An Analysis of the Performance of Low Capacity Diversion Routes during Motorway Incidents

A thesis submitted in fulfilment of the requirements
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Master of Philosophy

by

Wayne Brennan
BEng (Civil)

from

Griffith School of Engineering
Science, Engineering, Environment and Technology Group

Griffith University
Gold Coast Campus

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DECLARATION

This work has not been previously submitted for a degree or diploma in any university. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

Wayne Brennan

March 2008

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EXECUTIVE SUMMARY

The effective operation of any transport infrastructure component is essential in maintaining and developing the growth of communities, towns and cities. In particular peak traffic times it may be hard for the transport agency to keep the network operating in an optimal state, as there may be many conflicting priorities. When an incident happens on the road network, Incident Management procedures and plans play a major role in helping the network work through the impacts of the incident to achieve pre-incident traffic conditions. There are many objectives with these incident management programs including reducing costs, delays and emissions while trying to provide benefits to the wider community.

Part of the incident management plan may include the use of a diversion route where incident-induced traffic queues are directed from the incident bound motorway, around the incident site, to later re-join the motorway. The ability of this diversion route to cope with this extra traffic can be measured qualitatively and quantitatively by examining level of service and capacity criterion respectively. The rate of diversion from the motorway plays a major part in determining the optimal operating conditions for a diversion route, particularly if the diversion route has a small capacity. Unfortunately, low capacity usually plays hand in hand with low level of service and as such, the achievement of a fine working diversion route during motorway incidents is paramount. With the addition of another diversion route, the management of incident-induced traffic queues could be seen as a little easier, but this may not be totally true.

The present research aims to address these difficulties which are faced by road and transport operating authorities. This is achieved primarily by the use of a traffic microsimulator (AIMSUN) which can be used to model different incident scenarios to give an indication of how to effectively use a diversion route network with the aim to restore pre-incident traffic conditions. These outcomes can then be utilised by Traffic Management Centres in their incident management procedures and be further used (with some modifications if necessary) to other areas of motorways in this local area and other parts of the state.

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ACRONYMS

AADT	Average Annual Daily Traffic
ADSL	Asymmetrical Digital Subscriber Line
AIMSUN	Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks
CCTV	Closed Circuit TeleVision
CD	Compact Disc
CMS	Changeable Message Sign
EMME/2	Transport Planning Model building package
GCCC	Gold Coast City Council
ISDN	Integrated Services Digital Network
LOS	Level of Service
MOE	Measure of Effectiveness
MSF	Maximum Service Flow
NB	Northbound
NZ Transit	New Zealand Transit
O/D	Origin / Destination
QDMR	Queensland Department of Main Roads
SB	Southbound
SCHD	South Coast Hinterland District
SMS	Short Message Service
STREAMS	Syngerised TRaffic REsponse Management System
TMC	Traffic Management Centre
Veh/h	Vehicles per hour
VMS	Variable Message Sign
vplph	Vehicles per lane per hour

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CHAPTER 1

Introduction

1.1 A Brief History of Incident Traffic Management

The first road accidents involving cars and other vehicles were reported in London and New York in 1896 (Lay 1992). Apparently, the London accident involved a car colliding with a pedestrian. The driver, in his defence, claimed that he was driving at only 7 km/h and shouted "stand back" to the pedestrian. He also sounded his bell to no avail. The American incident occurred in New York City between a cyclist and a car, with the cyclist breaking his leg and the driver spending the night in jail.

From about 1903 onwards, traffic problems began to emerge, thus planting the seed for the beginning of safe and efficient traffic management practices. Automobiles and bicycles were largely being seen as a danger to horse drawn vehicles and pedestrians. This practice was increasing to such an extent that a new ordinance was imposed on automobiles and bicycles that restricted their speed to 10 km/h. By 1910, the next stage of traffic management occurred when the San Antonio Police Department bought automobiles and motorcycles to patrol the city and took on the growing problem of traffic enforcement. By the 1950s, the police department was equipped with an aerial surveillance unit as well as radio-equipped patrol cars. Around this time, in the United States of America, the urban freeway system was being constructed and good traffic management practices were becoming well-established.

1.2 General Remarks

Traffic incidents are becoming an increasingly common occurrence on many minor and major roads. These incidents lead to congestion and delays to traffic. The random nature of the occurrence of an incident can intensify the existing congested traffic conditions of a particular road at a particular point in time. The length of time for motorists driving in congested conditions has increased from 29% to 51% over a period of around 13 years and is costing up to $12.57 million per annum in major capital cities (USDOT 2002). This has been manifested in many cities around the world in recent times. Building extra capacity into the network may not provide a solution to this problem and is costly and time consuming. However, by managing the existing transport network in a more efficient way, the effects of incident related traffic congestion can be reduced.

Within major urban areas, traffic congestion has significant adverse economic, social and environmental impacts. Traffic incidents, temporary road works and special events are major causes of congestion. The UK Highways Agency (2002) suggests traffic incidents account for 25% of congestion on the trunk road network, while in the United States Shrank & Lomax (2003) estimate incidents cause somewhere between 52 and 58 percent of total delay experienced by motorists. As traffic volumes continue to increase and infrastructure provision not keeping up, managing traffic is becoming an increasing priority. A key means of reducing congestion and improving safety is the rapid integrated response and clearance of traffic incidents – incident traffic management.

One strategy of incident traffic management is the use of diversion routes, where a percentage of motorway traffic is diverted (diversion rate) around an incident onto another road or route. The diversion rate during an incident can be seen as a function of the motorway capacity shortfall, while allowing, for the limited capacity of the local diversion routes. For motorway incidents that cause a delay, it is normal practice that local diversion routes are used when a particular delay threshold is reached. The maximum diversion rate could be aligned to an equilibrium type traffic assignment between the motorway and the diversion route, using delays, flows, speeds and travel time as the governing traffic parameters. With low capacity diversion routes, this equilibrium of flows could be hard to achieve. The incident duration may change and this may lead to the diversion rate also changing, leading to a different traffic assignment for the motorway and diversion route.

As an general suggestion, an *incident* refers to any event that can degrade safety and/or slow traffic, including disabled vehicles, crashes, maintenance activities, adverse weather conditions and debris on the roadway. Emergencies, such as extreme weather, natural disasters and terrorism incidents that impact safety and traffic flow can also be included in this definition.

1.3 Benefits of Improved Incident Traffic Management

There are many benefits as a result of improved traffic management at incidents. Transport agencies are always looking for ways to improve this aspect of incident management and there are many papers written on this topic, with most of them focussing on the actual operational aspects. Most research looks at the operations of the incident bound major road in isolation with little study done on the operation of the diversion routes (if they are invoked). There are many challenges facing road and traffic agencies in the world in deciding the priorities for incident traffic management. With a good incident management program (including traffic management) and system, benefits may include (Booz, Allen, Hamilton, 2006):

- 6% - 12% reduction in travel time;
- 30% reduction in secondary incidents;
- 8% reduction in incident severity;
- 20% reduction in incident response time;
- 55% reduction in freeway closure time;
- 2.3 : 1 Benefit / Cost ratio.

The use of diversion routes to assist with the dissipation of traffic queues is a measure which can be used to achieve the above benefits. By offering an alternate travel route, the motorists can effectively examine their own situations and then choose an alternative which will help to achieve their own travel path objectives. This choice is helped by offering driver information to the motorist, for example, a message on the increased travel time to reach a destination, or how long delays are likely to be. This information will have been the result of some analyses of the restricted traffic flows with an emphasis on the examination of different traffic parameters. The ability of the diversion routes to carry particular traffic flows will also be an outcome of the analyses of motorway incident induced traffic flows. Low capacity diversion routes can still play some positive part in an incident management plan, but to what extent will be studied in this research.

1.4 Research Goals and Activities

The main goal of this research is to undertake detailed analyses of traffic management strategies of particular incident scenarios and to make some positive recommendations to improve the management of this traffic. This methodology will give transport agencies further ideas of how to improve traffic flows at incident sites, particularly motorway incidents and using diversion routes with very low capacities. The research deploys the use of the traffic microsimulation package AIMSUN to derive different models in order to investigate the various scenarios. Both the quantitative numerical analysis and the "driveablility" or qualitative subjective type appraisal will be examined. This is intended to give some appreciation of the level of traffic diversion that can be achieved and then to what level of satisfaction the users will perceive the diversions.

Road safety is becoming a higher priority in project objectives. Improved, continued efforts in safety have reduced the occurrence for driver error (through better visibility and signs, divided roads with improved design) or reduced the consequences of error (removal of roadside hazards, provision of car seat belts and airbags) (Lay 1992). However, there is still a need to manage and operate the network effectively. The management of traffic on low capacity diversion routes, used when an incident occurs on the motorway, is a major element in this research and this can be a high level item in the incident management procedures. The productive use of available diversion routes can assist positively with specific road safety programs by reducing motorist frustration and sometimes dire behaviour.

The research framework consisted of the following activities: literature review, materials and methods, modelling, results and conclusions. While some parts of the research may be limited with material, including existing data, other parts contain huge amounts of useful matter which derived many helpful outcomes. This research also has some direct linkages back to the operational "grass roots" side of the equation – the research is not totally bound in theory and impractical data. While this research examines particular areas and derives particular outcomes, the framework is established to develop similar methodologies and models for use on other similar networks and incident scenarios.

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CHAPTER 2

Literature Review

2.1 General Motorway Road Traffic Operations

Most road travel undertaken by the public today is on congested roadways. Indeed, in parts of America more that half of all travel occurs in "moderate" to "extreme" traffic congestion. Research by Texas Transportation Institute says that traffic congestion delays are up 213% since 1982 (ARTBA 2001). Statistics from the United States also indicate that 70% of travel on urban interstate highways is severely congested during peak periods. In addition, traffic accidents and related inadequate incident management procedures are the cause for 50 – 60% of total congestion and are often responsible for a number of secondary crashes. The construction of new infrastructure, as a measure to cope with extra travel demand, has increased very little in present times. As the travelling public demands more and more services, new and existing roads need to be constructed and repaired under traffic, with few traffic diversion routes available. Therefore, construction and maintenance work has to be done under traffic and this has many disbenefits, in particular maintaining a safe workplace for road workers and adverse feedback from stakeholders.

Many professionals and practioners describe how well a roadway is operating by referring to a Level of Service (LOS) criteria. This is a basic scale arrangement consisting of A, B, C, D, E or F levels (A being the most free flowing and F being the most congested) which usually examines the qualitative aspects of traffic flows, with the principal elements being vehicle speed and traffic volume. The current method of examining Level of Service discounts factors such as trip time, interruptions, safety, comfort and convenience of the particular travel route. Maitra (1999) suggests that congestion could be a suitable measure of effectiveness for assessing LOS. The quantification of congestion is also based on the observed speed – volume relationship.

The spread of a particular LOS in a traffic stream on a roadway can possibly be a measure of the severity of congestion. This has been developed as the congestion severity index (Lindley 1992), roadway congestion index (Turner 1992) and freeway congestion index (Thurgood 1995). These measures combine the flow, the level of mobility and the demographic characteristics to determine these indexes. The principal traffic parameter of the indexes is traffic flows. Again Maitra (1999) has studied LOS and has modelled particular LOS elements and boundries to derive a new criteria. This includes a nine step LOS (*A* – *I*) in the stable flow zone and one LOS (*J*) for the unstable operations. He does this by examining other elements contributing to the LOS such as mix of traffic, roadway widths, road surface type and number of lanes. Further still, the Highway Capacity Manual (2000) uses a six step scale LOS of A to F (A being the most free flowing to F being the most congested). However, for this study, LOS will be examined using the traditional traffic operating characteristics of speed and volume only.

In general terms, the level of service can be best viewed with illustrations showing the different traffic flow conditions. These are presented below accompanied with some general notes on each level.

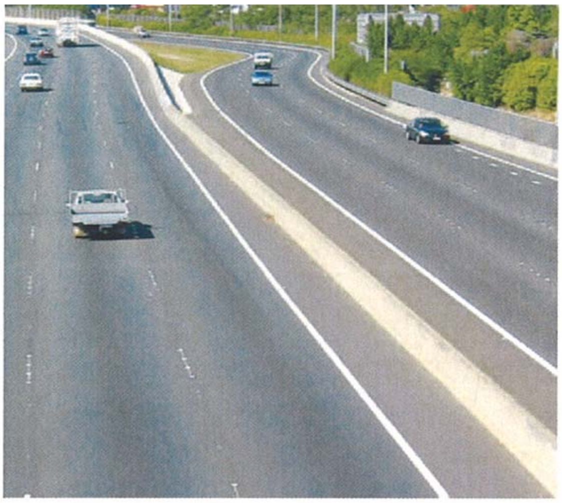

Figure 2.1 Road section exhibiting level of service A

With a LOS A condition , drivers can travel at their own speed with little interference or influence from other vehicles in the traffic stream, showing a condition of free traffic flow. General level of comfort and convenience for the motorist is excellent.

Figure 2.2 Road section exhibiting level of service B

With a LOS B condition, drivers have reasonable freedom to select their speed and manoeuvre in the traffic stream, with a little less comfort and convenience than with LOS A.

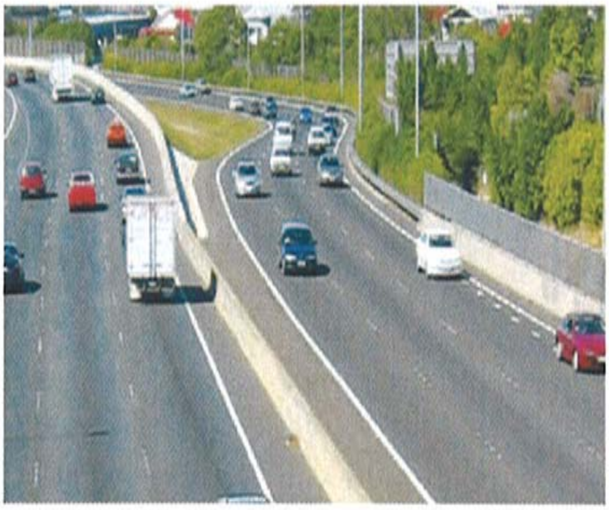

Figure 2.3 Road section exhibiting level of service C

With a LOS C condition, drivers are restricted in their freedom to select speed or manoeuvre, but speeds are still at or above optimum speed. Traffic is still in a zone of stable flow. The general level of comfort and convenience decline noticeably at this level.

Figure 2.4 Road section exhibiting level of service D

With a LOS D condition, drivers are severely restricted in their freedom to select their desired speed and to manoeuvre within the traffic stream. Traffic is close to limit of stable flow and is approaching unstable flow.

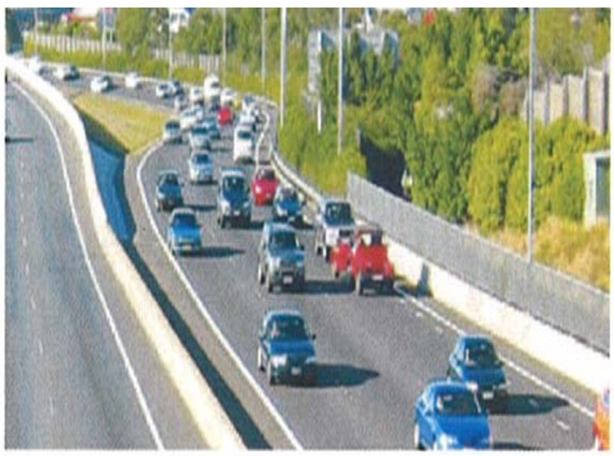

Figure 2.5 Road section exhibiting level of service E

With a LOS E condition, traffic volumes are close to capacity with unstable flows and minor disturbances in the traffic stream will cause breakdown of flows.

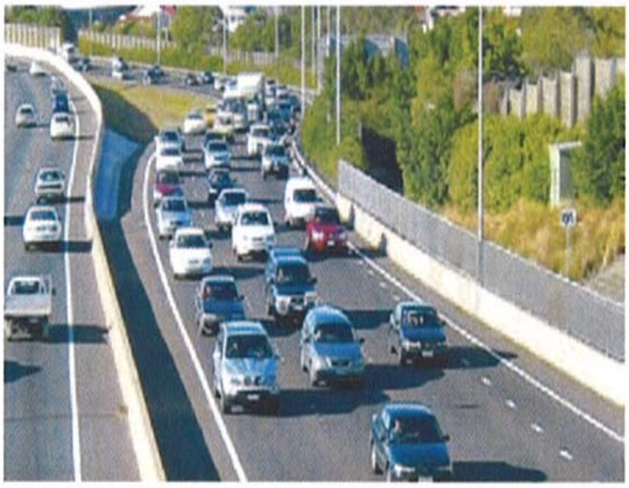

Figure 2.6 Road section exhibiting level of service F

With a LOS F condition, the traffic condition is in a zone of forced flow with flow breakdown and queueing and delays. The traffic flows are saturated with the volume far exceeding the capacity.

The topic of the variations in lane pattern usage with traffic lanes is interesting. This subject has been briefly included as part of this research and it is relevant to have a look at it now. The common thinking could be that lane usage is more or less the same at a particular location on a particular day and at a particular time. Lane use behaviour is important as it affects roadway capacity and the transitions between uncongested and congested flow. Amin (2005) cites studies which conclude that the proportions of flow in the median lane increase as volume increases and that the transition to congested flow involves a redistribution of traffic across the lanes. Drivers tend to use a particular lane in order to maintain their desired travel speed. When that lane has reached capacity, before the roadway has as a whole, then the flow may decrease and force a shift in lane flow distribution. In addition, Amin's study was based in San Diego in California, and his graphs indicate traffic volumes of approximately 1200 – 1500 vehicles/hour/lane. This is approximately 20% more than volumes that are typically experienced on the Pacific Motorway at this present time.

