident management strategies; however, there is a lack of good real incident data available. Incident data can be generated using microsimulation, but it may be necessary to better calibrate microsimulation models to incident conditions (where driver behaviour may be different than under normal conditions). Microsimulation models should be linked to SCATS to provide better results than fixed-time signal systems, both for existing conditions and for modelling incidents.

The ever-changing nature of ITS technology may mean that some newer congestion management treatments may emerge by the time this research is fully completed. While we do not expect this to make current systems and treatments immediately redundant, this does need to be constantly monitored.

3. Modelling methodology

Based on the findings from the literature review and discussions amongst the research team, industry steering group and other relevant people, an outline plan of the modelling tasks to be undertaken was developed. This included a list of potential situations or treatments to examine in modelling, although most of them would be investigated at a later stage of the project.

3.1 Proposed modelling

The initial work was an exploratory study modelling incident detection and response in a New Zealand urban network using microsimulation. It was proposed to set up a replica of an existing urban network (or part thereof) and model the performance of the network (eg, in terms of total travel times, delays and stops) under various abnormal conditions (eg, by introduction of a ‘blockage’). The model would include a simulation of the SCATS signal control system to assess how well it automatically responded to significant changes in network flows. The same network would then be tested using alternative management plans (either pre-existing or newly derived) to assess their effectiveness at improving overall network reliability. Different measures of network performance and reliability would be assessed for their usefulness in evaluating options.

Particular questions to be assessed would be:

- How well do existing traffic signal control systems (eg SCATS) identify and handle significant incidents, in terms of network reliability?
- How do specific incident management plans compare with default schemes when handling significant incidents?
- What is the impact of different response times to the overall performance and recovery of the network during and after an incident?
- How can incident management plans be automatically invoked when significant incidents occur?
- How do motorists perform when faced with congestion related to an incident, particularly when provided with information about the situation and alternatives?

3.2 Key testing factors

The proposed modelling would involve a number of key factors:

- **incident scenarios** to be replicated
- **management treatments** to be tested
- **performance measures** to be evaluated

These are discussed in more detail below.

3.2.1 Incident scenarios

For the incidents to be replicated, combinations of different types of incidents should be considered such as:

- **Planned** (eg, event) or **unplanned** (eg, accident) incidents. There is likely to be more interest in unplanned rather than expected events (where a contingency plan may already be prepared), as there is usually a need to determine acceptable treatment solutions in a relatively short time-frame.
- Incidents on the **motorway** versus those on the surrounding **arterial network**. It would be ideal to test both situations as there are likely to be different response/intervention times, given the lack of incident detection off the motorway corridors.
- Varied **capacity reduction**, from speed reduction to single lane blockage to total road closure. For example, a major incident on one side of a road may also have some effect on the opposing traffic; a 20–30 km/h speed reduction on a road segment could be used to represent ‘rubber necking’.
- A range of **response times** by authorities in resolving the incident. For example, an incident on the motorway may have a quick response (due to good CCTV coverage), whereas an incident on an arterial road may have a slower response (due to the longer time to detect it, particularly in terms of effects on the monitored parts of the network).

The time period to be modelled (and subsequent volume/capacity ratios) would also greatly affect the effects of any incident modelled. A network with relatively low traffic volumes (eg, late at night) may see little effect on travellers if an incident occurs, and thus fairly few benefits accrue from any management treatments. Conversely, for a network already operating at near capacity, it may be very difficult (if not impossible) to achieve any meaningful improvement in network performance if an incident occurs. Taking these factors into consideration, for the purposes of this exercise, the assumed modelling time period would be the shoulder of the peak period, where some excess capacity on the network still exists but traffic is still relatively sensitive to any incidents.

Similarly, it must be accepted that some extreme-demand incidents are probably impossible to handle adequately by any intervention, eg, the recent opening of the Sylvia Park shopping complex in Auckland (NZ Herald 2006).

One aspect of network reliability that may be worth considering when creating suitable incidents is where the most vulnerable points in the network are, ie:

- Where are incidents most likely to occur? This may be as a consequence of the road geometry or location of key conflict points (eg, location of high numbers of crossing, merging, weaving manoeuvres).

- Where are incidents most likely to have the greatest impacts on overall network performance? This may be in terms of network topology (ie, few alternative routes) or locations of greatest demand for links.
- Are incidents more likely to occur at certain times or with certain volumes? Speed-volume relationships may mean, for example, that low-speed near-capacity situations are not as hazardous as higher-speed medium flow situations.

ATTOMS produces monthly reports of notable events; these could be used to determine suitable timeframes and locations for modelled incidents.

3.2.2 Management treatments

The work to date has identified various treatments to be evaluated:

- **Letting the existing SCATS setup automatically adjust** to the new situation by itself (either in an optimised or 'sub-optimal' SCATS configuration). Since SCATS is designed to dynamically adjust the system to better manage flows, its ability to do this under all circumstances needs to be tested. It should be noted, however, that by default, SCATS has been 'dampened' down to change behaviour gradually.
- **Changing SCATS signal timing plans** so that alternative detour routes are given greater priority. Key issues will be in determining suitably generic alternative plans that can be applied to a range of incidents, knowing when to apply such a plan in lieu of the default configuration and knowing which plan to apply.
- **Providing driver information** (eg, through dynamic VMS or in-car navigation) and advising motorists of the incident and suggested detours. As well as determining suitable communication strategies, some local research is probably necessary to determine driver response to this information.
- **Limiting additional vehicles into the incident-affected section** (eg, via ramp metering or reduced signal phases). While this may help to limit the local effects of an incident, it needs to be compared with the wider network effects of shifting some traffic elsewhere, or causing cancellation or postponement of trips.
- **Temporarily reallocating roadway space** (eg, allowing shoulder or bus-lane use by general traffic, or reassigning variable traffic lanes). Again, key issues are to identify when this is appropriate and the broader network-wide effects of doing so.

Note that some of these treatments could be implemented together.

The biggest difficulty will probably be in determining the most suitable (or a sufficiently suitable) treatment for the particular incident being considered. There are a lot of different scenarios in many potential locations and treatments cannot be generalised for all scenarios. Ultimately, for a large complex network, it may require a considerably large selection of management plans to be developed to cover the range of incidents that may occur (particularly with regard to location). Investigation of specific case studies, as is being done here, may produce solutions that are only applicable to that particular situation and not widely applicable elsewhere. While to a certain degree this is always the case, the study will endeavour to infer general conclusions based on observed trends across a number of different test cases, and from the literature review.

For longer incidents, it may be that a suitable treatment strategy can be identified once some traffic data has been obtained either from field observations or modelling. For example, when maintenance works were carried out on the Mangere Bridge in Auckland, reducing its capacity, there were initially significant delays across the network. Once the capacity reduction was known, the Auckland TMU was able to modify SCATS to cope and there was a 30% increase in throughput after the appropriate changes were made (Monk pers.comm).