The mobilisation of a queue to free flow traffic speeds can be important when examining capacity of saturation flow rates. This is particularly important around where incident-induced queues upstream encroach upon an on-ramp area. The prediction of this time to mobilise a queue has been modelled and is presented in work by Long (2005). Different traffic compositions can affect this parameter. A queue consisting of a large number of cars will take longer to mobilise than a mixed queue of large heavy vehicles and cars. This brings about a variation in the prediction times for "start-up". An average departure time of around 1.25

second with a standard deviation of 0.1 second can give good results with a 95% confidence level (Long, 2005). However, with so many variations in vehicle acceleration and deceleration characteristics and widely varying driver behaviour, there would still be an average but with a much different standard deviation. The motion of a wave, corresponding to vehicles starting sequentially, can propagate back through the queue. Long (2005) suggests the speed of this motion to be around 6 metres / second especially where there are long queue lengths (up to 330 metres).

2.2 Driver behaviour and Route Choice from VMS messages.

The behaviour of drivers under particular circumstances is widely variable, especially when in extraordinary situations. There are many different situations which can generate particular responses from the driver (behavioural) which is in response to some external stimuli. Whilst performing the driving task, conditions on the network may change and the driver may not be aware of any incident and also of any implications which may influence his/her trip. The incident will generate traffic management plans to assist with traffic flows at the incident site. Part of this may involve a diversion from the main travel route onto another road system for traffic to use while the incident cleanup is happening. Various research sources indicate that the weakest link in the chain of incident management plans is the traffic management during an incident (Hidas, 2000).

An effective method of the communication of traffic management information, during an incident, to a driver is by a Variable Message Sign (VMS). The message may detail information on incident location, length of likely delays, traffic lane closures and the possibility of using alternate travel routes (diversion routes). The selection of a suitable diversion route and then persuading incident-induced traffic queues to use it does present some difficulties. This may include extra travel time and more congestion on the diversion route, time of the day and associated traffic composition and when to introduce and close out diversion plans.

There is a link between the extra travel times, for a particular route, for incident-induced diversion as opposed to using the usual travel route. This has a strong effect on route choice behaviour, particularly in the presence of VMS messaging. With respect to VMS, some field studies have shown that traffic diversion occurs in the range of 5% to 80% of the total number of drivers subjected to the message. In addition, it appears that the diversion rate may decrease with the increase of travel time on the usual route for travel times up to 45 minutes (Hidas, 2000).

If the extra travel time caused by using the diversion route is approximately the same as the duration of the incident, then the traffic diversion rate is likely to be high. Also, the diversion rate for a diversion route with an extra travel time of 20 minutes (accident delay 20 minutes) for 10, 20 and 30 minute delays are about 15%, 50% and 90% respectively (Hidas, 2000). However, there appears to be no definitive rules for driver decision on route diversion.
Some motorway road systems restrict diversion routes to those parts of the road network which can accommodate additional traffic during abnormal conditions. On a typical British motorway, VMS are usually located in pairs, approximately 1.6 km and 0.8 km on the approach to junctions. These signs are used to assist with local incidents, eg, queues related to minor incidents, high winds or pedestrians on the motorway (Carden et all, 1997). The signs do not display predicted incident duration due to legal liabilities associated with providing inaccurate delay related information. In addition, VMS can suggest drivers to exit the incident-induced queue at a particular exit onto another travel route. But the actual named route is not displayed, due to possible legal complications.

In Britain, the messages are kept on the signs until the queued traffic has been released to keep traffic away from the incident locations as the road is being re-opened to traffic. A further issue that needs to be borne in mind is that with large amounts of traffic being diverted, there is likely to be an increase in the number of incidents and breakdowns on the alternate route (Carden et all, 1997).

Some studies have been done to ascertain the number of motorists that would divert as a response to the incident-induced delays and queues. Three scenarios could be:-

- Number of motorists diverting with no information displayed on VMS;
- Number of motorists diverting with incident-related traffic management messages, and;
- Number of motorists who divert when specifically told to.

If a particular diversion route has been found to have a capacity to handle 30% freeway diversion and studies have shown that 25% of the motorists divert without instruction, formal diversion should not be introduced (Craig et all, 1995).

Incident traffic management strategies for the motorway depend greatly on the network structure. This includes traffic diversions, interfaces between motorway and adjacent service roads, changing traffic flow conditions and available Intelligent Transport System (ITS) devices. Traffic diversions, in particular, can add congestion to the service road and arterial road network, even if they are carefully managed. Ramp metering and good arterial traffic signal operations can enhance traffic flows – both normal arterial flows and added flows from a traffic diversion. Ideally, diversion traffic flows would operate optimally when the arterial network is not congested (that is, out of peak traffic periods) and then using ramp metering when the arterial network is congested. Diversion rates, from other studies, have used figures of 10% and then 15% with reduced speed limits to achieve good network operations around the "outer core" of the incident precinct. Currently, there is no valid behavioural model accounting properly for drivers' reaction to VMS information (Barcelo et all, 1999).

Diversion traffic characteristics from on-site driver surveys also yield various results. Peeta and Ramos (2001) concluded the following:-

"Drivers diverting even when believing that :-

Alternate route would be longer – Agree to divert – 30.2%;
Travel time savings, of 10 – 30 minutes, under work related trip – Agree to divert - 48%;
Travel time savings, of 30 – 60 minutes, under personal trip – Agree to divert - 38%;
Delay, of 10 – 30 minutes, before diverting – Agree to divert - 40%".

These findings present some varying diversion rate parameter measurements. To draw some more exact definitive conclusions from these results would not be possible due to lack of data. Further research into diversion behaviour, under the influence of different VMS message contents, may provide some insights to driver behaviour. VMS message content is an important control variable with its response not fully understood.

"The incident case studies have indicated that drivers do, in fact, modify their routes if they are given accurate information" (Inform Evaluation, 1992). This would include the whole gambit of methods to communicate information to drivers. Regarding VMS messaging, building up the confidence of drivers, in incident-induced queues, is paramount. Drivers need to believe the VMS messages and then carry out the action associated with it. This is essential to successful route diversions. With a credible VMS messaging system and obliging drivers, good diversion rates are possible. Again, the Inform Evaluation (1992) says that for a typical incident using passive messages (that is, no recommended alternate route), they have had 5 - 10% of mainstream traffic divert, but over several upstream off-ramps (typically 3 – 4% at an individual ramp). Strongly worded messages can be counterproductive. Approximately 45% of drivers stated that they change their route in response to the sign messages (Inform Evaluation 1992). Slightly over 25% have never changed their route in response to a message.

This degree of faith in the system together with the perception of faster travel on the alternate route instills driver confidence in the system. A good diversion route could mean higher diversion rates. Passive, generic VMS messaging puts the system at less risk of being criticised and also tends to avoid the major shifts in traffic volume that can create congestion on the alternate route. It would be exceptional if the incident-induced diversion route was aligned with a direct arterial / service road and had excess capacity to cope with extra traffic volumes. Really, the success of the corridor diversion plan really depends on the ability of the alternate routes to absorb the extra traffic. In addition, good traffic control on the arterials can add significant benefits to the effectiveness of incident-induced diversion strategies. Arterials quickly break down when capacity is exceeded and some never recover.

Driver response surveys are of particular use to gauge the driver's interpretation of VMS messages as mentioned above. One strategy was to have two question survey, firstly, to inquire about drivers' attitudes and interpretations of VMS information and, secondly, to determine the stated diversion response to a warning VMS message. Thompson (2001), states that Metropolitan Police set the message texts on the signs (not the Traffic Management Centre (TMC) operator) in one London survey. One particular area of ambiguity was in the interpretation of exact locations and the extent of the problems with most drivers underestimating the sizes of the areas affected. Other key problem areas were related to irrelevant information or the lack of sufficient information. In particular, message texts with the words "ACCIDENT", "ROADWORKS", DELAY 30 MIN" and "AVOID AREA" had the greatest effect in the stated diversion response (Thompson, 2001).

One other study has shown the use of VMS messages in incident traffic management. Hidas (2000) used his own traffic simulation software "SITRAS" to demonstrate traffic diversions on the divided four lane M2 motorway in Sydney. Generally, the proportion of drivers diverting is highly dependant on a number of factors, including message content on the VMS stating cause and severity of the incident. He used the total delay of the network as a measure of effectiveness of a particular incident management strategy. The optimum solution had the minimal total delay. For his particular incident scenarios, the optimum solution was to utilise 2 VMS on the approach and let traffic on the approach still use the route, but divert north and south. The one remaining lane on the M2 could cope with this traffic (Hidas, 2000).

Efficient use of the available capacity in the highway corridor network through integrated operation of the highway and surrounding service roads is a major objective of incident management schemes. In response to real-time information and route diversion advice via VMS upstream of the incident, highway users may divert to the adjacent service road network. To absorb the diverted traffic, the capacity of the service roads and adjoining arterial road network should be optimised by modifying the traffic signal control to serve the new traffic flow patterns to give a good overall co-ordinated network with optimal flow patterns.

The operations of the adjacent arterial / service road can be based on two schools of thought. Path-based traffic signal co-ordination considers flow patterns around the network, while arterial-based co-ordination (a subset of path-based solutions) considers smaller shorter route sections. With dominant traffic flows, as a result of incidents, being diverted to the service roads and arterial road network, path-based co-ordination outperforms arterial-based co-ordination. The path-based co-ordination scheme is shown to outperform the arterial-based coordination in the cases of both pretimed fixed traffic signal control and vehicle-actuated signal control.

An experiment was conducted in the Fort Worth area with part of the I-35W freeway and surrounding street network with 178 nodes and 441 links with 61 signalised intersections, peak flow of 17,000 vehicles, 62 intersection (no control), 24 intersection (give way), 31 intersections (stop sign). The use of the "DYNASMART-X" simulator allows the prediction of traffic flow pattern and the identification of dominant flows/paths in the network (Abdelghany et al, 1999).

Table 2.1 Results of the pretimed traffic signal control experiment (Abdelghany et al, 1999)

Case Scenerio	Coordination Scheme	Average Overall Travel Time(Min)	% Improvement	Average Stopped Time (Min)	% Improvement	Average Trip Distance (km)
No Incident	No Coord	25.34		16.71		6.58
	Arterial Coord	26.71	-5.42%	17.99	-7.70%	6.58
	Path Coord	22.46	11.36%	14.42	13.68%	6.58
Incident	No Coord	29.37		20.42		6.58
	Arterial Coord	29.90	-1.81%	20.84	-2.07%	6.58
	Path Coord	27.92	4.94%	19.18	6.10%	6.58
Incident + VMS	No Coord	27.06		18.27		6.62
	Arterial Coord	26.72	1.36%	17.91	1.97%	6.62
	Path Coord	26.48	2.15%	17.51	4.15%	6.65

Table 2.2 Results of the vehicle-actuated signal control experiments (Abdelghany et al, 1999)

Case Scenerio	Coordination Scheme	Average Overall Travel Time(Min)	% Improvement	Average Stopped Time (Min)	% Improvement	Average Trip Distance (kms)
No Incident	No Coord	20.22		12.31		6.58
	Arterial Coord +10	19.74	2.40%	11.70	4.99%	6.58
	Path Coord +10	19.10	5.54%	11.31	8.11%	6.58
Incident	No Coord	24.91		16.31		6.58
	Arterial Coord +10	26.26	-5.42%	17.19	-6.58%	6.58
	Path Coord +10	24.06	3.41%	15.48	4.06%	6.58
Incident + VMS	No Coord	22.61		13.99		6.57
	Arterial Coord +10	22.66	-0.22%	13.94	0.35%	6.62
	Path Coord +10	22.59	0.08%	13.99	-0.04%	6.62

Note:- +10 refers to an extra 10 seconds given to the maximum green time.

There appears to be an overall average reduction of around 2.5% in travel time and stopped time. Under the incident based condition, arterial based coordination failed to significantly improve overall network performance. There was a 2.4% to 8.11% improvement in the travel time and stopped time parameters of the various scenarios.

Traffic control during times of incidents can be based on data from particular feedback control mechanisms. One result of this may be the prediction of travel times on alternate routes for display on VMS. This real time approach is fairly robust to uncertainties in demand, compliance rates and incident severity. However, all incident traffic management systems are often limited to detour plans that cannot effectively account for demand uncertainty and system instability such as incident severity and driver's compliance with the provided control.

Rerouting highway traffic to other parts of the network, with sufficient remaining capacity on a real time basis, is a logical response to highway capacity reduction caused by an incident. Dynamic route control strategies can divert traffic in an orderly fashion to other parts in the network with enough capacity to absorb incident traffic. Then, ideally they also adjust the signal timing plans to cater for the new traffic conditions. Hot spots, or areas which have the potential to cause most congestion under incident-induced traffic, are often a focus for incident traffic management.

Existing route guidance strategies can be categorised into these two general groups:-

(a) anticipatory strategies, which use real-time data and an estimate of system disturbances to model traffic to specify route guidance recommendations that minimise a given control objective over a future time horizon, and;

(b) feedback strategies, which effectively react to real-time measurements without ever explicitly predicting or measuring any system disturbances. (Sawaya et all, 2002).

Control strategies based on prevailing traffic conditions, with an estimate of system disturbances and consequences of future route guidance can be efficient. They rely however, on accurate prediction of system instability, such as the level of demand, incident severity, and compliance rate. As a result, they may also have the potential to lead to catastrophic network performance and breakdowns.

No feedback strategies can guarantee optimal performance of the network. Particular mathematical algorithms can give the best possible operating conditions in conjunction with the anticipatory type strategy. Instantaneous travel times rather than predictive travel times can give far from optimal conditions on the network. A measure of performance can be the consideration of the different equilibrium procedures used to determine the diversion route. A number of usable diversion routes can give an option of producing travel times closer to being equal. Traffic equilibrium patterns are the desired response of any traffic control strategy, generally as a result of forcing the network to behave in conformance with this strategy.

Some difficulties may be presented by utilising a user equilibrium system (control by Traffic Engineer or TMC operator) as opposed to a system optimal control strategy. The equalisation of predictive travel times on selected paths can be viewed as forcing that portion of the network to perform in a peculiar way. The anticipatory approach predicts the impact of a given route choice recommendation. The traffic microsimulator uses consistent real time data to run in future time to give predictive travel times and also uses estimated path flows obtained in a dynamic traffic assignment.

For off-peak traffic periods, when existing traffic volumes are low, the proposed diversion routes may be able to handle the additional traffic with acceptable increases in delays and reductions in travel speeds. However, it is highly unlikely that a particular incident will occur at a particular location, at a particular time, and warrant a diversion along a particular arterial route. In fact, the opposite usually happens. A large heavy vehicle will turn over and spill a large amount of divisible material over two traffic lanes, closing that whole carriageway on a

Friday afternoon in peak traffic times. Police resources will be stretched and all traffic will be diverted onto an already over-congested urban network. The network recovers approximately five to six hours later and there are negative press articles in the newspaper on Monday morning on inefficient traffic management practices in times of incidents.

In converse with the above, peak traffic times on the highway, along with some historical incident data, can determine the most efficient alternative route for traffic diversion. A series of diversion routes from the highway can be developed and would be based on time of day and expected highway closure duration. One "static" diversion plan will not work efficiently for all incident scenarios. A decision to determine the urban route (and associated signal timing plans) to be used can be made based upon the historical data of the highway volumes, the time of the day and the location of the incident. An additional measure is the use of more than one route at the same time (Stamatiadis and Culton, 1999).

The adoption of reduced speed limits for the incident-induced traffic queue, along with traffic passing past the incident precinct, does assist to achieve maximum flows. By "smoothing" out the speed of vehicles in the queues, there is a more consistent flow. This does not encourage lane-changing by drivers, vehicle headways are more constant and therefore lowering the likelihood for any secondary incident. Vehicle emissions are also lowered and travel times can also be more accurately assessed. Reduced speed limits are introduced on the motorways by Variable Speed Limit signs, which is another ITS device deployed in various areas around the world. The findings from the use of this technology is slowly being circulated.

2.3 General data on Incident Management and Systems

There are many types of incidents. The Traffic Incident Management Handbook (2000) defines an incident as any non-recurring event that causes a reduction in roadway capacity or any abnormal increase in demand. In particular, there are two general types of incident, planned, which includes roadworks, road occupancies, special events and so on, and unplanned, which includes accidents, vehicle breakdowns, debris on the road and so on. These events can have significant impacts on the operations of the transport network and affects many users and the different parts of the wider community. The delays to traffic caused by an unplanned incident on the road can be immense and may have wide-reaching consequences to the community.

Every incident is different in some particular way and they may require specific incident management procedures. However, with regard to major freeways or motorways, the function and class of the asset needs to be maintained. Thus there is high importance of clearing incidents and returning traffic flows back to normal as quickly as possible. One of the major elements of an incident on the road is the cost, in terms of congestion, queues and delays.

Approximately 50% of the congestion in Brisbane is due to both planned and unplanned events and costs around $200 million per annum (Queensland Traffic Incident Management Strategy, 2003). Indeed, in California in the United States of America, incident related congestion costs approximately $1 million per day. This is broken into 65% being minor and 35% being major (Craig et all, 1995). The average duration of an incident is approximately 37 minutes.

Incident management plans need to concentrate on early detection, verification and clearance of the incident. Traffic management during the incident is usually the weakest link in the chain of Incident Management plans. This is because the effects of an incident are difficult to predict. Empirical data on the effects of incidents is very difficult and expensive to obtain from field surveys, and it is even more difficult to establish general trends from the data collected for a few specific incident location, time, duration and severity (Hidas, 2000).

The number of blocked traffic lanes caused by an incident, in conjunction with the incident duration, can have immense effects on the road capacity. For a typical highway traffic lane carrying 2000 vehicles per hour, an incident that blocks one lane out of three can reduce that highway's capacity by nearly 50%. The time taken for return to normal traffic flows still has an impact on network capacity. As an approximation, for every minute a traffic lane is blocked, it takes four minutes to restore the flow after the incident has been cleared (Craig et all, 1995). Some studies have shown that the relationship between the duration of an incident and the delay resulting from an incident may increase exponentially. An incident lasting 30 minutes would have a delay 4 times as high as the same incident lasting only 15 minutes (Craig et all, 1995).

The Traffic Incident Management Handbook (Federal Highway Administration, 2000) states that: "*In general, when two or more lanes of a freeway are expected to be shut down for two or more hours, institution of the alternative route plan should be considered*". This generic incident management strategy would be the result of many analyses of actual incident-induced traffic queues and being careful not to move the "problem" around the network.

There are many types of incidents which may impact on the traffic flow. Each level and type of incident may require different treatments. As an example of a particular incident management strategy to address a particular problem, Sydney's M4 Motorway had experienced a large number of rear end crashes along the route west of Parramatta. Lowering of the speed limit was a solution, but was not well received by the public. A study of the safety and engineering issues of the problem concluded the following :-

- Dominant crash pattern was rear end crashes (52%);

- Major driver behaviour problems (slow traffic in right lane, driving too close, U-turns across median strip);

- Traffic flow problems (stop/start traffic, slow merge speeds, congestion);

- Geometric problems (short on-ramps, insufficient lanes).

Differential traffic speeds led to differing traffic conditions, sometimes with a dire result (crash). Appropriate speed limits can be set to keep traffic moving at its optimum speed in order to achieve maximum flows and reduce accidents. For this example, the Roads and Traffic Authority (RTA) implemented a pilot incident management scheme, geometric improvements, dynamic traffic management, driver education and an enforcement campaign (Steele and Edwards, 1995). This included Variable Speed Limits (VSL), which are a ITS device that actively manages traffic at all times, particularly in periods of recurrent congestion. With these devices, a traffic smoothing function is introduced which is aimed at creating smooth traffic conditions and reduces the frequency of primary crashes.

The "rubber necking phenomenon" (which occurs when drivers in adjacent lanes slow down to look and examine what is happening at the incident site) also lowers speed and reduces capacity. This happens in the traffic lanes flowing past the incident, in the same direction, but it also occurs to traffic flowing in the opposing direction – to the same or sometimes to a worse extent. Even an emergency breakdown on the shoulder can affect through traffic flows. The capacity is reduced through the speed aspect of the drivers passing the incident – even with no through lanes blocked. A reasonable estimate at capacity reductions due to rubber necking can be in the range of 10% to 25%.

The road alignment, interchange and ramp geometry and layout can greatly influence the optimum traffic diversion percentage for a highway. Vehicles weaving to attempt an exit at critical ramps, in a diversion scenario, may hinder the mainline flow and cause excessive queueing. In addition, these motorists may produce secondary incidents associated with unnecessary lane changes and differential vehicle speeds. Each incident scenario would be different, and there would be many different permutations of incident duration, traffic diversion percentage, ramp and interchange capacity with a view to obtaining an optimum diversion rate for incident-induced traffic queues.

Depending on the particular environment, incident management strategies will focus on different areas. In some precincts, it may be the urban areas where incidents may account for up to 60% of highway congestion. A program in Colorado concentrates mainly on reducing highway delays and to improve incident response (Noyes, 1998). One major emphasis in their program was on technology and resources, which included reviewing engineering strategies, alternate routes, detour options and resource needs. Technology included updating their communications network in the area of fibre-optics. Incident levels, depending on the impact to the roadway (based on length of delays), triggered certain actions by the response groups, and varied from routine procedures to regional multi-agency co-ordination.

The management of traffic on the network is principally the domain of the operators at the Traffic Management Centre (TMC) and traffic engineering professionals. They can increase delays for motorists on the urban network or divert traffic from motorway incidents with a view to increasing overall network performance. The operators can play a major part in incident management by assisting with:-

- Detection;
- Verification, and;
- Response.

Some typical strategies for traffic management at incidents may consist of:

1. Displaying basic messages on VMS (outlining congestion, presence of incidences etc);
2. Displaying more dissuasive information messages on VMS (showing delay and travel time estimates, change of speed limits etc);
3. As per 2, but with more rerouting information (messages to try and force drivers to use specific off-ramps and alternate routes);
4. As per 3, but with ramp metering at on-ramps upstream of the incident/congestion location) (Barcelo, 2001).

There are several uncertainties associated with the incident itself that can affect the incident management operations (severity, duration, affected traffic and so on). Even with ITS technologies and well trained TMC staff, transportation professionals have very little control over how many drivers actually divert (Abdel-Rahim, A, 2002). An ideal approach would be to have an incident management strategy based on estimated demand and incident severity based on real time data sent back to the TMC from the incident site (and surrounding road network). Datasets from the vehicle detectors upstream in a real time incident scenario can be used as a comparison against actual, normal demand datasets to be used to give anticipated reductions in highway capacity. An incident of moderate severity and duration (22 – 31 minute duration) and utilising a traffic diversion plan can result in a reduction of total travel time. Above this incident duration threshold, the capacity of diversion routes may hinder good diversion rates.

Particular highway networks may often have to send diverted incident-induced traffic through local towns as part of the incident management strategy. Interchanges on the highway can be used to divert traffic from the mainline flows upstream of the blockage and then return traffic at the immediate downstream interchange. The selection of the diversion routes in these environments can be based on particular elements. One incident management strategy in Lexington in the United States of America used the following criteria to determine diversion routes through the town:-

(a) minimise travel on local roads;
(b) provide ease of access for local residents;
(c) provide ease of navigation for diverted traffic;
(d) reduction of turning points with significant heavy vehicles.

A total of eighteen routes were developed, including six through town with a large number of traffic signals and heavy local traffic (Stamatiadis and Culton, 1999).

Some road travel corridors, namely parallel highways, can provide a good opportunity for traffic diversions in order to optimise traffic flows in times of incidents. Long Island in New York is a 64 km long highway corridor with two major highway facilities: The Long Island Expressway and the Northern State Parkway/Grand Central Parkway. Their INFORM (INformation FOR Motorists) advanced traffic management system consists of electronic surveillance, communications, signing, and control components, providing motorist information for warning, route diversion, ramp control and traffic signal control (US DOT 1992).

The system combines an advanced traffic management system with a motorist information system that provides route guidance to individual drivers. It has a hierarchical structure. The corridor level control acts in a supervisory capacity dynamically allocating traffic among different corridor facilities, including freeways, frontage roads, and signalised arterials. Then the local level control selects control parameters for the individual facilities based on the predicted usage at the corridor level. There is evidence that there are only small differences in performance between user-optimal and system-optimal flow patterns for large scale networks.

Route diversion also has a functional structure – the corridor executive, the corridor level control and local level controls (Gartner and Improta, 1999). These modules consist of:-

1. Corridor executive;
2. Corridor Level Control:
    - Demand estimation;
    - Corridor control;
    - Message selection;
    - Performance evaluation.
3. Local level control:
    - Ramp metering control;
    - Arterial signalisation;
    - Incident detection;
    - State and parameter estimation.

Studies on system performance undertaken before and after the commissioning of the INFORM system show that there is up to 25% reduction in delays, 54% reduction in congestion clearance times and 52% reduction in queue lengths.

2.4 Traffic Simulation Modelling

In order to test and evaluate incident management strategies, traffic simulation software can be used to model particular scenarios. This can be for virtually any road environment, from limited access highways and motorways across to urban arterial roads to larger transport networks. AIMSUN is a microscopic, stochastic traffic simulator. "Microscopic" means that the model tracks the movements of individual vehicles in the traffic stream, as opposed to tracking platoons of vehicles or other macroscopic simulation techniques. "Stochastic" means that a random element is inherent in the model. The operation of the model depends on the following input data requirements:-

- network layout;
- traffic demand data;
- traffic control data, and;
- public transport data as required.

This input data, along with simulation parameters, constructs a simulation scenario which defines an experiment. The simulation parameters are fixed values that describe the experiment (simulation time, warm-up period, statistics intervals, and so on) and some variable parameters used to calibrate the models (reaction times, lane changing zones, and so on). The outputs provided by AIMSUN are a continuous animated graphical representation of the traffic network performance, statistical output data (flow, speed, journey times, delays and stops), and data gathered by the simulated detectors (counts, occupancy and speed).

In addition, the calibration of the model increases the degree of confidence of the model's absolute predictions (Kerenyi, 2000). The calibration effort may involve comparing predicted as against actual queue lengths and also predicted as against actual mainline traffic flow speeds (as an example). The average detector occupancy can also be used as the main calibration factor (Abdel-Rahim, A., 2002). By adjusting other model parameters, differences between actual and simulated can average as low as 7.3%. With this low variance, a model is validated. Further, by using microscopic simulation, different elements can be modelled in order to evaluate their effectiveness in the network over a specified time and for particular traffic control circumstance.

Models can be run a number of times in order to obtain accurate results (with little final variance and high confidence in results). Different random generator seeds can give a more robust result with multiple runs of the model. The seeds can control vehicle entry headways, route decisions and responses to traffic choices (Kerenyi, 2000). The simulation of incidents can be implemented for 15 minutes and then maybe leaving the network to recover for 45 minutes, thus giving a 1 hour scenario. A warm-up period for the model allows some vehicles to fill the network to some point and gives a more realistic beginning to the scenario. By modelling a network with and without some incident management strategies, the result can be a reduction of around 31% in queue lengths (Kerenyi, 2000).

The dynamic testing (by simulation) of incident management strategies dealing with incident-induced traffic queues can enable benefits of the mitigation of impacts to be assessed. Nathanail (2001), used the following components in one part of a particular incident management module (traveller information) to assess the benefits:-

- Time of trip information provision;
- Location where information is provided;
- Type of traffic management scheme (information systems, alternate routes).

After testing three scenarios, the measures of effectiveness (as indicators) consisted of delay, total travel time, total travel distance and journey time for the entire modelled network. For his site in Greece, Nathanail achieved reductions of 30% – 50% in these measures.

The simulation of incidents in an urban corridor also provides useful data for comparison with a motorway incident scenario. In the Central Business District in Brisbane, an incident was simulated for 60 minutes and blocked both lanes of a major arterial road. This resulted in approximately 15% increase in fuel consumption and 73% increase in hydrocarbon emissions (Cottman et al, 2001). The model parameters that were changed included mean headways (1.65 sec to 2.0 sec) and reaction times (0.3 sec to 2.0 sec). However, in the particular traffic simulation package used by Cottman (2001) (Paramics), mostly the default values were used. Cottman (2001) also concluded that with an incident blocking both lanes, with a 60 minute duration, there was an increase in network travel time of 38%.

It has been shown by many authors (Mayne (1951), Pacey (1955), Miller (1960)), that only when the rate of flow of vehicles is very light with vehicles overtaking freely, are they deemed to be randomly distributed on a road. This would equate to a Level of Service A. Research done by Mayne (1951), Pacey (1955) and Miller (1960) also concluded that if the intervals between the times at which consecutive vehicles passed a point were greater than 8 seconds, they would not be considered as queueing. If the intervals were less than 8 seconds, then the vehicles may have been queueing. Another crude rule of this era was that all vehicles more than 6 seconds apart or within a relative velocity of more than 10 km/h were not queueing. However, the present accepted way of defining queues is by speed or velocity. In research done by the above authors, the velocity parameter was usually disregarded in theories on different queueing distributions (thus leaving the time parameter to dictate the theory).

The real time traffic forecasting and simulation tools are both needed to support network management during incident conditions. Simulation studies are fine, but traffic assignment, future traffic evolution and the likely impact of strategies are difficult to manage in real time. Rapid changes can occur in the traffic situation during incident conditions and to forecast journey times for motorists to complete their trips can be difficult. Historic Origin – Destination Matricies can be used to assign paths of traffic through the network in times of incidents. However, this may prove to be unreliable and would not give a real indicator of travel patterns of incident-induced traffic diversions and queues. As stated above, the travel movements of traffic in incident times can be very unpredictable.

The use of a macrosimulator for traffic flows is useful as it accounts for traffic as one homogenous flow and not where each individual vehicle is assigned with certain parameters and uses origin / destination matrices to determine traffic flows. Lane closures, ramp closures and incidents can be simulated before decisions are made on a closing strategy and implementing it. Typically a VMS message will consist of the nature of an incident, its location, and advise of a given route. If no alternative is available (to take the expected volume of traffic) then a message informing the drivers about the location of the incident and the delay they will experience. Forecasts are used to search for network optimisation strategies using the macrosimulator. To assist with this, a questionnaire was issued on opinions of the VMS messaging. Out of 9000 questionnaires issued, there were 345 responses. Out of these 47% of these drivers had changed their route as a response to the messages on the signs (Morin and Tarry, 2000).

Different types of traffic engineering software can be used for various traffic scenarios. Some American programs like PASSER II can produce traffic signal timing splits for the main travel route but sometimes at the expense of the cross street traffic. TRANSYT-7F is used to develop the timing splits and then also to optimise the signal timing splits for the entire system. Both PASSER II and TRANSYT 7F use a macroscopic, deterministic-based algorithm for optimisation, where platoons of vehicles are addressed. TRAF-SIM (and AIMSUN) are microscopic stocharstic simulation models where individual vehicle movements are studied.

Simulation can also be used to test traffic incident management strategies, especially in the area of preplanning, in order to ascertain the best possible response actions. Incidents of various scales and durations can be modelled on a highway network and the impacts can be assessed. Wirtz et all (2005) mentions that the impacts of incidents simulated with his study were primarily measured in lane mile hours of highway links at level of service F.

Lane mile hours were measured by converting the average vehicle density over a 5 minute period to the Level of Service. A density greater than 45 vehicles a mile (28 vehicles a kilometre) indicates LOS F, or congested traffic flow. The total amount of time a link performs at LOS F during the simulation is summed and then multiplied by the number of lanes on the link and the length of the link (in miles) to get a measure of lane mile hours. This unit of measure has been developed independently but has been used by the Florida Department of Transportation as a performance measure for highways (Wirtz et all, 2005).

2.5 Traffic Flows and Reductions in Capacity

The behaviour of any vehicle in any traffic stream is not easily understood. This is further complicated when an incident occurs with associated breakdown in traffic flows. In this case, vehicles cannot divert at a nominal capacity rate of around, say, 2000 vehicles per lane per hour (vplph). Various studies show freeway queue diversion rates range from 1500 vplph to 2000 vplph (Transport Research Board, 2000).

Some basic calculations carried out in line with the Highway Capacity Manual can yield a few quick incites into incident-induced traffic queues. Consider a three lane freeway with a demand of 5500 vehicles per hour (vph) during a peak hour, 4500 vph during the hour after the peak, and 3000 vph thereafter. If an incident blocks one lane for 15 minutes at the start of the peak period, then through some basic calculations, there will be a queue of approximately 3 miles (5 kilometres) of the three lanes of traffic (Transport Research Board, 2000).

These basic calculations and approximations simply require reviewing the expected traffic demands and comparing them with the applicable capacity reduction. If the demands do not exceed the reduced capacity, there will not be any major difficulties in handling the traffic. The roadway will still have capacity.

Capacity reductions due to traffic accidents or vehicular breakdowns are generally short lived, ranging from less than 1 hour before they can be cleared (for a minor nose to tail accident with only light vehicles) to as long as 12 hours (for a major accident involving fully loaded semi-trailers). This data gleaned from American sources, aligns with those experienced in the particular case of the Pacific Motorway, at the present time.

The effects of incidents on capacity depends on the total number of traffic lanes and number of lanes blocked. Information on these values is presented in Table 2.3 below.

Table 2.3 Proportion of freeway segment capacity available under incident conditions (Transportation Research Board, 2000)

Number of Freeway Lanes by Direction	Shoulder Disablement	Shoulder Accident	One Lane Blocked	Two Lanes Blocked	Three Lanes Blocked
2	0.95	0.81	0.35	0.00	
3	0.99	0.83	0.49	0.17	0.00
4	0.99	0.85	0.58	0.25	0.13
5	0.99	0.87	0.65	0.40	0.20
6	0.99	0.89	0.71	0.50	0.26
7	0.99	0.91	0.75	0.57	0.36
8	0.99	0.93	0.78	0.63	0.41

The stop-start driving conditions associated with incident-induced traffic queues can be one characteristic of an incident scenario. The generation of a shockwave can be seen as a result of a sudden restriction of the flows in the traffic stream and the elements involved with its origin can be immense and complex. Identifying and monitoring the shockwave from an incident on the M25 in England has led to a fuller understanding of the characteristics of shockwaves, both in their derivation and their propagation. As stated, shockwaves can generate from the experience of stop-start driving and can propagate upstream at a typical rate of around 18 – 21 km/h. The passage of the vehicle acts as a moving seed point, with shockwaves being generated in its wake. Headways in the traffic stream and slow vehicles can inhibit this process.

Shockwave analysis is also done in order to protect the backs of queues – with speed reductions over a fair distance. For the system to remain credible, the applied speed limits need to be appropriate as an accepted speed limit for this condition. Setting advisory speeds to protect the backs of queues has proven to give an 18% reduction in secondary accidents (Abou-Rahme et all, 1999). This also results in less lane changing with safer travel, but travel times may increase 5 – 6%. On some major highways, the delay caused by a slow moving vehicle (vehicle travelling say, 20 km/h under the speed limit), in the peak periods, can be as much as 30% of the total delay. In addition, slow vehicles moving under escort can have their journeys optimised in order to reduce congestion and delays to other road users.