Systems such as SCATS can also be adjusted manually to deal with incidents, but generally CCTV coverage is needed to see effects and adjust the system accordingly. The base personality does not change, but order of phases and ‘voting’ can be changed. Parameters can be set up to make these changes.

3.2.3 Performance measures

From the simulation runs, various measures can be defined and collected to evaluate the effectiveness of treatments:

- Overall total network **travel times**. For most economic evaluations of treatments, this provides the most authoritative measure of effectiveness. However, it may not always match the desired objectives of transportation agencies or the perceived effects on road users.
- **Variability** in vehicle travel times. As discussed in section 2.4.1 above, this measure may provide useful information about the way the performance of the network is perceived by road users.
- Amount of **detouring** undertaken by motorists. The level of diversion will be affected by the relative proportion of familiar and unfamiliar drivers (a parameter that can be set in Paramics) and the available alternative route information (eg, VMS, in-car navigation). It is likely that unfamiliar drivers will be making longer trips, either in terms of distance (by not knowing about short-cuts) or in time (by staying on the originally affected route).
- **Time to recover** to normal travel times following an incident. Two things that can affect this are the time taken to detect an incident (and respond accordingly to it) and the treatment applied to clear any built-up queues once the initial trigger event itself has been resolved.
- **Relative performance** of motorway network versus arterial network. Unless a reduction in overall travel demand is achieved, any treatments to divert traffic or change route priorities will have a positive effect on some road users and negative effect on others. Given the different functions of different parts of the network (eg, through-movement versus local access) it may be deemed acceptable for some parts of the network rather than others to bear the burden of additional delays. Flow weighting could be used to capture this effect.

If using modelling to derive predicted performance measures, it is important to remember that measures such as overall network travel time are only comparable if the whole traffic demand is able to get onto the network in each scenario; there may be a need to ensure that the modelled period is long enough to capture this.

Over time, any changes in the capacity of the network or in the way that incidents are treated may affect the relative demand for travel on that network. For example, people who currently avoid travelling at certain times or on certain routes because of the consequences of any incidents, may shift their departure times or route choices if they find that incidents there are now being better dealt with. For now at least, our ‘design incidents’ will assume no long-term change in travel behaviour.

Incidents will usually cause localised travel time changes and thus the impact will be greater on local trips. Longer trips will not be affected as much, in relative terms. Factors can be developed to dampen the measured reliability based on total trip time.

3.3 Modelling considerations

For this study it was proposed that S-Paramics, WinTraff and FUSE software would be used to model the road network, control traffic signals (replicating SCATS management of them) and respond to simulated incidents. Key information such as overall travel times and number of stoppages could then be extracted from the microsimulation model for analysis.

It was envisaged that at least one model from a major New Zealand city (Auckland, Wellington, Christchurch) would be set up to investigate the issues raised above. Based on discussions with the research review team and other industry practitioners, attention focused initially on a suitable model from the Auckland region. Section 4 describes the preliminary model tested.

It may be difficult to test some particular scenarios on this preliminary network or another suitable real network. If necessary, theoretical test networks could be created to replicate real-life conditions instead, although then there would not be any opportunity to validate the model against real-world field data.

For practical purposes, it has to be assumed that any incident to be modelled would occur within the model area and that its effects would also be sufficiently captured within this area. Technically this may be difficult to achieve unless an exceptionally large network is modelled. A SATURN model of a larger area could be used to capture any wider changes in demand resulting from an incident; this may be considered at a later date.

At the very least, the traffic demand should be consistent across all scenarios. It is important to make sure that all of the demand is loaded onto the network and trips are not queued into zones at the end of the simulation run. This is achieved by simulating a sufficiently long ’after’ period to make sure that the incident and its effects clear up during the simulation run.

Microsimulation has a variability in demand (due to the stochastic nature of the simulation), which affects predicted travel times. Microsimulation linked to SCATS will cause even greater variability. Multiple simulation runs therefore become important, using different 'random seeds' to reflect day-to-day variations typically observed (but with the same seeds replicated for each treatment option). The results would then be collated and performance measure statistics derived.

For the preliminary modelling, field survey data (eg, observed travel times) would not be collected to calibrate and validate the model under all circumstances. This data is particularly important to confirm driver behaviour patterns under revised network management plans (particularly for behaviour-change treatments such as VMS). However, the initial aim was to find a model that is at least sufficiently calibrated/validated under normal traffic situations. It would be assumed for this stage that any models are still valid under incident conditions as well.

Later modelling work could then determine the validity of this assumption in a number of ways:

- Historical SCATS data could be used to determine actual traffic flows, queues, phasing, etc during incident conditions. Because of the volume of data obtained, such historical data is not usually stored continuously, so particular arrangements would need to be made to capture it. The proposed ARTIS software trial in Auckland might also provide a more efficient way of storing key incident data.
- To a large degree, SCATS data is confined to capturing effects at intersections. Collecting information along motorway or other arterial corridors is more sporadic. However, in the near future Transit NZ plans to have detector loops every 500 m on the Auckland Northern Motorway collecting speed/classification data. The ramp metering installations in Auckland also collect upstream traffic flow data.
- Observed field data, such as floating-car runs for travel time and observed queue lengths, could be organised. While collecting such data under normal base conditions is reasonably straightforward, the challenge is in being able to collect such data promptly when an incident occurs (particularly an unplanned one). A suitable number of runs may also be needed for statistical confidence in the measures.
- For planned incidents, such as maintenance works, field data could be collected and compared with a similar model. An interesting side-study would be to consider the effects on the behaviour of prior knowledge of planned incidents (eg, via media reports). In practice, however, most significant planned events are held during off-peak periods to avoid any major effects on the network.
- A possibility to consider is artificially contriving a severe incident (eg, a road closure during roadworks) and monitoring its effect on the network. The practical and ethical implications of doing this would need to be considered however. It is very unlikely that a road controlling authority such as Transit NZ would allow such an event on a major arterial.
- Similarly, for testing the effects of VMS locally, various signing strategies may need to be trialled in practice and monitored to see their relative effects on route diversion.

The costs and practicality of doing this, however, should not be under-estimated. Alternatively, it may be possible to test such scenarios on drivers away from the road network using a driving simulator.

- Live traffic data collected for adaptive signals and incident management is not usually stored permanently, due to the high storage capacity needed. For high-risk locations where incidents are relatively common, it may be feasible to monitor such sites for a specific period (eg, switch on saving of data) in order to capture for later analysis relevant information during any incidents that occur there.

4. Preliminary modelling

For the initial preliminary modelling, an existing, calibrated model was chosen from North Shore City, and referred to as the Wairau Road Model. The model was originally developed using S-Paramics to test the impacts of a proposed new land-use development.

4.1 Model description

Figure 4.1 shows the approximate location of the Wairau Road Model. The model featured a portion of the Auckland Northern Motorway (State Highway 1) as well as a parallel signalised route along Wairau and Taharoto Roads. Two interchanges (Tristram Ave and Northcote Road) were included to enable motorists to switch between routes. It should be noted that this section of the Northern Motorway had also been undergoing significant roadworks recently due to the construction of the adjacent Northern Busway and the upgraded Esmonde Interchange (bottom of map).