The generation of a shockwave grows and declines in surges. In fact, the shockwave could be seen as a queue which moves backward, sometimes at a rate of 50 – 70 km/h. This can create a large speed differential of around say, 160 km/h, as a vehicle approaches the end of the queue at normal highway speeds (100 km/h) with a backward moving queue at 60 km/h. Poonam et all (2002) cites various parameters regarding generation of queues from around the world, namely:-

- In Belguim, on the E313 Highway from Antwerpen to Hasselt, the detection of traffic queues is based on occupancy – 0% no traffic, below 20% normal flows, over 50% traffic moving slowly, 100% traffic stopped;

- In Denmark, speeds below 50 km/h indicates a queue;

- In Norway, a queue is detected by speeds below 30 km/h, zone occupancy higher than 30% and the limit for speed and zone occupancy exceeded for more than 15 seconds;

- In Scotland, with the COMPANION system, a queue is determined when the speed differential between vehicle detector loops (every 500 metres), exceeds 50 km/h.

The propagation of rear-end collisions and secondary accidents is also a critical aspect to manage in traffic queues forged by an incident scenario. A report cited in a reading revealed that a 1992 study done by Daimler-Benz determined that if car drivers had 0.5% second additional warning time, about 60% of rear end collusions could be prevented. The Daimler-Benz study also estimated that an extra second of warning time for drivers would prevent about 90% of rear end collisions.

The nature of a change in traffic flow conditions, in particular the change from uncongested to congested flow, is the point of initial flow breakdown or a "Bottleneck". The exact determination of this point is difficult. By using rigorous analysis of loop detection data and traffic volume data, this study can be improved. Ogut (2005) cites three theoretical models of flow breakdown. These are:-

(a) Flow breakdowns can occur when the capacity of a roadway segment is exceeded, or;

(b) Flows can break down spontaneously, resulting from the internal dynamics of the traffic stream, or;

(c) Flow breakdown can be associated with queue formation, over a relatively narrow flow range and influenced by location-specific factors.

The variability of the location of flow breakdown is an important clue to the nature of the transition between uncongested and congested flow. Flow breakdown coincides with an abrupt reduction in speed and then this region of low speed spreads upstream as the queue grows. A further insight into bottleneck location and functioning may be provided by using cumulative flow counts to determine changes in the numbers of vehicles stored at different locations. However, serious consideration needs to be given to the variations in speed drop sequences observed as a result of random variations in capacity.

Freeway networks do not always perform optimally. The spread of traffic jams and capacity drops can be controlled by spatial and temporal relationships between control actions and traffic behaviour. At a network level, this may be easier to manage than at a local level. The relocation of a traffic jam, in order to achieve a suitable network state, can be done using specific control measures. It may be necessary to create a traffic jam temporarily somewhere else in the network in order to solve a given jam. Capacity drops have been estimated for some typical bottleneck situations and, for on-ramps, a typical amount of capacity drop may be around 15% and upstream propagating jams could have about 30% capacity drop (Hegyi, 2005).

Other control measures which are effective in managing bottleneck propagation include the implementation of minor geometric and operational improvements. Some causes of freeway bottlenecks include lane drops, vertical curves, horizontal curves and extended grades. However, these minor improvement works are rarely done. Walters (2005) cites the following cases:-

(a) Tight left hand freeway curve had bad accident history with heavy vehicles. The adjacent exit ramp was changed to an entry ramp to reduce the weaving manoeuvres in this section;

(b) The signposting of this new entry ramp was not done, so truck drivers had to tell one another. This assisted with the concerns of too many drivers suddenly diverting and creating more congestion;

(c) Converting shoulders to traffic lanes in specific congested locations which can increase capacity.

In nearly all the above cases, microsimulation was used to ascertain the effects of the proposed improvements. A reduction in injury rates from such changes can be in the order of around 35% with benefit cost ratios as high as 400 : 1.

2.6 Intelligent Transport Systems (ITS) Technologies

The implementation of various ITS devices can result in improved traffic flow, lower travel times, higher average speeds and improved safety. En-route travel information can provide travel time savings by offering up to date information on road congestion or incidents or suggesting alternate routes. Implementation of VMS can result in a decrease in vehicle emissions, especially in peak times and a reduction in secondary crashes.

Frameworks for implementing Incident Management strategies can often include ITS devices. PRIME (Prediction of Congestion and Incidents in Real Time for Intelligent Incident Management and Emergency Traffic Management) was a framework project for the program of the European Union (Barcelo et all, 1999). This program developed systems and algorithms for incident detection, improve incident verification and also integrated motorway and urban network incident management strategies.

The Intelligent Transportation Society of America has determined that 12 freeway operation centres, 85 local traffic control centres, 31 freeway service patrols and 47 incident management programs are in operation or are being established across the country (Gangisetty, 1996). In general, traffic management systems have had approximately 25 % decrease in accidents, 20 minute reduction in accident response times, 32 % increase in travel speeds and decrease carbon monoxide and hydrocarbon emissions by 10%.

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CHAPTER 3

Materials and Methods

3.1 General Remarks

The materials and methods used in this research consist of many different, widely varying types of data in many formats. This compilation of data "sets the scene" on which to conduct the research. The data presented covers many areas from traffic flows, level of service, accident history and the use of diversion routes. There may appear to be a great number of unrelated groups of topics and datasets, but they all represent some small relevant part of the study and they all contribute to the total research.

The corridor chosen for this research is the Pacific Motorway between Coomera River and Hotham Creek, which encompasses both the Yawalpah Road Interchange at Pimpama (Exit 49) to the north and Foxwell Road Interchange at Coomera (Exit 54) to the south. The Pacific Motorway is the major connector between Brisbane and the Gold Coast and carries a significant amount of traffic. This total travel corridor is approximately 5.83 kilometres in length with the distance between the interchanges being approximately 4.78 kilometres and the is shown in Figure A2. There is an adjacent local service road layout running parallel to the Motorway which carries local traffic around the nearby commercial and residential areas. The justification for the selection of this motorway section is given in this chapter.

3.2 Examination of Motorway Elements

This motorway alignment essentially consists of large radius horizontal and vertical curve elements, evenly dispersed throughout the section. The motorway in this area consists of four traffic lanes (each 3.5 metres wide), with a three metre shoulder on the outside and a 2.4 metre shoulder near the centre median. The median is approximately ten metres wide and contains vegetation and roadside barriers for protection. The pavement crossfall is approximately 2.5% - 3.0% on the straight sections and rises up to 6% around the horizontal curves. The pavement is heavy duty concrete with deep lift asphalt used for the outside and median shoulders and has a posted speed limit of 110 km/h. There are concrete jersey type barriers through the cuttings and

Armco guardrail protection in some areas as well. This configuration is typical of motorway layouts around the world. Typical southbound and northbound views of the motorway appear below in Figure 3.1 and 3.2. The road environment is very open and looks and feels safe with wide shoulders and protection from roadside hazards. There are sixteen grade-separated interchanges along the whole length of the motorway which link the motorway to the extensive service road network and to major roads in each locality.

Figure 3.1 Typical view of Pacific Motorway travelling south

Figure 3.2 View of Pacific Motorway travelling north – looking at Yawalpah Interchange in the distance (northern extremity of research area)

A review of the design drawings and as-constructed plans for this area of the motorway gives the horizontal and vertical alignment data as outlined in Table 3.1 below.

Table 3.1   Alignment details for Pacific Motorway in study area (data suppled by QDMR)

		Horizontal Alignment Details		
-				
Chainage		Horizontal Alignment		Horizontal Curve Details
319000		Start of Section (Yawalpah Road Overpass)		
319000		Start of straight		
319401		End of straight		
319401		Start of right hand curve		Radius 1939m
321052		End of right hand curve		Radius 1939m

321052		Start of straight		
321972		End of straight		
321972		Start of right hand curve		Radius 5000m
322690		End of right hand curve		Radius 5000m
322690		Start of left hand curve		Radius 4499m
323495		End of left hand curve		Radius 4499m
323495		Start of left hand curve		Radius 3050m
323800		End of left hand curve		Radius 3050m
323800		End of Section		
		(Coomera Road Overpass)		
		Vertical Alignment Details		
Chainage		Vertical Alignment		Vertical Curve Details
319000		Start of Section (Yawalpah Road Overpass)		
319000		Start of crest curve		Radius 14382m
319278		Start of crest curve		Radius 14382m
319278		Start of downgrade		- 1.56% gradient
319400		End of downgrade		- 1.56% gradient
319400		Start of sag curve		Radius 8000m
319672		End of sag curve		Radius 8000m
319672		Start of upgrade		1.72% gradient
319822		End of upgrade		1.72% gradient
319822		Start of crest curve		Radius 18500m
320416		End of crest curve		Radius 18500m
320416		Start of downgrade		- 1.49% gradient
320743		End of downgrade		- 1.49% gradient
320743		Start of sag curve		Radius 12066m
321040		End of sag curve		Radius 12066m
321040		Start of upgrade		1.00% gradient
321583		End of upgrade		1.00% gradient

321583		Start of crest curve		Radius 13500m
322125		End of crest curve		Radius 13500m
322125		Start of Downgrade		-3.01% gradient
322182		End of Downgrade		-3.01% gradient
322182		Start of sag curve		Radius 8000m
322567		End of sag curve		Radius 8000m
322567		Start of crest curve		Radius 13500m
323013		End of crest curve		Radius 13500m
323013		Start of downgrade		- 1.51% gradient
323265		End of downgrade		- 1.51% gradient
323265		Start of sag curve		Radius 10000m
323538		End of sag curve		Radius 10000m
323538		Start of crest curve		Radius 13500m
323800		End of crest curve		Radius 13500m
323800		End of Section		
		(Coomera Road Overpass)		

3.3 Current ITS Infrastructure on the Gold Coast

Intelligent Transport Systems (ITS) have been identified as a key mechanism for more efficient use of the existing transport system as well as providing greater information for informed decision making by travellers worldwide. There is already a significant amount of ITS infrastructure in place on the Gold Coast. As new road projects are implemented, ITS infrastructure has generally been included as part of implementation, with specifications and requirements established on a project by project basis. The ITS devices and equipment in the Gold Coast area and along the Pacific Motorway includes:

- Communications Infrastructure

  Data and video communications requirements are currently being served using a range of communications infrastructure including ISDN lines, ADSL, optical fibre cables, microwave and wireless communications. The use of fibre optic, microwave, wireless and ADSL to replace or supplement existing ISDN lines is being investigated in an effort to reduce costs. This investigation will include the current communications, field equipment, fibre and wireless communication details, examining other options for new designs and then providing some recommendation for future action.

- Traffic Signal Coordination System (STREAMS)
  STREAMS provides a central control and monitoring system for traffic signals and other devices. The SCHD and GCCC currently use STREAMS version 2.94. There are 329 signalised intersections in the SCHD including 140 provided by the GCCC. With the remaining 189 intersections for the Main Roads network, 165 intersections are controlled by STREAMS. Similarly, 110 of the GCCC signalised intersections are controlled by STREAMS.

- Vehicle Detectors
  These detectors provide information about traffic flow characteristics, and depending on the type, may include vehicle counts, occupancy, speed, vehicle length and other data. The detectors are used to improve real-time traffic operating conditions and also assist with the collection of traffic data. All intersections with traffic signals incorporate vehicle detectors. The Pacific Motorway also has 150 detector sites, placed 500 metres apart, which provide volume, speed and occupancy data.

- Variable Message Signs (VMS)
  These provide information to motorists about traffic conditions, road maintenance, and incidents. In some cases, they are also used to provide safety messages to the travelling public. VMS can be useful during an incident by providing advance warning of hazard locations and can also reduce congestion and delays through the use of implied, suggested or directed diversions. A total of 26 VMS are installed in the district, including 2 provided by GCCC. Currently, there are six VMS northbound and five VMS southbound on the Pacific Motorway.

- Closed Circuit TV Cameras (CCTV)
  CCTV cameras provide surveillance of road and traffic conditions. Cameras are monitored by the TMC. They are also utilised for early detection of hazards and incidents and to improve incident response and provision of accurate information to response agencies.

- Changeable Message Signs (CMS)
  CMS provide an alternative to VMS especially where a limited number of pre-defined messages are used to address all possible situations. Like VMS, they are used to improve safety through the provision of advanced hazard warnings. A total of eight

CMS are installed in the SCHD and these are associated with the Queensland Transport Weigh-in-Motion Station at Coomera for heavy vehicles.

- Weather Monitoring Stations

  These are used to collect a range of weather parameters including air temperature, relative humidity, wind speed and direction, rainfall etc. These stations provide valuable information that can be used to improve road safety conditions during adverse weather. As an example, this information can be used to warn drivers of unusual weather incidents (for instance, heavy rain and high winds) and advise them to reduce speeds and maintain safe travel headways. A total of eight weather stations are installed on the Pacific Motorway between Nerang and Logan Motorway.

- Emergency Telephones

  These telephones are used by motorists to report incidents or seek assistance in emergency situations. They are usually provided on limited access facilities and are aimed at enhancing road safety and expediting incident response and the removal of stalled or damaged vehicles. A total of fourteen groups of emergency telephones are installed on the Pacific Motorway (each group consisting of four telephones, two on each carriageway).

- Traffic Hotline 13 19 40

  The traffic hotline is a public access telephone service allowing the public to report incidents and to seek information regarding traffic conditions. It is aimed at improving safety and reducing delays through early reporting of incidents by the public.

Within the immediate research area, between Coomera Interchange and Yawalpah Road Interchange, there are:

- Eleven vehicle detector loop sites embedded in the pavement (at 500 metre intervals);
- Fibre Optic communications running down the median sending data back to the TMC;
- One northbound VMS located just north of the Coomera River bridge;
- One southbound VMS, located approximately two kilometres south of Yawalpah Interchange;

- One CCTV located on the Yawalpah Interchange overpass bridge and another located adjacent to the Foxwell Road Interchange and another approximately mid distance between the interchanges;

- Three CMS northbound from the Coomera River bridge to the northbound off-ramp to Foxwell Road Interchange;

- Four CMS southbound from just north of Hotham Creek to the southbound off-ramp to Foxwell Road Interchange.

3.4 Motorway Traffic Volume Characteristics

The traffic on the Pacific Motorway is variable depending on particular circumstances. There appears to be the normal peaks and troughs for the peak travel times throughout the day with particularly heavy traffic on weekends, school holidays and when there are planned events. Unplanned events (incidents, debris and hazards) also transform the normal traffic flows to situations of congestion. Figure 3.3 below gives a typical indication of the traffic flow profile of the motorway around the Coomera River area.

The eight lane section of the Pacific Motorway, between Logan River and Pappas Way, was opened in October 2000 and carries a traffic volume in the range 80,000 vehicles per day (near Pappas Way) to 120,000 vehicles per day (crossing the Logan River). The southern section of the Pacific Motorway, between Nerang and Tugun, is a lower standard four lane corridor with traffic volumes in the range 50,000 vehicles per day (at Tugun) to 88,000 vehicles per day (south of Nielsens Road).

Traffic count information is shown in Table 3.2 and Table 3.3 below for the subject sites and for an additional traffic count site near Currumbin Creek Connection Road (Stewart Road), at the southern end of the Pacific Motorway. The tables show the typical weekday traffic volume, the typical peak hour volume (for each of the peaks), the average hourly traffic volumes during the period 7.00am to 7.00pm, and the average hourly traffic volumes over the full 24 hour period. This gives some indication of the different traffic flows on the motorway for a typical day.

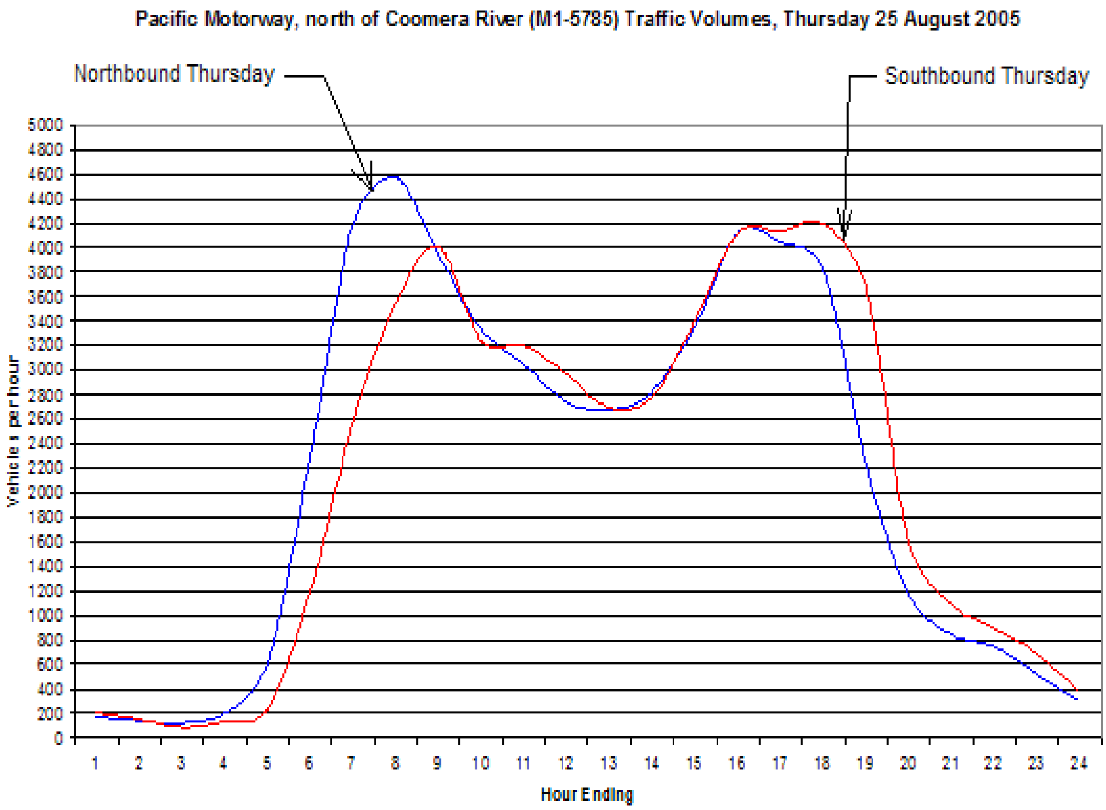


Figure 3.3 Traffic volume profiles for around Coomera River, Pacific Motorway

Table 3.2 Pacific Motorway traffic volumes – northbound direction (2005)

LOCATION	SITE NO	NO LANES	TRAFFIC VOLUME (VEH/DAY & VEH/HOUR)				
			AVERAGE WEEKDAY VOLUME	AM PEAK HOUR	PM PEAK HOUR	AVERAGE HOUR 7AM-7PM	AVERAGE HOUR 24 HOUR
Albert River	**5720**	4	57000	4750	4750	3770	2360
Pimpama River	**5749**	4	49000	4400	3850	3170	2020
Coomera River	**5785**	4	52000	4600	4300	3400	2170
Coombabah Creek	**5817**	4	62000	4500	5400	4040	2580
Gaven Hill	**5830**	3	49000	4100	4000	3160	2020
Pappas Way	**5846**	3	40000	3700	3100	2600	1680
Nielsens Road	**-**	2	49000	4100	3900	3230	2020
Robina Parkway	**5850**	2	31000	2600	2600	2140	1270
Stewart Road (2004)	**-**	2	25000	1900	1850	1620	1040

Table 3.3 Pacific Motorway traffic volumes – southbound direction (2005)

LOCATION	SITE NO	NO LANES	TRAFFIC VOLUME (VEH/DAY & VEH/HOUR)				
			AVERAGE WEEKDAY VOLUME	AM PEAK HOUR	PM PEAK HOUR	AVERAGE HOUR 7AM-7PM	AVERAGE HOUR 24 HOUR
Albert River	**5720**	4	57000	4350	4800	3760	2370
Pimpama River	**5749**	4	49000	3600	4350	3270	2030
Coomera River	**5785**	4	51000	4000	4500	3500	2130
Coombabah Creek	**5817**	4	63000	5900	5200	4310	2610
Gaven Hill	**5830**	3	53000	4800	4800	3680	2220
Pappas Way	**5846**	3	40000	3300	3800	2740	1670
Nielsens Road	**-**	2	48000	4100	4100	3440	2010
Robina Parkway	**5850**	2	32000	2400	2800	2180	1330
Stewart Road (2004)	**-**	2	24000	2000	1950	1700	1010

The directional peak hour traffic volumes vary from less than 2000 vehicles per hour at the southern end of the Motorway to approximately 6000 vehicles per hour, measured to the north of the Smith Street Connection Road. The weekday peak periods typically last for three hours in the morning and four hours in the afternoon. The weekend peak periods typically extend from 9.00am through to 6.00pm (that is peak traffic for most of day). As an observation, a major incident at the start of a peak period has the potential to impact on up to 15,000 vehicles or 20,000 persons (with a vehicle occupancy rate of 1.3) over a three hour period.

3.4.1 Selection of Traffic Flows for Study Area

A particular day was chosen to gather traffic information on which to base all traffic microsimulation experiments. The analysis of the accident data on the particular parts of the Pacific Motorway (refer Section 3.9) concluded that the am peak traffic times were most accident-prone. The am peak traffic periods generate slightly higher traffic volumes and slightly varying traffic compositions, different to those of the off-peak traffic times. Therefore, for the purposes of this research, the traffic flow data for the morning peak period will be used for the simulation experiments (as concluded from the accident analysis detailed later in 3.9).

The vehicle detector loops (STREAMS traffic flow data) in the southbound concrete pavement, just south of Yawalpah Interchange, gave some reasonable data for the week of Monday 01/05/06 to Friday 07/05/06 (Detector Group No. M1-5769 SB). Hourly traffic counts for the days of that week gave a typical trend of morning and afternoon traffic peak periods. The traffic volume counts for the Saturday and Sunday also yielded data that is very comparative to the weekday volumes. This indicates that weekend peak traffic times are becoming similar to weekday peaks and that there is no real decrease in traffic for a weekend. It appears that, for a weekend, work commuter and freight traffic may decrease but then recreational weekend traffic increases to give nearly the same total traffic volumes. This is an increasing trend also on some major arterial roads in the Gold Coast area, particularly major northbound and southbound arterials servicing the coastal areas along with some major eastbound / westbound connector arterials.

The resultant southbound traffic volumes, after examining the data (Detector Group No. M1-5769 SB) was:-

- 4568 vehicles Southbound for am peak (7:45am – 8:45 am), and;
- 5388 vehicles Southbound for pm peak (5:30 pm – 6:30 pm).

For comparison, the volumes for the same day, in the opposing direction (Detector Group No. M1-5769 NB) were:-

- 5024 vehicles Northbound for am peak (6:45 am – 7:45 am), and;
- 5036 vehicles Northbound for pm peak (5:00 pm – 6:00 pm).

Common traffic engineering folklaw (Akcelik, 2000) suggests that the peak traffic hour for a typical site would be around 10% of the Average Annual Daily Traffic (AADT). Therefore, from the above traffic counts, for the peak traffic times at these sites, a typical AADT could be around 46000 to 53000 (or approximately 110% of the above peak hour volumes). This is a very general type assessment of the AADT figures and aligns effectively to the results from Table 3.2 and 3.3 above (within 5% - 10% of these values). The traffic count data for Detector Group No. M1-5769 SB and Detector Group No. M1-5769 NB (above) is slightly higher than the results in Table 3.2 and 3.3 above (within 10% of these values).

In addition, field tests were conducted on the motorway pavement vehicle detector loops on the northbound carriageway just north of the Detector site M1 – 5769 NB. This was to ascertain the performance of the vehicle detector loops, field processors and other hardware and software with regards to the output of vehicle speed and volume data. The report from this exercise is currently in draft format in Head Office, but an informal discussion with the personnel who conducted the tests reveals that the detector loops produced useable data for that location and around that particular time period.

3.4.2 Determination of Percentage Commercial Vehicles

The percentage of heavy vehicles was derived after looking at the Traffic Census data from the Department of Main Roads for the year 2005. There is a counting site in the area of interest which also recorded percentage Commercial Vehicles (% CV). The data for the northbound and southbound directions are presented below in Tables 3.4 and 3.5.

Table 3.4 Percentage commercial vehicles (% CV) for Pacific Motorway – northbound direction

Start Date	Estimated AADT	% CV
2005	47381	6.0
2004	51337	14.9
2003	49138	14.5

Table 3.5 Percentage commercial vehicles (% CV) for Pacific Motorway – southbound direction

Start Date	Estimated AADT	% CV
2005	49868	6.0
2004	50647	14.9
2003	47558	Not available

The % CV data presented in Tables 3.4 and 3.5 above could be viewed as being slightly suspect, as there is a notable decrease in the percentage from the year 2004 to 2005. The estimated AADT looks fine for all the years indicated and the % CV for 2003 and 2004 looks fine, but the figure for 2005 does appear to be incorrect. A more plausible figure for % CV would still be around 10% – 14%. This aligns to the findings of the manual video counts for commercial vehicles (refer Section 3.4.3 below) which concluded a typical % CV of around, say, 10%. This finding also points to the % CV for the year 2005 being incorrect.

3.4.3 Use of CCTV Video Recording to Estimate % Commercial Vehicles

The purpose of this exercise was to gain an idea of general traffic flows, lane usage and to obtain a percentage Commercial Vehicles (% CV). The CCTV at Exit 54 – Coomera Interchange Overpass – was used to record video footage of the Pacific Motorway northbound and southbound traffic flows. These recordings were done on the afternoon of 03 / 08 / 04 from 4:00 pm to 5:00 pm, and on the morning of 14 / 09 / 04 from 7:30 am to 8:30 am and the data was recorded straight onto a video cassette as opposed to the Elbex analogue recording system of the

Traffic Management Centre. Readily available VCR machines do not play the Elbex video format so the recording onto a plain video cassette was an advantage.

A methodology was forged on how best to record the required traffic movements. The video tape was played several times with a tally sheet being used which recorded the different types of vehicles using the traffic lanes in 15 minute intervals over the full time of the recording. This Masters' candidate and his wife noted the number of light vehicles and the number of heavy vehicles for each direction and in which particular lane and in each 15 minute time period. The protocol was to count the vehicles just as they entered the television screen, just after crossing the lower edge of the screen. This yielded the following results in Table 3.6 and Table 3.7.

Table 3.6 Percentage commercial vehicle (% CV) for specific time periods – northbound direction

Northbound Direction 14 / 09 / 04	7:30 am – 7:45 am	7:45 am – 8:00 am	8:00 am – 8:15 am	8:15 am – 8:30 am
% CV	10%	8%	12%	9%

Table 3.7 Percentage commercial vehicle (% CV) for specific time periods – southbound direction

Southbound Direction 03 / 08 / 04	4:00 pm – 4:15 pm	4:15 pm – 4:30 pm	4:30 pm – 4:45 pm	4:45 pm – 5:00 pm
% CV	16%	10%	7%	8%

Therefore, the figure for % CV for use in the microsimulation analysis was chosen as 10%. This particular part of the research entailed some additional work but a good result was reached.

3.5 Criteria for Assessment of Operational Performance of a Traffic Network

There are many parameters that enable the assessment of the performance of a traffic network to be carried out. These are used to ascertain new strategies, measure before and after effects and to measure network performance. A comprehensive list of traffic measures used mainly to gauge performance of the network includes (examples only):-

- Degree of saturation – measuring volume over capacity;

- Total travel – the total vehicle / kilometres per hour of travel;
- Total travel time – the total vehicle / hours per hour of travel;
- System speed – average vehicle speed in the network;
- Delays – a total in terms of vehicle hours per hour or average delay, in seconds per vehicle;
- Level of service – operating characteristics of a road section or network;
- Stops – uniform, random number of stops per vehicle and percentage of vehicles stopped;
- Length of queue and queueing capacity – by number of vehicles;
- Fuel consumption – number of litres consumed per hour on network;
- Operating cost – total cost of vehicle operation in the network;
- Time jammed – percentage of the network time that vehicles cannot move because other road sections are at capacity.

There is a need to include different traffic performance measures in this research so as to measure the effectiveness of any changes in the experiments. However, to include all of the above parameters is not necessary for this research. Therefore, the traffic performance criteria selected for analyses in this research will include the following:-

- Travel speeds - the speeds for all vehicles travelling in the network;
- Travel Time - the time a vehicle needs to cross a section inside the network;
- Delays - the delay time per vehicle per kilometre, say;
- Number of Stops - the number of stops per vehicle per kilometre, say;
- Queue length - the length of queue in that section, by the distance or number of vehicles.

3.6 Level of Service

On multi-lane roads (for example, Pacific Motorway) the operating characteristics may include wide ranges of rates of flow over which speeds may be relatively constant. However, speed is not an adequate performance measure to define the level of service. Density is a measure that quantifies the proximity of other vehicles and the degree of vehicle manoeuvrability in the traffic stream.

Density and speed have generally been accepted as the measures to define the level of service. At an analytical level, the level of service criteria reflect the shape of the speed – flow and density – flow curves, particularly as speed remains constant at particular levels, but is reduced as capacity is approached. Some basic published diagrams of these relationships are shown below in Figure 3.4. The level of service parameter will also be used to ascertain network performance (qualitative measure) under incident conditions.

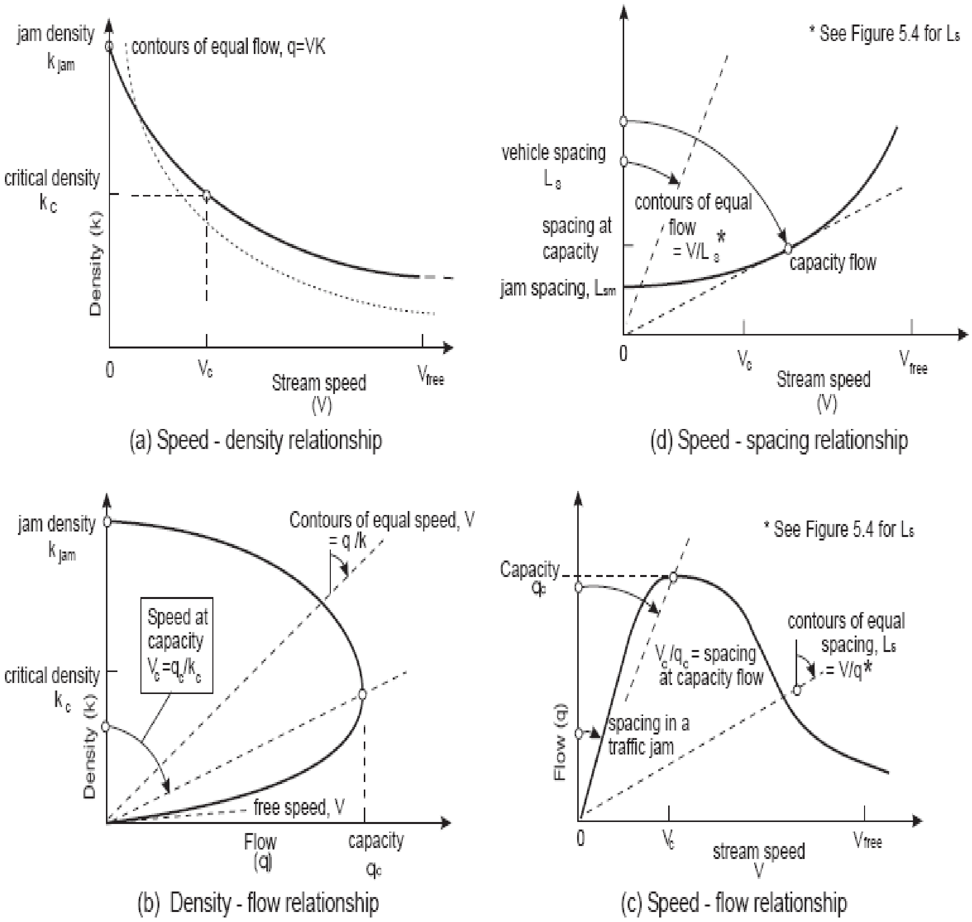
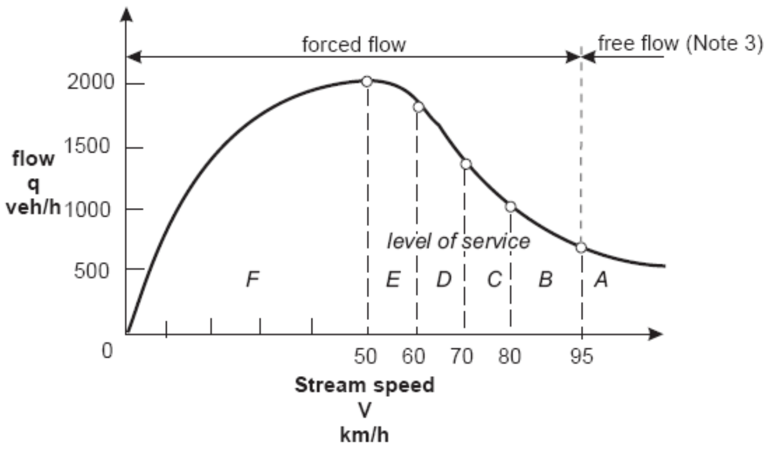


Figure 3.4 Basic traffic flow relationships (Road Planning and Design Manual)



Notes:

1. The speeds used are trip speeds and, on urban roads, would include average delays at signalised intersections.
   The capacities are for the uninterrupted flow of cars on a two-way road in good conditions, but with some sight
   distance restrictions.
2. “Forced” (or “impeded) flow occurs when flows are sufficiently high for a vehicle to be impeded by a slower vehicle
   ahead and forced to adopt its speed and the minimum spacing associated with that speed.
3. “Free” flow occurs when vehicle speeds are not influenced by vehicle spacing.

Figure 3.5 Level of service representation (Road Planning and Design Manual)

There is numerous published level of service criteria from different parts of the world. Three sources which were examined for this research include:-

- Department of Main Roads - Road Planning and Design Manual;
- Highway Capacity Manual 2000 (HCM), and;
- AustRoads - "Guide to Traffic Engineering Practice", specifically Part 2.

The Department of Main Roads Road Planning and Design Manual uses traffic flow and traffic speed criteria to set the level of service. This criteria is a more basic element approach than the HCM and AustRoads criteria. The Transport Research Board and American Association of State and Highway Transport Officials (AASHTO) also had input into the compilation of the HCM.

Table 3.8 Motorway / freeway level of service criteria (Road Planning and Design Manual)

Level of Service	Traffic Flow (veh/hour/lane)	Traffic Speed (km/h)
A	< 700	> 95
B	700 - 1000	80 - 95
C	1000 - 1500	70 - 80
D	1500 - 1800	60 - 70
E	1800 - 2000	50 - 60
F	> 2000	0 - 50

The Highway Capacity Manual 2000 (USA) has set the following to determine level of service.