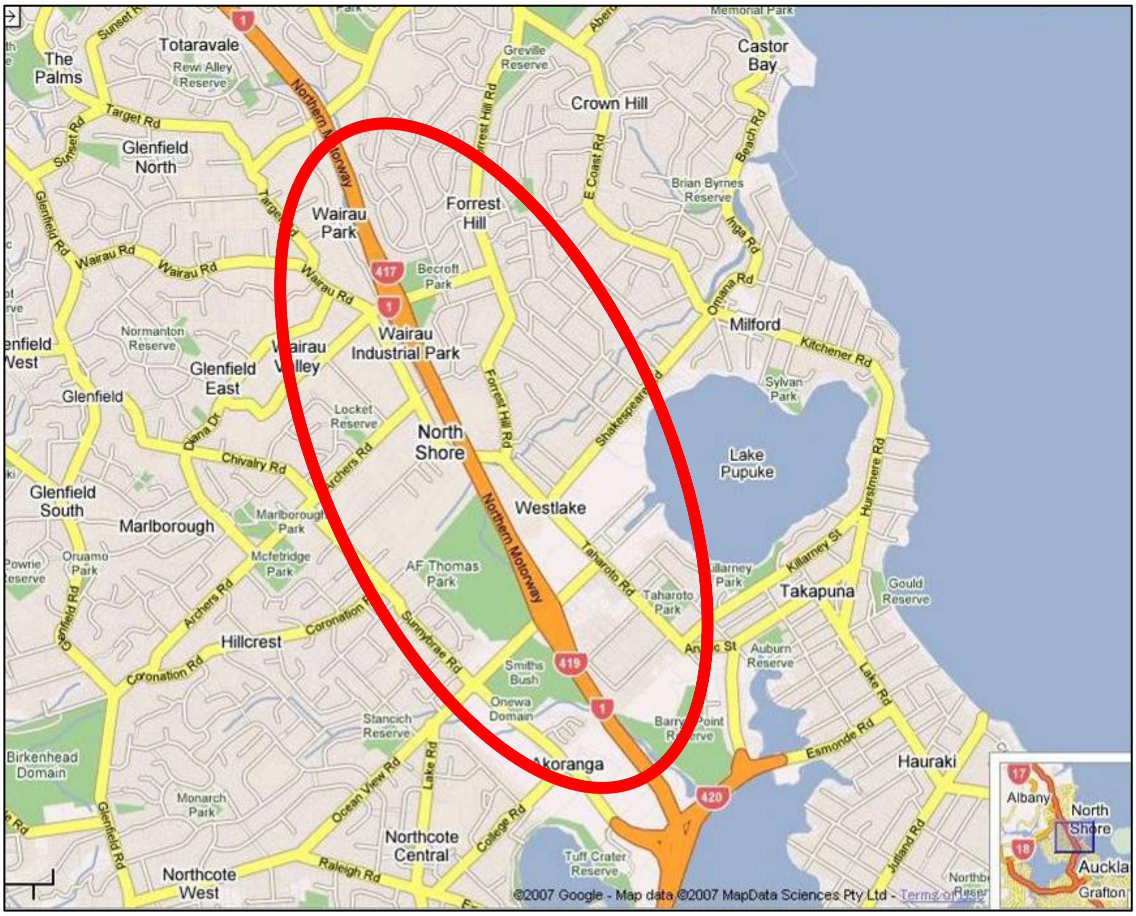

Figure 4.1 Location of Wairau Rd Test Model network.

Figure 4.2 shows the network layout in the existing model. In looking at the wider road network, it can be observed that there were potentially additional links outside of the modelled area that might act as suitable parallel detour routes for some motorists (eg, Sunnybrae Road). Similarly, major incidents occurring within this model area might produce impacts outside of the model boundaries (eg, further north on the motorway). While such modifications to the network would not be undertaken for the preliminary modelling, consideration would be given to expanding the model at a later stage to include these alternatives.

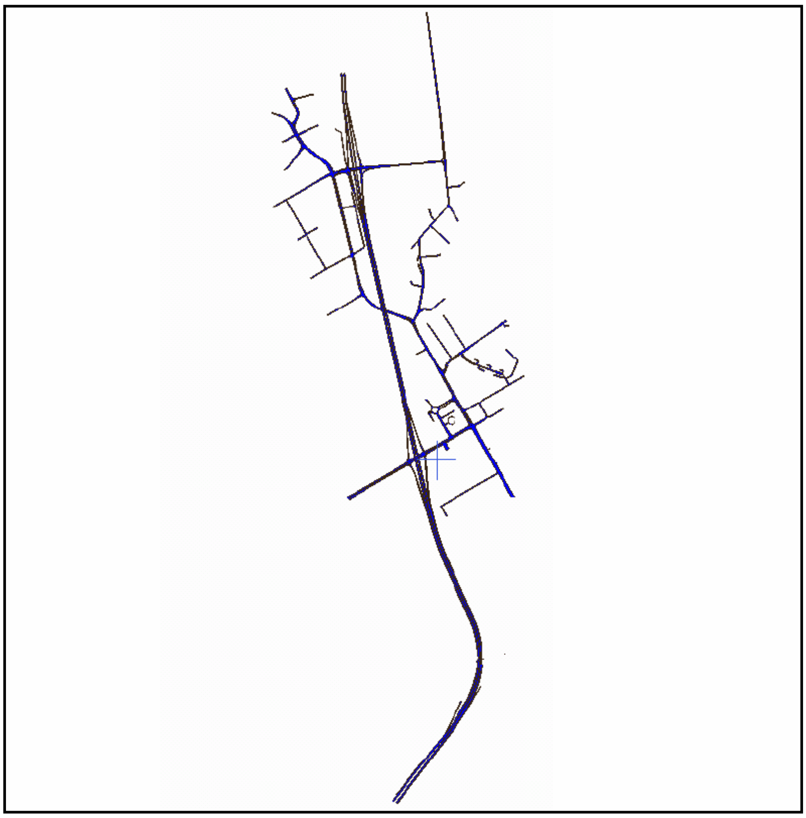

Figure 4.2 Layout of Wairau Road Network Model.

4.2 Incident modelling

The following features were modelled in this study:

- One time period 3.15 pm–4.30 pm (before the evening peak)
- Incidents on motorway SH1 northbound (three-lane section between Tristram and Northcote interchanges) see Figure 4.3
- Closure of the kerb lane from 3.30 pm–4.00 pm and closure of centre lane from 3.30 pm–3.45 pm. Figure 4.4 shows both incidents.

This scenario was used as the incidents would cause enough congestion on the motorway for some motorists to divert onto alternate routes. The pre-peak demand allowed for some spare capacity in the network during the base condition. This allowed SCATS an opportunity to make changes as the demand changed due to the incidents. When the network is already fully congested, SCATS cannot adapt well to the change in demand as phases times and cycle lengths may already be at their maximums.