EXHIBIT 21-2. LOS CRITERIA FOR MULTILANE HIGHWAYS

		LOS				
Free-Flow Speed	Criteria	A	B	C	D	E
100 km/h	Maximum density (pc/km/ln)	7	11	16	22	25
	Average speed (km/h)	100.0	100.0	98.4	91.5	88.0
	Maximum volume to capacity ratio (v/c)	0.32	0.50	0.72	0.92	1.00
	Maximum service flow rate (pc/h/ln)	700	1100	1575	2015	2200
90 km/h	Maximum density (pc/km/ln)	7	11	16	22	26
	Average speed (km/h)	90.0	90.0	89.8	84.7	80.8
	Maximum v/c	0.30	0.47	0.68	0.89	1.00
	Maximum service flow rate (pc/h/ln)	630	990	1435	1860	2100
80 km/h	Maximum density (pc/km/ln)	7	11	16	22	27
	Average speed (km/h)	80.0	80.0	80.0	77.6	74.1
	Maximum v/c	0.28	0.44	0.64	0.85	1.00
	Maximum service flow rate (pc/h/ln)	560	880	1280	1705	2000
70 km/h	Maximum density (pc/km/ln)	7	11	16	22	28
	Average speed (km/h)	70.0	70.0	70.0	69.6	67.9
	Maximum v/c	0.26	0.41	0.59	0.81	1.00
	Maximum service flow rate (pc/h/ln)	490	770	1120	1530	1900

Note: pc/km/ln = passenger cars per kilometre per lane.

Pc/h/ln = passenger cars per hour per lane.

Figure 3.6 Level of service criteria for multilane roads (HCM 2000)

The AustRoads "Guide to Traffic Engineering Practice", specifically Part 2 details this criteria for Level of Service.

Table 4.1 Level of Service Criteria for Multi-Lane Roads

Level of Service	Density pc/km/lane	Design Speed 110 km/h			Design Speed 100 km/h			Design Speed 80 km/h		
		Speed[a] km/h	v/c[b]	MSF[c]	Speed km/h	v/c	MSF	Speed km/h	v/c	MSF
A	≤ 7.5	≥ 91	0.36	700	≥ 80	0.33	650	-	-	-
B	≤ 12.5	≥ 85	0.54	1,100	≥ 77	0.50	1,000	≥ 67	0.45	850
C	≤ 18.8	≥ 80	0.71	1,400	≥ 70	0.65	1,300	≥ 62	0.60	1,150
D	≤ 26.3	≥ 64	0.87	1,750	≥ 64	0.80	1,600	≥ 56	0.76	1,450
E	≤ 41.9	≥ 48	1.00	2,000	≥ 48	1.00	2,000	≥ 45	1.00	1,900
F	> 41.9	< 48	d	d	< 48	d	d	< 45	d	d

a. Average travel speed
b. Volume/capacity ratio
c. Maximum rate of service flow per lane under ideal conditions, rounded to the nearest 50 pc/h/lane.
d. highly variable

Source : Adapted from TRB (1985) Table 7.1

Figure 3.7 Level of service criteria for multi-lane roads (AustRoads)

The three examples cited above (Department of Main Roads Road Planning and Design Manual, HCM 2000 and AustRoads) all exhibit essentially the same characteristics. There are some minor differences however. Generally, the HCM adopts some lower thresholds for particular parameters (especially maximum density and V/C ratio). The Road Planning and Design Manual adaptation could generally be seen as the most "accommodating" to all elements. However, for this research, the AustRoads Guideline will be adopted for the motorway (which is very similar to the Road Planning and Design Manual).

Table 3.9 Motorway level of service thresholds adopted for this research

Level of Service	Motorway Speed (km/h)	Motorway Flows (veh/h)
A	112	675
B	96	720
C	85	1100
D	80	1400
E	64	1750
F	0	0

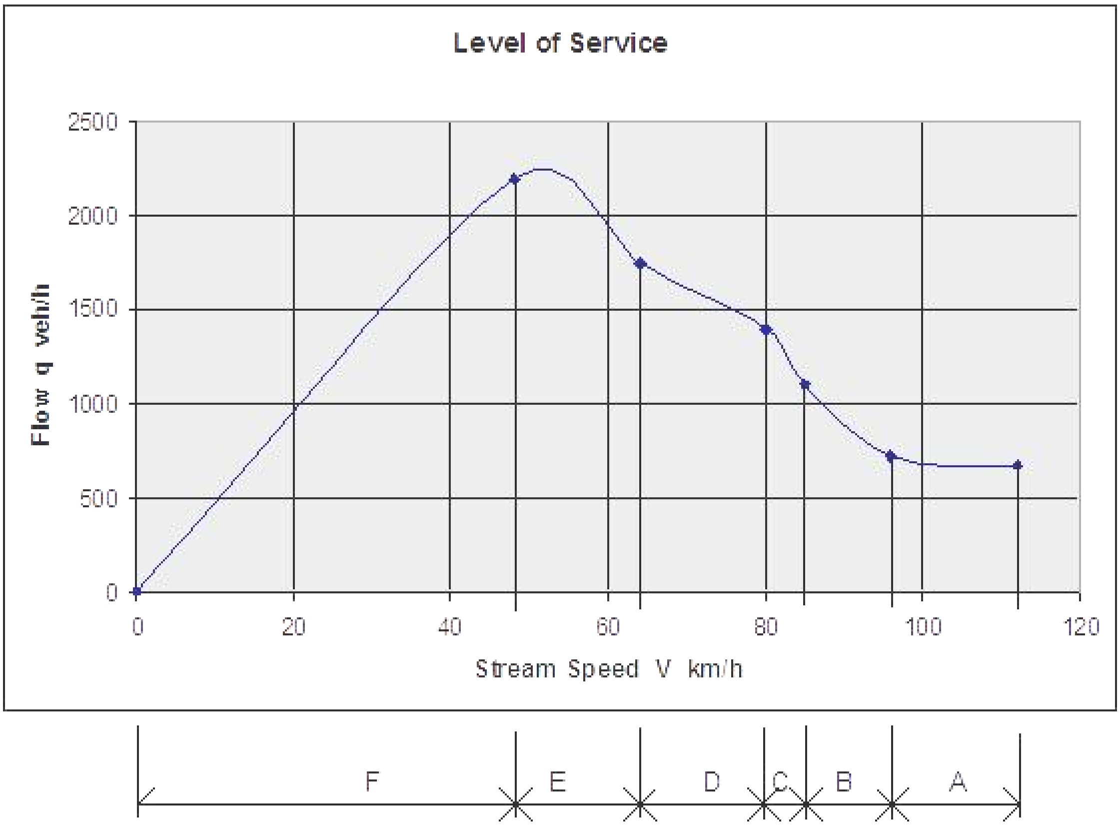


Figure 3.8 Motorway level of service thresholds adopted for this study

3.6.1 Diversion Route Level of Service and Capacity

Looking at the AustRoads Guide to Traffic Engineering Part 2 (1999) gives a basic capacity of approximately 2800 passenger cars per hour total of both directions of flow. However, this is for a rural, medium to high speed, wide, excellent piece of road with exceptional traffic characteristics. This is definitely not the case for the diversion route being studied. A typical level of service for diversion route traffic could be around a level of service C. This may be slightly optimistic, as the horizontal and vertical alignments along with the intersections and private accesses could dictate a lower level of service. The general level of service equation for "Uninterupted Two-lane Two-way Roads" from AustRoads Guide Part 2 can be refined to our situation by using the equation and the adjustment factors as follows:-

$$SF_1 = 2800\,(v/c)_i\, f_d\ f_w\ f_{hv} \qquad \text{Eq 3.01}$$

Where:-

SF_1 = Total Service Flow in vehicles per hour in both directions under prevailing roadway and traffic conditions for level of service *i*.

$(v/c)_i$ = Maximum volume / capacity ratio which can be achieved at level of service *i* for a given terrain.

f_d = adjustment factor for directional distribution of traffic.

f_w = adjustment factor for narrow lanes and shoulders.

f_{hv} = adjustment factor for heavy vehicles.

Therefore, the above equation becomes (assuming level of service C for diversion route traffic):-

$$SF_1 = 2800\,(v/c)_i\, f_d\ f_w\ f_{hv}$$
$$= 2800 \times 0.30 \times 0.97 \times 0.78 \times 0.95$$
$$= 603 \text{ vehicles per hour}$$

This results in approximately 301 vehicles per hour northbound and 301 vehicles per hour southbound with a 50 / 50 directional assignment of traffic (northbound or southbound). This determination of the level of service for the diversion route will be used in this research.

To select a compliance diversion rate and incident type to match the level of service criteria for the characteristics of the diversion route may be difficult. There are many considerations. For a 30 minute incident blocking two lanes, the modelled average traffic flow and average traffic speed parameters may have some difficulty meeting the equivalent figures for the level of service criteria for level C, and to meet at a particular compliance diversion rate. This shows that the capacity of the diversion route is achieved and the addition of more traffic just compounds the situation. This shows, in fact, for a 30 minute incident on the motorway blocking two lanes, the diversion route may operate at a higher level of service, probably at a level B. This level of service B, can be examined by re-calculating equation 3.01 above.

$$SF_1 = 2800\,(v/c)_i\, f_d\ f_w\ f_{hv}$$
$$= 2800 \times 0.15 \times 0.97 \times 0.78 \times 0.95$$
$$= 302 \text{ vehicles per hour}$$

Therefore, again looking at a 50 / 50 directional assignment of traffic flow on the diversion route, this gives approximately 151 vehicles / hour in each direction.

With the average diversion route traffic flows and traffic speeds at a level of service around level B, there would be some variance around this mean during the duration of the incident and also then when the motorway starts returning back to normal traffic conditions. Depending on these traffic parameters, the level of service would fluctuate between level A and level C or D. At virtually every 15 minute time interval during the experiment, the flow and speed parameters change enough to warrant the next level of service – either improving or declining the diversion route level of service.

Table 3.10 Diversion route level of service thresholds adopted for this research

Level of Service	Diversion Route Speed (km/h)	Diversion Route Volume (One-way) (veh / hr)
A	70	65
B	64	151
C	58	301
D	52	579
E	46	1160
F	0	0

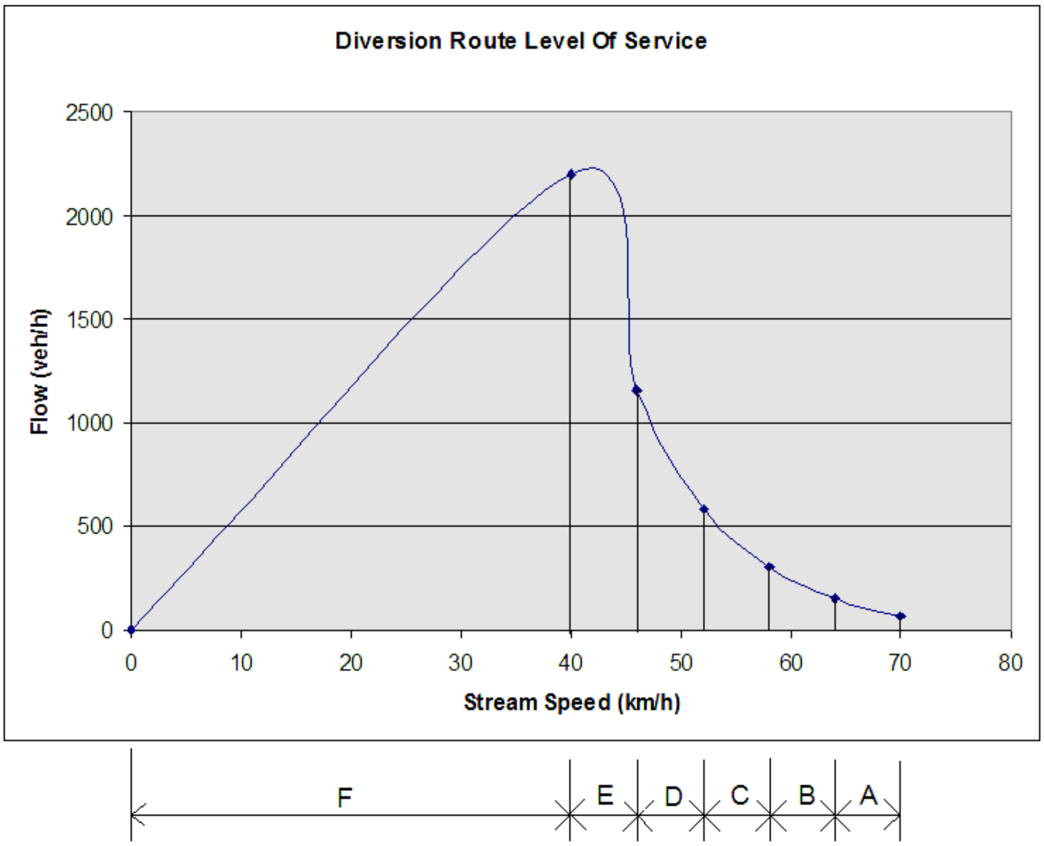


Figure 3.9 Diversion route level of service thresholds adopted for this research

3.6.2 Notes on Level of Service using the Highway Capacity Manual (USA)

Table 3.10 may appear to show low results for a typical service road with a level of service C type operating conditions. As an additional measure, the Highway Capacity Manual (2000) was consulted to verify this result. This service road would be a Class 2 type two lane highway – acting as an access route, serving short trips and serving as beginning and ending portions of longer trips (in the U.S.A.). The use of the word "highway", by the HCM, in this quick comparison, could be seen as misleading as the research diversion route / service road may not be applicable. However, the manual also mentions:-

"Efficient mobility is the principle function of highways that connect major traffic generators or that serve as primary links in road networks", and;

"The classes of two-lane roads closely relate to their functions – most arterials are considered Class 1, and most collectors and local roads are considered Class 2".

Therefore, the description of Class 2 could be viewed as being applicable to this diversion route – and able to be analysed under the conditions of the HCM. Reading the general notes on level of service on page 12-16 of the HCM, the LOS C criteria for a Class 2 Highway gives a speed around 70km/h or less and a service flow rate of around 1281 passenger cars / hour total in both directions. Therefore, with a 50 / 50 directional traffic assignment, this gives a one way volume of approximately 640 passenger cars / hour. This result from the HCM is approximately double to that calculated from the AustRoads Part 2 guideline above and therefore is not a valid outcome and will not be considered further in this research.

3.7 Calculation of Directional Distribution of Traffic

In order to assist with the calculation of the level of service, an assessment of the directional distribution (or traffic assignment) needs to be made. The Department of Main Roads Traffic Census CD (2005) has documented traffic count data for the western roundabouts at both the Coomera and Yawalpah Interchanges. This data can be used to calculate this parameter to give an idea of the proportions of traffic flow occur in each direction.

The traffic data (from the Census CD) gives Days' Road entry / exit leg of the western roundabout at the Coomera Interchange a total am peak traffic volumes of 301 light vehicles with 11% heavy vehicles entering the roundabout and 707 light vehicles with 11% heavy vehicles exiting the roundabout. Looking at the western roundabout at the Yawalpah Interchange gives total am peak traffic volumes of 56 light vehicles with 23% heavy vehicles entering the roundabout and 105 light vehicles with 35% heavy vehicles exiting the roundabout. As the Yawalpah Interchange is some distance away from the Coomera Interchange, with a large percentage of heavy vehicles around the adjacent residential area, then this traffic data could be understood to be skewed in a particular way (the percentage of heavy vehicles is not really representative). Looking at the data presented gives a directional traffic flow assignment of around 2/3 northbound, 1/3 southbound at the Coomera Interchange and 1/3 northbound and 2/3 southbound at the Yawalpah Interchange. So an average directional distribution (assignment) for the traffic could be around 50 / 50 (50% northbound and 50% southbound). This result will be used for all computations where needed (level of service calculations as above).

3.8 Driver Information to Achieve Desired Diversion Rates

In the real world, with many different people, there are very few real, positive ways to address the issue of presenting a message on a VMS in order to achieve a particular diversion rate for motorists. There is not yet a valid behavioural model accounting properly for drivers' reaction to VMS information (Barcelo et all, 1999). Different motorists perceive different messages in different ways and then take different actions as a result. Hidas (2000) mentions that there appears to be no definitive rules for the route diversion decision by the motorist. The role of Incident Management Planning is significant here, as a motorway diversion has impacts on many areas and stakeholders. Prescribed diversions should only be used where they are essential, are of adequate standard and where they can be provided with additional resources as necessary to assist with traffic flows.

The construction of a VMS message needs to consider particular elements. To begin, a VMS message should really address the following elements:-

- A problem statement (accident, maintenance, construction and so on);
- An effect statement (delay, heavy congestion, and so on);
- An attention statement (addressing a certain audience);
- An action statement (what to do).

In addition, a location statement and time information will enhance the credibility of the message. The entire VMS message elements cited above may appear to be easy to state, but the interpretation of the message content is understood by different motorists in different ways. Catering to all levels of the behavioural aspects of the motorist is an additional problem adding complication to the construction of a message.

In a typical incident scenario, using passive VMS messages (that is, no recommended alternate route), may have a result of diverting 5 - 10% of mainstream traffic (Inform Evaluation, 1992). A small traffic diversion percentage really is only needed before the diversion route reaches capacity (that is, around 20%). There is one immediate VMS (for northbound traffic) just north of the Coomera River and south of Coomera Interchange. This VMS would display critical type messages relating to incident traffic management, including traffic diversions. The next upstream VMS for northbound traffic would be at Coombabah (south of Coomera Interchange). This would display a broad accident type message.

As travel time is a performance measure / indicator for most motorists – and is one of the main parameters used to measure performance in this research – then this factor should be used in the VMS message. There are further aspects to consider, namely what facet of travel time to display. It could be the additional travel time that is anticipated or maybe the delay time which could be expected as caused by the incident. The additional travel time parameter will be only for the main through route (which is the additional travel time to travel to Brisbane). This will not take into account other destinations apart from the main destination at Brisbane.