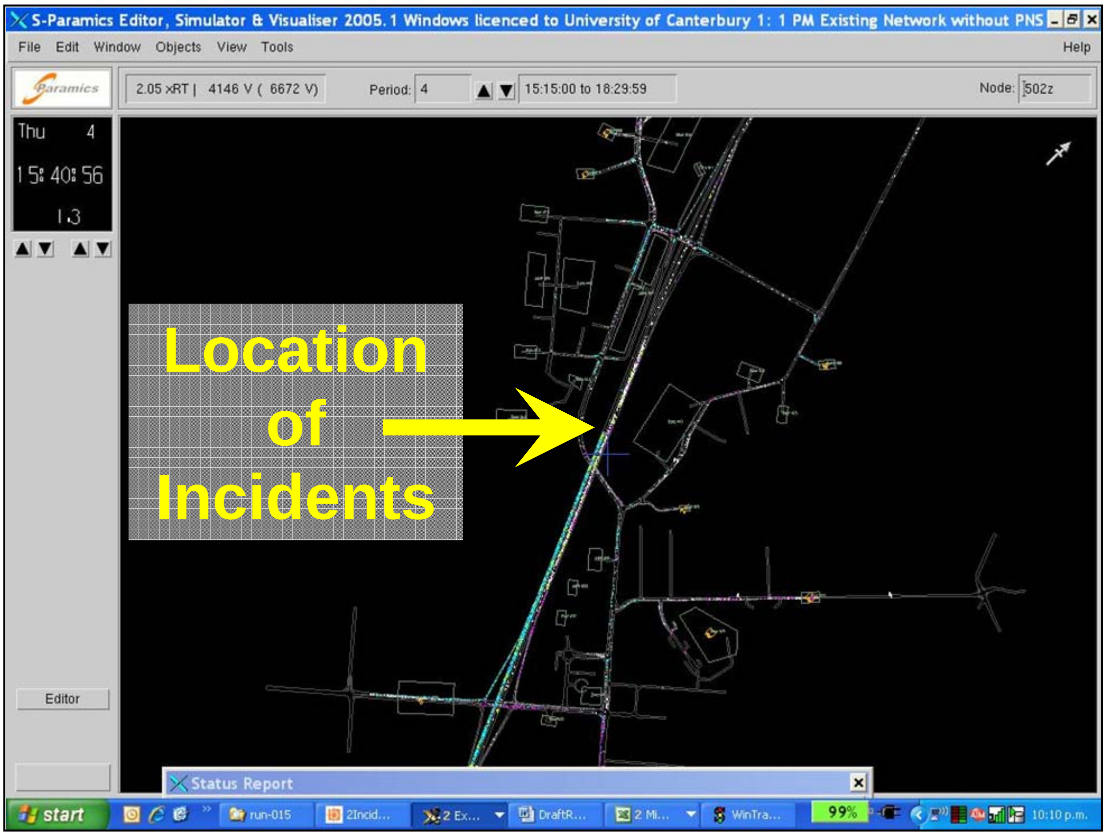

Figure 4.3 Location of incidents SH1 northbound.

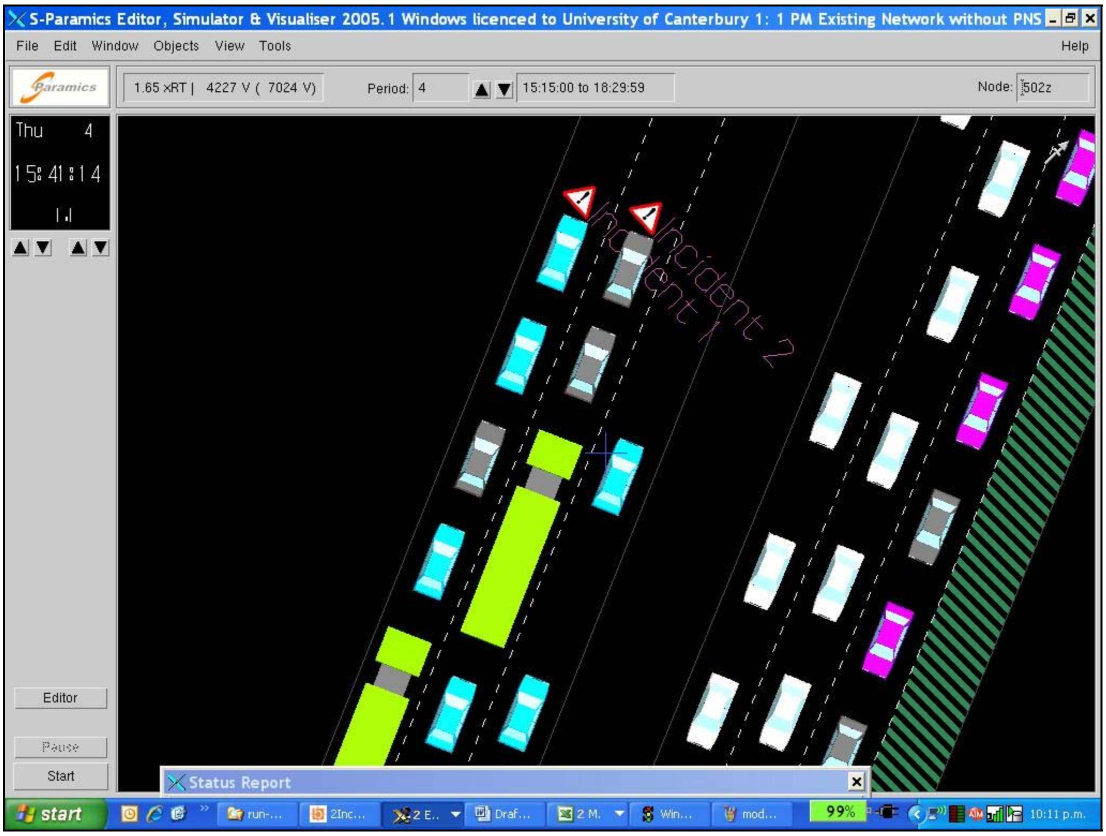

Figure 4.4 Two incidents in Paramics.

The following treatments were tested against these scenarios:

- SCATS configuration provided in the base condition
- 'Good' SCATS configuration optimised for re-routing from the motorway.

4.2.1 Model results

The incidents modelled created a great deal of delay northbound on the SH1 motorway south of the Tristram interchange. Queues spilled back past the Northcote off-ramp to the Northcote on-ramp. This created two diversion scenarios for trips heading northbound on SH1 to the northern extent of the model (north of the Tristram interchange).

The first diversion (Northcote Diversion) is shown in magenta in Figure 4.5. Due to the additional delay northbound on SH1, vehicles exited at Northcote Road and travelled eastbound to Taharoto Road, northbound on Wairau Road and rejoined SH1 at the Tristram Avenue interchange.