Possibly a more effective way to portray the effect of the incident on main through traffic flows and incident-induced traffic queues is displaying the delay time on the VMS. This is the amount of time that a motorist can expect to be delayed on this particular trip to a particular destination. Again, the VMS message will have relevance for the main through traffic proceeding to Brisbane as their destination. This will not take into account other destinations apart from the main destination at Brisbane. Whether the VMS displays a message related to extra travel time or delay time, motorists will have to work out how these statements will affect their own individual trip and decide on an appropriate course of action.

In addition, before any new initiative with VMS messaging can be approved, certain steps in this procedure need to be signed off. This will also include an assessment of the proposed message wording by Queensland Transport in order to assess the worth of the message, then how it will be perceived and a typical compliance level by motorists. Then, ideally, a media campaign should be put together to target the specific topics and maybe the new message concepts (for some motorists). Any new method of using the VMS will be an extension to existing known traffic management information systems and should present no real problem for motorists to understand. The important items are that the information is correct and credible and that the motorists take heed of the information presented to assist with the incident management strategy.

Typical general type VMS messages relating to travel time and delay time could be:-

- Related to additional travel time "ACCIDENT AT COOMERA"
"CONGESTION AHEAD"
"LOGAN RIVER 50 MINUTES"

• Related to delay time	"ACCIDENT AT COOMERA" "CONGESTION AHEAD" "EXPECT MINOR DELAYS"

Looking at the particular case of an incident on the northbound motorway traffic lanes, with diversions in place as part of the Incident Management Plan, typical VMS messages may be:-

• At the Coombabah VMS (network type message) This message alerts motorists to conditions ahead	"ACCIDENT AT COOMERA" "CONGESTION AHEAD" "PROCEED WITH CAUTION"
• At the Coomera VMS (incident message) This message may induce traffic to divert	"ACCIDENT 1KM AHEAD" "REDUCE TRAVEL TIME" "DIVERSIONS IN PLACE"
• Alternative for Coomera VMS (incident message) This message will induce traffic to divert	"ACCIDENT 1KM AHEAD" "EXPECT MAJOR DELAYS" "DIVERSIONS IN PLACE"

Delay times have been rated according to the severity of the delay. Some research has been conducted into this area with some inconclusive results. Again it is a balance of a few elements (including the way the message is interpretated by motorists) and then coming up with a workable solution. Some practical examples, used by the Department of Main Roads (Traffic Management Centre), would include:-

- Message says "EXPECT DELAYS" could mean delays of up to 15 minutes;

- Message says "EXPECT MINOR DELAYS" could mean delays of 15 minutes – 30 minutes;

- Message says "EXPECT MAJOR DELAYS" could mean delays of more than 30 minutes.

In order to further effectively manage incident-induced traffic queues, there may be a need for control feedback strategies, which effectively react to real-time measurements without ever explicitly predicting or measuring any system disturbances. These can be efficient and effective. There are vehicle detector loops at all the off ramps exiting from the motorway and these could be used for vehicle counting and then sending this data back to the STREAMS Traffic

Management System for data analysis to gauge the rate of traffic diversion. In addition, the CCTV on the Coomera Interchange can be pointed to view the northbound off ramp diversion traffic flows and some judgements can be made on the traffic volumes, on whether there is too much or not enough traffic diverting from the motorway.

3.8.1 Influences of Other Motorway Variable Message Signs (VMS)

As mentioned above, there is one VMS for northbound traffic just north of the Coomera River. There are a total of six VMS on the northbound carriageway of the Pacific Motorway from Tugun to the Logan River. These are located in the areas of Tugun, 19^{th} Avenue (Palm Beach), Nerang, Coombabah, Coomera and Yatala. Southbound there are four VMS, which are located at Logan River, Pimpama, Helensvale and Gaven. All of the available VMS can assist with incident traffic management in some small way.

In times of an incident, for assistance of incident – induced traffic queue management, the next VMS upstream could be used to manage traffic. This northbound VMS, located at Coombabah, may be of limited value with a short traffic diversion plan (30 minutes or less) in place. This is because this VMS may be too far away to effectively assist with incident induced traffic queues from an incident north of Coomera Interchange. But, for network management, it could be effective. The effects of a short duration type of incident would not really reach this far. However, in the event of an incident with a duration of 60 minutes, then this VMS could be used to assist with traffic management. Even then, its use could be beneficial coming towards the end of the incident, where incident induced traffic queues would be large. There are two interchanges between the Coombabah VMS and the Coomera VMS where decisions could be made by motorists with regard to changing their travel route due to an incident.

The southbound traffic flows would also most likely be affected by an incident on the opposing northbound lanes. There is a proven human behaviour phenomenon known as "rubber necking" which has detrimental effects on traffic flows in the other direction. This leads to differential speeds of vehicles and weaving between lanes thus creating conditions for another traffic incident. This is undesirable, particularly if there is a small queue forming in a slightly "hidden" area of the Motorway, with traffic approaching, unaware of traffic conditions ahead. Thus some advance warning of any change in traffic conditions ahead is a positive gesture and would be beneficial to the travelling public. Viewing the CCTV will confirm the need for a VMS message. The southbound VMS at Pimpama could be used to display a generic type incident safety warning message like:-

- "CHANGED TRAFFIC CONDITIONS"
  "2 KM AHEAD"
  "PROCEED WITH CAUTION"

This would be deemed sufficient for some advanced pre warning for southbound motorists for any adverse traffic conditions, that is, "rubbernecking", which may be occurring ahead.

3.9 Analysis of Accident Data

The location of incidents on the Pacific Motorway is reasonably spread throughout the 43 km of the dual four lane section of the motorway from the Logan River to Nerang. The purpose of this analysis of accident data was to try and locate a specific location with a high frequency of accidents. This location would then be used to model traffic flows for the microsimulation experiments for this research. The findings below are the result of an intense study of approximately 1573 data entries for incidents as recorded by the Incident Response Unit (IRU) on the STREAMS (Syngerised Traffic REsponse Area Management System) traffic management system used in the Department of Main Roads Traffic Management Centre in Nerang.

The IRU is a mobile vehicle unit that attends traffic incidents. The roles and responsibilities of the unit include:-

- Rapid response;
- Traffic management at accident and other incident scenes;
- Removal of hazards or installation of warning devices;
- Assistance to stranded motorists;
- Documentation for infrastructure damage cost recovery;
- Promotion of Main Roads as a responsible and responsive agency.

Typical tasks of the unit include:

- Provision of a delineated incident precinct with traffic control devices that pre-warn and give emergency direction to approaching traffic for a safe, controlled and efficient passage through the incident precinct;

- Providing Emergency Services and affected member of the public with a safer environment for the duration of the incident;

- Cooperating with Emergency Services and other agencies to minimise the duration of an incident and its effect on traffic flows;

- Reducing consequential delays by using traffic management techniques to re-open lanes earlier than would otherwise be possible;

- Removing non-accident debris (where safe to do so) before it causes an incident;

- Assisting the Traffic Management Centre in providing incident management information to road users and emergency services;

- Collecting details and photographs for infrastructure cost recovery;

- Improving external stakeholders image of Main Roads as a valued contributor to incident management.

As can be seen from the data presented below, traffic accidents form a major part of the IRU's callouts for attendance, with then approximately another half that number to attend debris related hazards on the Pacific Motorway. A rough calculation would show that the IRU attends approximately 13 callouts per week or nearly two a day. The other types in the table below mostly refer to providing assistance to police with their investigations and operations (events not specifically related to traffic type incidents that is, hold ups, gathering / providing data and so on).

Table 3.11 All callouts attended by the Incident Response Unit in Main Roads South Coast Hinterland District for all state declared roads in the district for the period 01/01/04 – 30/06/06

Type of Callout	Number of Callouts
Accidents	895
Animal related	19
Fire related	56
Hazards - Debris	453
Hazards - Vehicle	8
Motorist Assistance	63
Police Investigations	40
Flood related	4
Cleared prior arrival	21
Other	14
TOTAL	1573

Table 3.12 All traffic accident callouts attended by the Incident Response Unit on the Pacific Motorway (Logan River to Tugun) for the period 01/01/04 – 30/06/06

Section of Pacific Motorway	Number of Traffic Accidents
Logan River to Pappas Way, Nerang	272
Pappas Way, Nerang to Tugun	145
TOTAL	417

The section of the Pacific Motorway south of Nerang currently is a four lane divided carriageway, with two traffic lanes northbound and two traffic lanes southbound separated by a median. It provides a much lower level of service but still provides a reasonable number of accidents (approximately 35%). This road corridor layout is different to the eight lane divided Pacific Motorway from the Logan River to Smith Street which has smooth grades and alignments. From Smith Street to Pappas Way, Nerang, the six lane part of the motorway still maintains a high level of service of motorists.

Table 3.13 All traffic accident callouts for Incident Response Unit according to general area for Pacific Motorway (Logan River to Pappas Way, Nerang) and for the period 01/01/04 – 30/06/06

General area	Number of Callouts
Beenleigh	14
Yatala	21
Ormeau	20
Pimpama	48
Coomera	20
Oxenford	33
Helensvale	13
Coombabah	1
Gaven	43
Nerang	59
TOTAL	272

Table 3.14 Traffic Flow direction directly affected by all traffic accidents for Pacific Motorway (Logan River to Pappas Way, Nerang) for the period 01/01/04 – 30/06/06

Traffic Flow direction	Number of Traffic Accidents
Northbound	142
Southbound	130
TOTAL	272

Table 3.15 Table indicating lanes affected by traffic accidents and duration of the relevant traffic accident for Pacific Motorway (Logan River to Pappas Way, Nerang) (both directions) and for the period 01/01/04 – 30/06/06

	1 lane affected	2 lanes affected	3 lanes affected	4 lanes affected	TOTAL
< ½ hour duration	48	5	0	0	53
½ hour – 1 hour duration	86	25	1	0	112
1 hour – 1 ½ hours duration	37	26	5	0	68
1 ½ hours – 2 hours duration	9	7	1	1	18
> 2 hours duration	9	9	1	2	21
TOTAL	189	72	8	3	272

Note: Lanes affected refers to an impact on that traffic lane from a traffic accident – it does not necessarily indicate a lane closure

Table 3.16 Table indicating lanes affected by traffic accidents and duration of the relevant traffic accident for Pacific Motorway – Pimpama and Coomera areas (both directions) and for the period 01/01/04 – 30/06/06

	1 lane affected	2 lanes affected	3 lanes affected	4 lanes affected	TOTAL
< ½ hour duration	9	0	0	0	9
½ hour – 1 hour duration	10	24	1	0	35
1 hour – 1 ½ hours duration	5	8	0	0	13
1 ½ hours – 2 hours duration	1	1	1	0	3
> 2 hours duration	5	2	1	0	8
TOTAL	30	35	3	0	68

Note: Lanes affected refers to an impact on that traffic lane from a traffic accident – it does not necessarily indicate a lane closure

Table 3.17 Time periods for traffic accidents on the Pacific Motorway (Logan River to Pappas Way, Nerang) for the period 01/01/04 – 30/06/06

Time period	Number of Traffic Accidents	Time period	Number of Traffic Accidents
00:00 - 1:00	0	12:00 - 13:00	20
1:00 - 2:00	2	13:00 - 14:00	21
2:00 - 3:00	2	14:00 - 15:00	21
3:00 - 4:00	3	15:00 - 16:00	18
4:00 - 5:00	3	16:00 - 17:00	15
5:00 - 6:00	5	17:00 - 18:00	18
6:00 - 7:00	16	18:00 - 19:00	22
7:00 - 8:00	20	19:00 - 20:00	6
8:00 - 9:00	17	20:00 - 21:00	6
9:00 - 10:00	13	21:00 - 22:00	3
10:00 - 11:00	16	22:00 - 23:00	6
11:00 - 12:00	16	23:00 - 24:00	3

The above table gives an indication of the occurrence of accidents based on time periods. It is worthy to note that the number of accidents appears to be of a reasonably low rate in the night off-peak time period, say, 7:00 pm to 6:00 am (approximately 14%) and then high for the rest of the day. For the main daylight part of the day, there appears to be an even spread of the number of accidents per hour, but at a rate 4 to 5 times the night rate of occurrence. By examining the above data further, it could be ascertained that the morning peak traffic time of around 6:00 am to 8:00 am and the afternoon peak traffic time of around 4:00 pm to 6:00 pm give approximately the same number of accidents. However, the morning peak traffic period gives a slightly worst time period for accidents occurring.

Table 3.18 Table showing appropriate lane locations of traffic accidents on the Pacific Motorway (Logan River to Pappas Way, Nerang) for the period 01/01/04 – 30/06/06

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            / \                              |     |
           /   \                             |     |
          /     \                            |     |
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			N	B					S	B		
	Shoulder	Lane 1 Slow	Lane 2	Lane 3	Lane 4 Fast	Median		Lane 4 Fast	Lane 3	Lane 2	Lane 1 Slow	Shoulder
Beenleigh		2			4	2		1			5	
Yatala	1	4	2		6	1	1	5			1	
Ormeau	1	3			5	3	3	1			2	2
Pimpama	2	9	3		6	2	1	8	2		9	6
Coomera		3	3		1		2	6	1		2	2
Oxenford	2	9	2	2	4		1	1	1	1	8	2
Helensvale	2	2	1		1		1				3	3
Coombabah								1				
Gaven	6	8		2	8			4	2		8	5
Nerang	6	17	1	2	4		4	2	5	1	14	3
SUB TOTAL	20	57	12	6	39	8	13	29	11	2	52	23
TOTAL			142							130		

From Table 3.18 above, approximately 65% of the accidents appear to occur in Lane 1 and Lane 4 – the slow lane and the fast lane – of both northbound and southbound directions. The number occurring on the shoulders is also worthy of note – being around 16% of the total number. The Lane 4 accidents are most likely related to high speed and the Lane 1 accidents possibly caused by ramp entry and exit traffic, slow vehicles and high speed. Lane 2 accidents are more noticeable for the northbound carriageways of the motorway.

From the above analysis of incident data, a suitable base can be developed for the microsimulation experiments. There is some variance in the shape and form of the incidents, with the majority occurring in one or two through traffic lanes of the motorway. This is partly due to the current low traffic volumes and the number of traffic lanes, giving a low volume to capacity ratio of the traffic lanes. As a significant number of incidents have occurred in Lane 1 (slow lane) and a number in Lane 2, this further adds to the specification for the incident scenarios for further analysis (Refer Table 3.18 above). In addition, by further drilling down into the incident data, the area around Pimpama and Coomera shows the majority of incidents occurring, with a duration of around ½ to 1 hour. Therefore, after consideration of all these elements, the incident scenarios for this research will consist of the following elements (time, location, direction, number of lanes affected and duration):-

- The time of the incidents is in the morning am peak (say 6:30am to 8:30am);
- The area of the incidents is primarily Pimpama and Coomera;
- The direction for incidents is northbound;
- The number of traffic lanes affected is two;
- The incident duration is 30 minutes or 60 minutes.

3.10 Incident-Induced Lane Closures and Queue Lengths from Actual Incidents

The need for a real set of data on lane closures, which are created by incidents, is necessary as a foundation on which to base further research. Since the Pacific Motorway opened on 6th October 2000, there have been many minor and major type incidents. The STREAMS suite of traffic management software manages traffic both on the Motorway and urban arterial roads. As part of this, the event logging module of STREAMS provides information on incidents of both a major and minor type as recorded by the TMC console operator at the time of the incident.

For the scope of this research, the data recorded in STREAMS event logging under the incident type "Major Incident" is a useful reference. This data principally details time of day, location of incident, direction of travel, incident duration and severity along with other relevant incident element particulars. This data, in some aspects, may be highly variable. Console operators have different perceptions of what constitutes a traffic queue, length of queue, severity and type of weather conditions, and these may be reported in various ways. What one operator sees as a queue moving off and starts to flow at a reasonable speed, another operator may see as a queue still being present. By the way, AIMSUN defines the threshold between a queue and a moving traffic stream occurring at a velocity of 4 m/s or around 14.4 km/h, with a queue forming at a velocity around 1 m/s (3.6 km/h).

An analyses of a number of Major Incidents (as reported on the Department of Main Roads Major Incident Database) on the Pacific Motorway (Logan River – Pappas Way) requiring lane closures is given in Table 3.19 below.