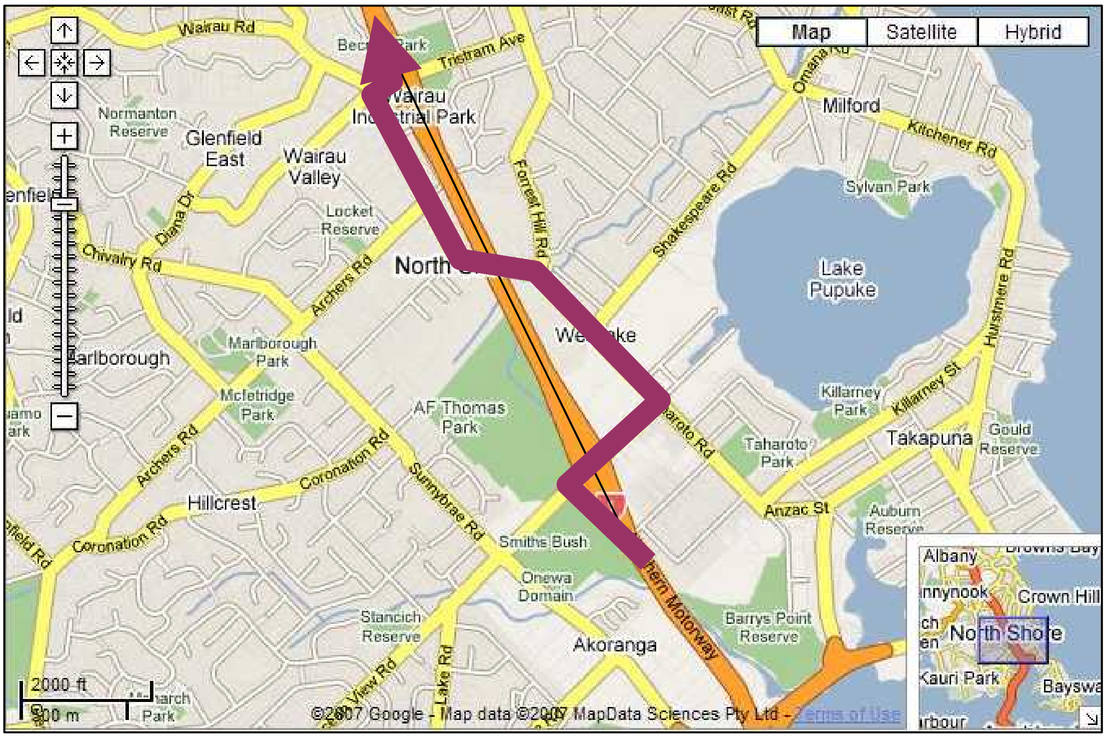

Figure 4.5 Northcote diversion route.

This diversion route was considerably longer with much lower speeds than the motorway. In the base condition, no vehicles took this diversion route so the average speed and journey time for this route could not be determined. In the incident condition, some vehicles took this route due to the stochastic nature of the model even though there was no decrease in travel time. When SCATS was modified to give additional priority to the northbound Taharoto Road/Wairau Road route, there was a decrease in the travel time versus the original SCATS settings. This is shown in Figure 4.6 and Figure 4.7.

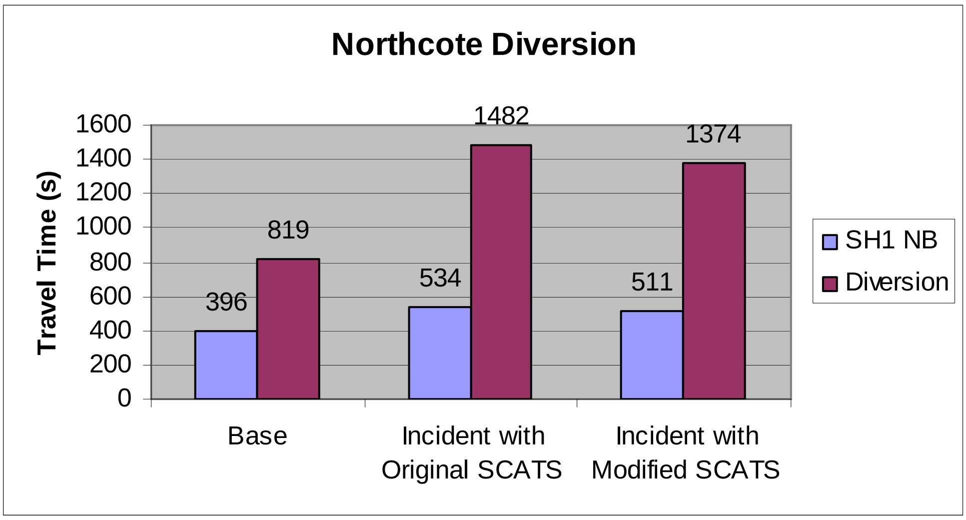

Figure 4.6 **Travel time comparison for Northcote diversion.**

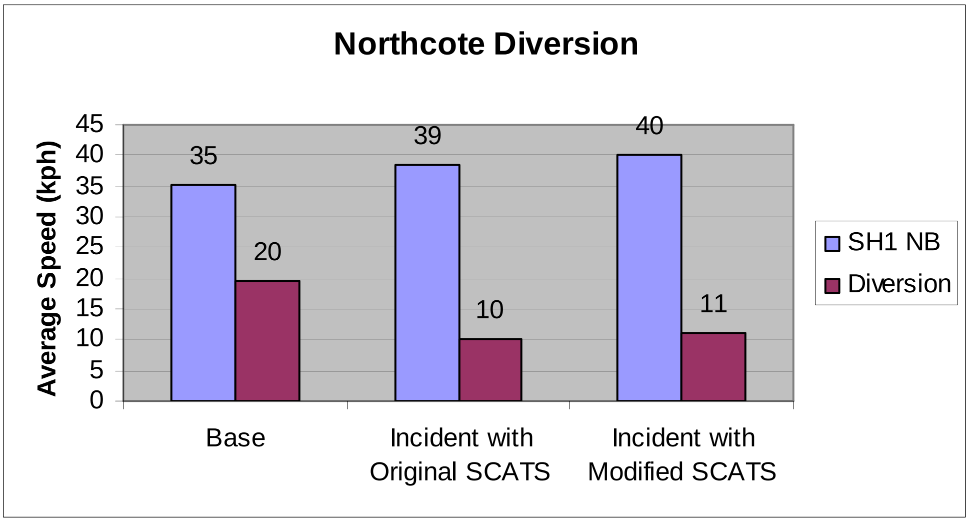

Figure 4.7 **Average speed comparison for Northcote diversion.**

The second diversion (Taharoto Diversion) observed is shown in magenta in Figure 4.8. In the base condition, most vehicles travelling northbound on Taharoto Road destined for the north end of the model on SH1 took the Northcote on-ramp (route shown in blue). In the incident scenario, a portion of these vehicles diverted away from the motorway as the on-ramp became blocked. Instead they continued northbound on Taharoto Road, onto Wairau Road and took the Tristram on-ramp to SH1 northbound.

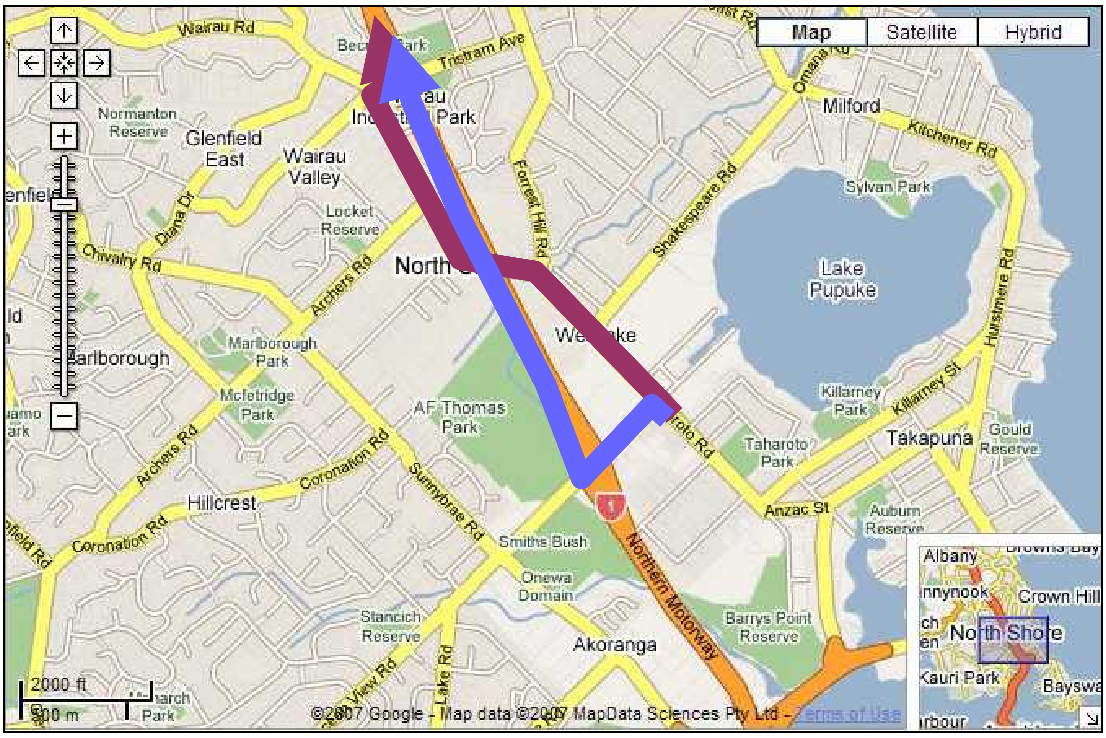

Figure 4.8 Taharoto diversion route.

Again, with the modifications to SCATS for priority in the Taharoto/Wairau route, the average travel times were reduced. The results of the Taharoto Diversion are shown in Figure 4.9 and Figure 4.10.

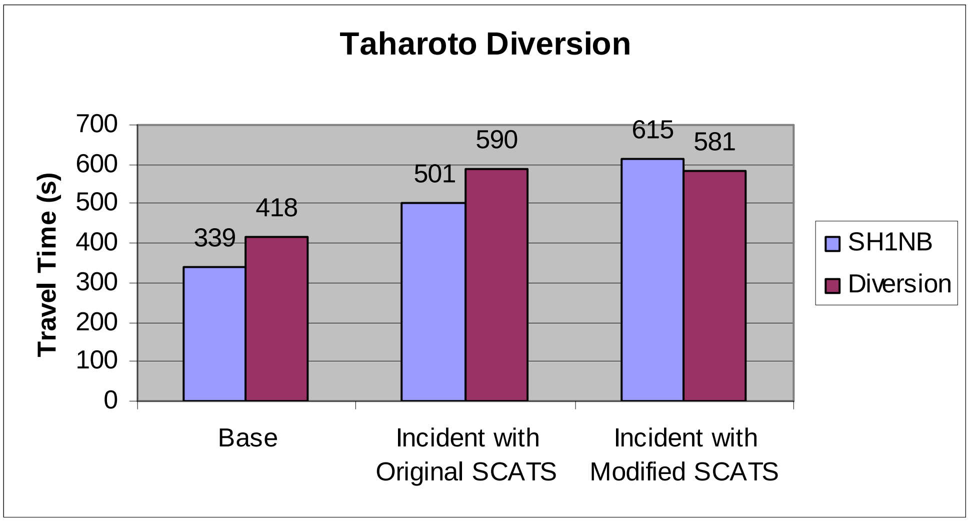

Figure 4.9 Travel time comparison for Taharoto diversion.

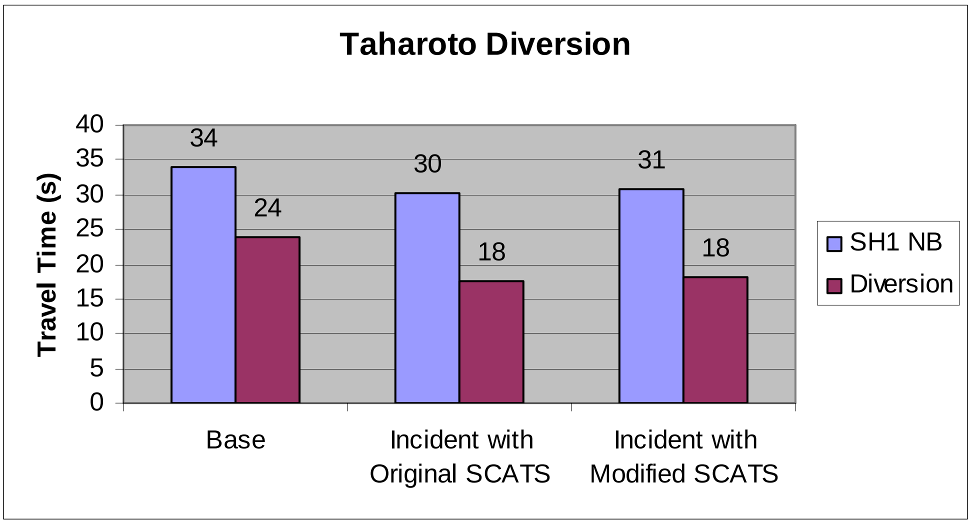

Figure 4.10 Average speed comparison for Taharoto diversion.

4.3 Discussion

The modelling work showed that an improvement in travel time for traffic diverted due to incidents could be achieved with modifications to SCATS. The modifications made were minor and similar to the modifications a SCATS operator at the ATTOMS traffic control centre would make when such an incident was detected on the motorway. The changes were made only for the duration of the incident after which SCATS reverted to the original settings. Although the improvement in travel times was small, if specific incident plans for particular incidents were developed, it is likely that the optimisation of the detour route could be improved.

The results also highlighted how such incident management plans are most effective when:

- there are sufficient vehicles present to benefit from any plan implemented (and hence, justify the work required to do this)
- there is sufficient capacity to enable diversion routes to work better than the original route.

The modelling also showed that the benefits of incident management plans may be limited to some particular journey paths. For example, travellers already on the motorway generally did not benefit by diverting onto the local road network; their journey still took longer via the diversion route even with the incident in place. However, local road travellers who had not yet entered the motorway could benefit by being diverted further north before joining the motorway. Thus modelling provides an important tool in determining which motorists should be given prioritised corridors and related diversion information.

5. Conclusion

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

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

An exploratory study modelling incident detection and response in a New Zealand urban network using microsimulation found that:

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

Both the literature review and the preliminary modelling highlighted the need for further research to be undertaken in this area in New Zealand.

6. Recommendations

The following items are recommended for further investigation or action:

- Further research should build on this study by expanding the modelling in terms of the incident scenarios tested and treatment options applied.
- Consideration should be given to further expansion of the existing modelled network to include a wider range of alternative detour routes and to capture the impact of incidents over a wider network area.
- Field data should be collected to investigate how motorists respond during incidents and to confirm the accuracy of the simulation model findings under incident conditions. Suitable data could include:
    - SCATS traffic count/occupancy and signal phasing data
    - CCTV images (queue lengths)
    - detector loop data (speed, occupancy)
    - floating-car or number-plate data (travel times)
    - survey of route choice during incidents, including drivers' response to VMS and other information regarding incidents,
- More widespread and robust means of incident detection should be considered in major New Zealand urban areas, on both motorway and arterial road networks. This includes more frequent mid-block detector loops (or alternative technology), expanded CCTV coverage and automated incident detection systems.
- The impact of different response times to the overall performance and recovery of the network during and after an incident should be investigated further.
- Further investigation is recommended into how drivers behave during incidents, particularly when provided with additional route information via VMS, radio reports, etc.
- Further investigation should be made into the ability of SCATS and other software tools to detect incidents automatically and to provide suitable guidance on appropriate treatment strategies. If necessary, develop improved capability for the tools to do these tasks.
- Investigation should be carried out into the ability of microsimulation to be linked directly to a live traffic situation, to enable 'on-the-fly' incident assessment, modelling and resolution.
- Monitoring should continue of ITS literature and practice worldwide for any newer technologies or congestion management treatments that may emerge and be applicable to the New Zealand context.

7. References

Ash, A. 1997. *Incident detection in urban areas controlled by SCOOT*. London: Institute of Electrical Engineers.

ARC (Auckland Regional Council) 2006. Regional profile.*www.arc.govt.nz* (November 2006).

Brown, T., Ensor, M., Vallyon, C., and Wee, L. 2006. Travel time performance programme: A step toward congestion management system. In *Proceedings IPENZ Transportation Conference*, Queenstown, New Zealand.

Cambridge Systematics. 2005. *Traffic congestion and reliability: Trends and advanced strategies for congestion mitigation*. Final report prepared for Federal Highway Administration.

Chu, L. and Recker, W. 2004. Micro-simulation modeling approach to applications of on-line simulation and data fusion. *California Partners for Advanced Transit and Highways (PATH). Research Reports: Paper UCB-ITS-PRR-2004-1*. University of California, Berkeley: Institute of Transportation Studies.

Department for Transport (UK). 2006, Urban Traffic Management and Control (UTMC) *www.utmc.gov.uk/*

Dia, H., and Cottman, N. 2004. Evaluation of incident management benefits using traffic simulation. Workshop on Traffic Simulation (Bridging Theory and Practice), Brisbane, August 2004.

Ensor, M. 2004. Searching for trip time reliability benefits. In *Proceedings IPENZ Transportation Conference*, Wellington, New Zealand.

Fehon, K. 2005. North American development of adaptive traffic signal systems. In *Proceedings Institute of Transportation Engineers Annual Meeting*, Melbourne, August, 2005.

FHWA, 2000. *Incident management successful practices – a cross-cutting study*. US Federal Highways Agency Publication FHWA-JPO-99-018, Washington DC.

FHWA, 2006. *Travel time reliability: Making it there on time, all the time*. US Federal Highways Agency Publication FHWA-HOP-06-070, Washington DC.

Gale, C., and Spiers, J. 2001. Urban Traffic Management and Control (UTMC) Report 4 (Network monitoring, modelling and management): Project summary and evaluation, *MVA Report UTMC-04 for Dept for Transport*, Oct 2001, United Kingdom.

Gartner, N., Pooran, F., and Andrews, C. 2001. Implementation of the OPAC adaptive control strategy in a traffic signal network. In *Proceedings IEEE Intelligent Transportation Systems Conference*, Oakland, California, August 2001.

Hidas, P. 2001. Simulation modelling for incident management. In *Proceedings 24th Australasian Transport Research Forum*, Hobart, April 2001.

James, R. 2006. Intelligent transport systems: What contributes best to the NZTS objectives? *Land Transport NZ Research Report No. 302*, Wellington.

Loane, G., and MacKay, D. 2004. Wireless CCTV for remote arterial applications: The Brock Road incident management system case study. In *Proceedings Transportation Association of Canada*, Quebec City.

Lowrie, P. 1982. The Sydney co-ordinated adaptive traffic system – principles, methodology, algorithms. In *Proceedings IEEE International Conference on Road Traffic Signaling*, London.

Lowrie, P. 2006. Interfacing microsimulation to intelligent transportation systems. In *Proceedings New Zealand Microsimulation Conference*, Queenstown, New Zealand.

Luk, J., and Tay, J. 2006. The use and application of microsimulation traffic models, *Austroads Project Report No. NS1016*.

Martin, P., Perrin, J., Chilukuri, B. R., Jhaveri, C., and Feng, Y. 2003. *Adaptive signal control II*. Report No. UT-03.28 prepared for Utah Dept of Transportation, University of Utah Department of Civil and Environmental Engineering.

Millar, G., Tudge, R., and Wilson C. 2004. Microsimulation evaluation of the benefits of SCATS coordinated traffic control signals. In *Proceedings Transportation Research Board Meeting*, Washington DC, January 2004.

Ministry of Transport (MoT), 2002. *New Zealand transport strategy*. Wellington.

Morris, P., and Negus, P. 1997. MIDAS system development on the M25. IEE Colloquium on Incident Detection and Management, London. 6pp.

Nicholson, A., and Dantas, A. (Ed.) 2004. *Proceedings of 2nd International Symposium on Transport Network Reliability*. University of Canterbury, 280pp.

NZ Herald. 2006. Sylvia Park shopping centre overwhelmed by crowds. *New Zealand Herald*, Thursday 8 June 2006.

Ozbay, K., Doshi, H., Mudigonda, S., Boile, M., Chen, J., Bongiovanni, T., Shah, J., and Desai, J. 2006. *Evaluation of adaptive control strategies for NJ highways*. USA Federal Highway Administration Final Report, Piscataway, NJ.

Payne, H. 1975. Freeway incident detection based upon pattern classification. In *Proceedings IEEE Conference Decision Control including 14th Symposium on Adaptive Processes*, 1975: 688–692.

Royce, B., Jurisich, I., and Dunn, R. 2006. Through-lane use at traffic signals. *Land Transport New Zealand Research Report No. 297*. 122pp.

RTA (Roads and Traffic Authority of New South Wales) 1997. *SCATS manual*. Sydney.

RTA (Roads and Traffic Authority of New South Wales) 2005. *Draft Traffic Management Centre – Concepts of operation, managing the NSW road network.* Sydney.

Samant, A., and Adeli, H. 2000. Feature extraction for traffic incident detection using wavelet transform and linear discriminant analysis. *Computer-Aided Civil Infrastructure Eng 15*, no. 4: 241–250.

Scotland Transport. 2007. Traffic Scotland website. *www.nadics.org.uk*

Scottish Executive 2001. *Collection of journey times through roadworks: Executive summary*. Research and Development Project, April 2001.

Scottish Executive. 2003. *Use of automatic traffic counters for event monitoring: Executive summary report*. March 2003.

Scottish Executive. 2005. *Congestion on Scottish trunk roads 2003*.

SIAS. 2005. *S-Paramics 2005 reference manual*. Edinburgh.

Sissons, B. 2006. Baseplus FUSE: The link between SCATS and S-Paramics. In *Proceedings New Zealand Microsimulation Conference*, Queenstown, New Zealand.

Srinivasan, D., Jin, X., and Cheu, R.L. 2004 (March). Evaluation of adaptive neural network models for freeway incident detection. *IEEE Transactions on Intelligent Transportation Systems*. *5*, no. 1: 1–11.

Stazic, B., Taylor, M., and Vogiatzis, N. 2004. Microsimulation at the Transport Systems Centre. Workshop on Traffic Simulation (Bridging Theory and Practice). Brisbane, August 2004.

Taylor, W., and Abdel-Rahim, S. 1998. Incident management under SCAT adaptive control system. *Final Report on Incident Management Under SCATS Adaptive Control System EECS-ITS LAB-FT98-084*.

Transit NZ. 2004. *ITS strategy 2004*. Wellington.

Transit NZ. 2005. *Auckland incident management strategy*, Auckland: Traffic Management Unit.

Transit NZ. 2006a. Transit NZ Central Motorway Improvements website. *http://cmi.transit.govt.nz/html/cmi/challenges1.htm.*

Transit NZ. 2006b. *Traffic Management Unit draft regional CCTV and VMS strategy*. Auckland: Traffic Management Unit.

USDoT (US Department of Transportation). 2000. *Incident management successful practices – a cross-cutting study.* Washington DC.

Versavel, J. 1999. Road safety through video detection. In *Proceedings IEEE International Conference on Intelligent Transportation Systems*, October 1999: 753–757.

Wang, K., Jia, X., and Tang, S. 2005. A survey of vision-based automatic incident detection technology. In *Proceedings IEEE International Conference on Vehicular Electronics and Safety*, October 2005: 290–295.

Whyte, D. 1997. Application of a real time expert system for incident management in Scotland. In *Proceedings IEE Colloquium on Strategic Control of Inter-Urban Road Networks*, London, March 1997: 7/1–7/4.

Williams, B., and Guin, A. 2007. Traffic Management Center use of incident detection algorithms: Findings of a nationwide survey. *IEEE Transactions on Intelligent Transportation Systems 8*, no. 2: 351–358.

Wilson, C., Millar, G., and Tudge, R. 2006. Microsimulation evaluation of the benefits of SCATS coordinated traffic control signals. In *Proceedings Transportation Research Board Meeting*, Washington DC, January 2006.

Wolshon, B., and Taylor, W. 1999. Analysis of intersection delay under real-time adaptive signal control. *Transportation Research Part C: Emerging Technologies 7*, no. 1: 53–72.

Yaguang, K., and Anke, X. 2006. Urban traffic incident detection based on fuzzy logic. In *Proceedings IECON 2006 – 32nd Annual Conference on Industrial Electronics*: 772–775.

Zhang, K., and Taylor, M. 2006. Effective arterial road incident detection: a Bayesian network based algorithm. *Transportation Research Part C: Emerging Technologie*s *14*, no. 6: 403–417.

8. Glossary

Adaptive signals	Traffic signals where the time allowed for each phase is dynamically determined from traffic conditions
AID	Automated incident detection
Area-wide traffic control	An automated system that attempts to coordinate all the signalised intersections over an area to optimise traffic flows and minimise delays
ATIS	Advanced traveller information systems
ATMS	Advanced traffic management systems
ATTOMS	Auckland Traffic and Transport Operation Monitoring Service: the Auckland traffic control centre
Capacity	The theoretical maximum sustainable volume of traffic that a particular road or intersection movement can accommodate
CCTV	Closed-circuit television: cameras that monitor traffic conditions with the video relayed to the traffic control centre
Cycle time/length	The time taken for a complete sequence of traffic signal phases to be run, before repeating
Degree of saturation	The ratio of the traffic demand (ie traffic volume or flow rate) to the theoretical capacity of the road or intersection
Detector	A sensing device (usually a loop of wire in the road) used to detect the presence of vehicles crossing or sitting at a location
Fixed-time signals	Traffic signals where the time allowed for each phase is held constant
Fuse	Software that links SCATS to S-Paramics
ITS	Intelligent transportation systems
Microsimulation	Traffic modelling whereby individual vehicles are simulated within the road network and driver decisions are made dynamically in response to conditions encountered throughout the network
Movement	A particular flow of traffic travelling from one intersection leg to another, or using certain traffic lanes
NADICS	National Driver Information and Control System (Scotland)
NNCC	National Network Control Centre, Scotland
Occupancy	The presence or otherwise of a vehicle at a particular location (usually at a detector), ie occupying that space
Offset	The difference in time between the same phasing point (usually the start of the green signal) in the operation of adjacent signalised intersections, often adjusted to provide synchronisation (or ‘coordination’) for vehicles travelling through both intersections
Peak period	The time of the day when traffic demand is at a maximum, eg morning and evening for commuter work trips. Other times are ‘off-peak’ periods

Phasing	A pre-set order of traffic signal phases and the time allocated to each one
RTA	Roads and Traffic Authority of New South Wales
SCATS	Sydney Coordinated Adaptive Traffic System, an adaptive control traffic system that adjusts signal timing, phasing, offsets and cycle length according to actual traffic conditions in real-time
Signal phase	A traffic signal state during which one or more vehicle movements receive right of way (ie green signal or arrow)
S-Paramics	Microsimulation software package developed by SIAS
Stop-line	A location right at an intersection where vehicles stop until they have right of way
TMU	Traffic Management Unit, Auckland
Upstream	A location prior to the current location, ie from where a vehicle has come. A location beyond the current location is 'downstream'
UTC	Urban traffic control
VMS	Variable message signs