Table 3.19 Major incidents occurring on the Pacific Motorway (Logan River – Pappas Way, Nerang)

Major Incident Database Records Date, Time, Location	Start and End Times of Incident	Duration of Incident	Number of Lanes closed	Approximate Maximum Length of Queue
23/08/03 Saturday Albert River Bridge NB	4:40 pm – 6:20 pm pm peak	1 hr 40 min	3 lanes closed	5 - 6 km
17/09/03 Wed Exit 89 Pac Mwy NB	8:20 am – 9:20 am off peak	1 hr	2 lanes closed	3 km
30/09/03 Tuesday Exit 66 Coombabah SB	4:48 pm – 5:35 pm pm peak	47 min	3 lanes closed	5 - 6 km
11/11/03 Tuesday Exit 38 Pac Mwy NB	2:50 pm – 3:40 pm off peak	50 min	2 lanes closed	3 – 4 km
13/04/04 Tuesday Albert River Bridge NB	5:04 am – 6:23 am off peak	1 hr 19 min	2 lanes closed	1.6 km
10/12/04 Friday Pac Mwy Yatala SB	2:41 pm – 4:01 pm off peak	1 hr 20min	2 lanes closed	2 km

14/05/04 Tuesday Exit 54 SB	3:55 pm – 5:00 pm pm peak	1 hr 5 min	2 lanes closed	2 km
26/07/04 Monday Exit 71 SB Nerang	8:35 am – 9:26 am off peak	51 min	2 lanes closed	3.5 km
20/05/05 Friday Ormeau SB	5:30 pm – 7:30 pm off peak	2 hr	1 lane closed	4 km
23/09/05 Friday Yatala NB	12:25 pm – 2:10 pm off peak	1 hr 45 min	2 lanes closed	5 km
11/10/05 Tuesday Peachy Rd Overpass NB	1:45 pm – 3:41 pm off peak	1 hr 56 min	2 lanes closed	5 km
02/05/06 Tuesday Nerang NB	2:50 am – 4:50 am off-peak	2 hours	3 lanes closed, 1 lane open	3 km
24/05/06 Wednesday Logan River Bridge NB	5:45 pm – 7:59 pm off-peak	4 hr 14 min	2 lanes closed, 2 lanes open	6 km
24/07/06 Monday Yatala SB	12:03 pm – 5:55 pm off-peak into pm peak	5 hr 52 min Fatality	Total closure of Southbound lanes	7 km
22/02/07 Thursday Kingsholme Exit 45 NB	4:00 pm – 7:20 pm pm peak into off-peak	3 hr 30 min Fatality	2 lanes closed, 2 lanes open	4 km at 5:00 pm 6 km at 7:20 pm
08/03/07 Thursday Oxenford Fast Diamond Exit 57 SB	Off- peak traffic	1 hr 30 min Cows on Motorway	4 lanes closed NB and 4 lanes closed SB	2.5 km NB and 3 km SB

Some notes on the terminology used in the above table are useful. The "Start and End times of Incident" are particularly relevant. The "Start Time . . . . of Incident" refers to the time when the TMC operator first becomes aware of the incident, either by a motorist phoning with details, routine viewing of the motorway with CCTV's or by notification on the Police Communications Radio Scanner. The current practice is notification by Police Scanner. The "End Time . . . . . . of Incident" refers to the time that the scene is cleared, Emergency Services have left and the road is again open to traffic. This time is usually reported back to the TMC by the Incident Response Officer at the incident site conducting traffic management and control. The "End Time of Incident" is not the time that traffic flows return back to normal, pre-incident conditions. The Incident Response Officer maintains a separate database on the incidents that he attends and provides traffic control for.

Again going back to Table 3.19 above, the column "Duration of Incident" is just the time from the start of the incident to the end of the incident or the time space over which the incident spans. This can also be seen as the time space over which traffic is disrupted. However, in reality, the actual time that traffic is disrupted is much longer than this. The AIMSUN program therefore equates the "Duration of Incident" to the length of time for traffic diversions, making both of these elements the same space in time (that is, same duration).

The "Number of Lanes Closed" refers to the number of lanes that are blocked as a result of the incident. However, this may be different to the number of lanes that are affected by the incident itself. In addition, the opposing traffic lanes may be affected as well (sometimes, they usually are) and this then proceeds to impact on the opposing traffic flow dynamics. However, the effects of this phenomenon will not be studied in this research.

The parameter "Approximate length of queue" is a quantitative description for how far the length of the incident – induced queue was at the worst point in time. This may be close to the end time of the incident, or, at some point after all traffic lanes are open again (post incident). In other words, traffic can still queue while all lanes are open, so the length of queue from the original incident site still may grow. As discussed above, this can vary with console operator, CCTV suitability for viewing, weather and so on. In addition, the exact description for a "queue" has various interpretations, although for the purposes of this research, the "AIMSUN" description for this parameter will be used (using velocity to determine start / end of queueing).

Queue lengths are influenced by incident type and duration. If an incident involves a fatality, then the incident duration is extended by around another hour. This is the time that is usually needed for Police to conduct their investigations and reports. The incidents reported above appeared to be caused by things such as lost loads, nose to tail type accidents, excessive speed, wet weather, broken down vehicles on side of road, vehicles crossing the median into opposing traffic and so on. In addition, there have been a few pedestrian fatalities – either as a pedestrian walking on the motorway shoulder or crossing the motorway (suicide). Pedestrian related type incidents are excluded from the scope of this research. A conclusion of the above data in Table 3.19 can be summarised as outlined below in Table 3.20.

Table 3.20 Summary of queue lengths from actual incidents on the motorway

Actual incident queues for different time periods from Major Incidents database	off peak travel times 8:00 am – 4:00 pm and 5:30 pm – 6:30 am	am and pm peak travel times am peak 6:30 am – 8:00 am pm peak 4:00 pm – 5:30 pm
2 lanes closed	1.0 km – 1.5 km queue	3.0 km – 4.0 km queue
3 lanes closed		5.0 km – 6.0 km queue

This queue propagation data is useful for the validation and calibration of the model for motorway incident related experiments. The above queue lengths appear to be "rubbery" in quantity with some variation of the lengths. Aiming for around the centre (or just above) of this range of queue length limits will generally be acceptable for the modelling. It forms a base on which to use as a datum for all other incident and route diversion type experiments. In this research, queue length is one valid criteria used to calibrate the model.

3.11 Future Motorway Traffic Growth

Traffic growth on the Pacific Motorway, from Logan River to Nerang, is pushed along by residential and commercial developments, with access to the motorway interchanges and service roads. Average Annual Daily Traffic (AADT) is usually the parameter that details traffic volumes. It is the average daily traffic flow taking into account holiday periods, planned events and any other factors which impact on the traffic volumes. The table below details the rate of traffic growth in the study area as part of the Pacific Motorway corridor and is approximate only.

Table 3.21 Traffic growth on the Pacific Motorway (approximate)

Year	Total Northbound AADT	Total Southbound AADT	Total AADT (Total for both directions)	Traffic Growth % per annum (average for NB and SB)
2004	48126	49373	97499	Base year
2005	49954	51249	101203	3.8
2006	52302	53658	105960	4.7

The outcome of this analysis is that congestion will increase, especially with more incidents happening, on length of queues, travel times, stop rate and so on. This will lead to an increased focus on managing traffic operations on the Pacific Motorway and surrounding routes, especially during incidents. The rate of the increase in these traffic parameters, in incident times, can be expected to increase, along a similar magnitude to the rate of increase in traffic growth as detailed above.

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CHAPTER 4

Modelling

4.1 General Remarks

Traffic simulation is a computer-based method that models dynamic traffic flows over a given time horizon for a given facility. Traffic simulation models can be applied to study complex situations when analytical approaches may not be appropriate or to test alternative scenarios in a computer, without touching the actual system. Due to these major advantages, microsimulation has become an essential tool in traffic operational analyses. Interchanges are critical elements of an arterial or motorway network by connecting various facilities to ensure a safe and efficient operation. The operation of an interchange with two closely spaced intersections is complicated due to the existence of interacting queues, composition of traffic, intensive weaving and unbalanced lane utilisation due to particular turning movements. There are numerous microsimulation packages available commercially which can analyse any given traffic related scenario, however, for this research, the AIMSUN microsimulation package will be used.

4.2 AIMSUN Traffic Microsimulator

Transport Simulation Systems (TSS), which are located in Spain, are the developers of AIMSUN NG which is a fully integrated suite of traffic and transportation analysis tools. It can be used for transport planning, microscopic simulation and demand and dynamic modelling. AIMSUN is a microscopic traffic simulator that can deal with different traffic networks, freeways, highways, arterials and any combination thereof. It is very useful for testing new traffic control systems and policies, based on traditional technologies or as a tool for the implementation of Intelligent Transport Systems (ITS).

AIMSUN follows a microscopic simulation approach. This means that the behaviour of each vehicle in the network is continuously modelled throughout the simulation time period while it travels through the traffic network, according to several vehicle behaviour models (for example, car following, lane changing, gap acceptance). The system provides highly detailed modelling of the traffic network, and distinguishes between different types of vehicles and drivers, while enabling a wide range of network geometries to be dealt with, and it can also model incidents, conflicting manoeuvres, and so on (TSS 2004).

Traffic Management strategies can be tested in AIMSUN as well, including rerouting of traffic (by origin, or by destination, or by vehicle type), lane closures and incidents. The activation of these actions can make evaluation of different management strategies more meaningful and able to be used by other expert systems. The simulator is able to model the driver's reasoning for route selection, before and during the trip. It includes four different algorithms to model dynamic route choice, a function editor to allow the specification of cost functions, and the option of considering the costs from historical routes and / or considering the driver's memory. Drivers will use different criteria: from always sticking to the same path to changing their path according to advice from a guidance system or the traffic conditions (TSS 2004).

A form of output from AIMSUN is system statistics, generated and collected by AIMSUN, which can be used to determine the performance of a particular methodology in order to gauge the effectiveness of the system. The statistical output may include data on speed, flow, travel time, delays, number of stops, along with detector type output on traffic counts, occupancy and speed. All of which can be stored in a database and used at any time.

4.3 Selection of Incident Scenarios

The selections of the incident scenarios to be studied are detailed in the Chapter "Material and Methods", where accident statistics and other data were examined to arrive at some particular incident scenarios which can be modelled. Chiefly, two incident scenarios will be examined in this research. This will include the following incidents:-

- 30 minute incident blocking two motorway traffic lanes, and;
- 60 minute incident blocking two motorway traffic lanes.

The rate of the gradual degradation of the level of service, induced by an incident, and then the consequent recovery of the traffic flows back to "normal" will be assessed to give some indication of the impacts on traffic flows. Diversion route capacity will also be examined and various traffic parameters relating to diversion routes will be studied. This could also be used to possibly predict the traffic flows under future similar type incident scenarios at similar locations on the motorway (areas with the same environment and traffic situation as in this research).

4.4 Methodology of Building the AIMSUN model

A step by step method of building an AIMSUN model comprises the following steps:-

(a) Formulate the problem and plan the study, determine the requirements and outcomes;
(b) Collect the data and build the model;
(c) Check whether the model is a valid representation of the system for the purposes of the study – checking the validity of model;
(d) Conduct the pilot runs and examine the results;
(e) Check the computer model performs correctly and gives acceptable results;
(f) Design and conduct experiments – production runs - using good sampling of results that will provide the expected answers;
(g) Conduct simulation experiments and analyse outputs.

In keeping with the above model-building process, the large scale final network was not built straight away. The process for this research included stepping the assembly of the final network. This included firstly building a small model (preliminary model) to run to gain some basic results and data (pilot runs) and understanding of the effects of some particular traffic elements and then slowly progressing to the larger model (final model for production runs). Two main models were constructed using the above approach:-

1. Straight section of motorway (Preliminary model);

2. Full motorway network of the Coomera / Yawalpah area including on/off ramps, interchanges and diversion routes (Final model)

The final model was validated using traffic flows and then calibrated using travel time, speeds and queue lengths (from real-time incidents).

4.5 Development of AIMSUN Microsimulation Model

This section entails the creation and development, validation and calibration of the traffic simulation model for the Pacific Motorway, from Coomera Interchange to the Yawalpah Interchange. The AIMSUN model was developed using the following tasks:

<u>Task 1: Collation of Data for Road Network Coding</u>

This task involved the collation of data for development of the traffic simulation model including digitised maps, raster images, detailed lane configurations, turning movements, road centrelines, visibility distances, traffic control data, location of detectors etc. This data was available from the Queensland Department of Main Roads, Nerang although there was a considerable amount of time spent collating and pre-processing the data before use in the models. This included many field trips to validate the data as some was out-of-date or did not exist. The corridor parameters for the model include the Pacific Motorway from Coomera

Interchange to Yawalpah Interchange and the immediate service roads adjacent to the Pacific Motorway in that area. This AIMSUN model comprised 103 sections, 54 section intersections, 18 centroids and 5 roundabouts.

Task 2: Determination of Traffic Demand Data

This task involved the extraction of traffic demand data from an existing EMME/2 transport planning model for the Gold Coast area for the morning am peak periods and adjusting the matrix using traffic counts and matrix estimation techniques. This was then cross checked with some individual traffic volume count data at specific locations. The original Origin – Destination (OD) matrix, which comprised 13 EMME/2 zones, was grouped into 4 zones based on the proximity of the zones to the subject research area. The EMME/2 model provided both 2 hour and 15 minute OD matrices for private vehicles and trucks for the am peak (07:00-09:00) period (Acknowledgement to UQ ITS Laboratory for assistance with this task).

Task 3: Network Coding and Data Input

This task involved a detailed coding of the road network including road sections and elements, traffic demand on the network, and so on. There was more detailed coding of the network which included the collation of detailed lane configuration, turning movements, road centrelines and so on. This task also involved further coding of the road network including adjustments to road sections and elements and traffic demand on the network. Approximately 4.61 kilometres of the Pacific Motorway and approximately 42 kilometres of service road layout were coded using raster images. The coding also involved two major interchanges on the motorway. The completed coded network, and associated raster images, is presented in Appendix A, Figure A1.

Task 4: Traffic Modelling

This task involved determining the AIMSUN global and local parameters and verification of the model's operation including checks on allowable turns, link connectivity, infeasible paths, undefined turnings and other traffic operations elements. Further examination of the AIMSUN global and local parameters was needed to produce results for modelled traffic counts and travel times, which were in close agreement with field data. The task involved the collation of data required for model calibration such as field traffic counts and travel time surveys from the Department's traffic census CD. A number of replications and statistical tests were applied to ensure statistical reliability of results (by using 4 – 5 replications of the model). This task also included verification of the model's operation including checks on link connectivity, infeasible paths, undefined turnings, lost vehicles etc.

Task 5: Model Validation and Calibration

This model building process extends through to a calibration and validation process with the aim of enhancing the accuracy of the model in replicating field conditions. The task is to first develop the microscopic traffic simulation model for the motorway and then to include additional service roads, detailed lane configurations, turning movements and then to make any necessary further adjustments to arrive at a validated and calibrated model. The above set of tasks aligns to the documented process of building a model as outlined in section 4.4 above. The other points listed below form further detail for the model building process.

The model calibration involved examining a large number of parameters including car following, lane changing, speed acceptance and other parameters as described below:

- Car Following Model

The car following models implemented in AIMSUN are based on the Gipps model. This entails vehicles accelerating to achieve the desired speed and then decelerate when drivers have to avoid a collision while trying to maintain the desired speed. The maximum speed depends on acceleration (Case 1). The speed is also influenced by vehicle characteristics and the limitation imposed by the leader vehicle (Case 2). The maximum desired speed during simulation is the lower value of returned by Cases 1 and 2.

- Reaction time

Reaction time in AIMSUN plays an important role in car following behaviour. Reaction time parameters of 0.5, 0.65, 1.0 second were investigated and traffic flow and speed data was obtained to evaluate network performance based on each of these settings. The simulation step is the time cycle for the model to update itself regarding vehicle parameters, road and traffic elements. This is seen to more closely represent real time behaviour. By using a multiple of the simulation step for the reaction time and reaction time at stop, the give way, gap acceptance, lane changing and car following components, the simulation model appears to work better resulting in a more complete outcome.

- Impacts of Slope

The slope (gradient) of all sections in this model is usually included to reflect field conditions. This could be important because the car following models in AIMSUN take the slope into consideration. However, for this research, the gradients for the network sections were not coded. As the Motorway is of a reasonable, relatively "flat" type gradient (slopes around 1.0% – 1.7%) the benefits of the extra section details was questionable.

- Speed at Section

The car-following model in AIMSUN runs such that a leading vehicle, i.e. a vehicle driving freely without interference from other vehicles, would try to drive at its maximum desired speed. Three parameters are used to calculate the maximum desired speed of a vehicle while driving on a particular section. Two are related to the vehicle (maximum desired speed of the vehicle, speed acceptance of the vehicle) and one to the section (speed limit of the section). The maximum desired speed of all vehicles/types was assumed as a normal distribution.

- Speed Acceptance

This represents the degree of acceptance or compliance with speed limits. A value greater than 1 means that the vehicle will take as maximum speed for a section a value greater than the speed limit, while less than 1 means that the vehicle will use a lower speed limit. Speed acceptance for all vehicle types was assumed as a normal distribution, and applied for both types of vehicles. Accordingly, when the vehicles reach the speed limit at a section, some will drive at the exact speed limit, some will use a lower speed while aggressive drivers will exceed the speed limit (where or when they want to overtake a slower vehicle).

- Calibrated Model Parameters

In the simulation, two different types of vehicles including cars and heavy vehicles were modelled in accordance with the EMME/2 OD matrices. The properties of vehicles which were used in the calibration are presented in Tables 4.1 and 4.2. Table 4.3 lists the calibrated parameters for the Pacific Motorway model.

Table 4.1 Vehicle properties for vehicle type "car" (AIMSUN default car vehicle)

Attributes	Mean	Deviation	Min	Max	Units
Length	4	0.5	3.4	4.6	Metres
Width	2	0	2	2	metres
Max desired speed	110	10	80	150	km/hr
Max acceleration	3	0.2	2.6	3.4	m/s^2
Normal deceleration	4	0.25	3.5	4.5	m/s^2
Max deceleration	6	0.5	5	7	m/s^2
Speed acceptance	1.1	0.1	0.9	1.3	
Min distance to vehicles	1	0.3	0.5	1.5	metres
Give way time	10	2.5	5	15	Seconds
Guidance acceptance	45	10	65	90	%

Table 4.2 Vehicle properties for vehicle type "truck"

Attributes	Mean	Deviation	Min	Max	Units
Length	7.5	2	6	10	metres
Width	2.3	0.5	1.9	3	metres
Max desired speed	85	10	70	100	km/hr
Max acceleration	1	0.5	0.6	1.8	m/s^2
Normal deceleration	3.5	1	2.5	4.8	m/s^2
Max deceleration	5	0.5	4	6	m/s^2
Speed acceptance	1	0	1	1	
Min distance to vehicles	1.5	0.5	1	2.5	metres
Give way time	50	20	30	80	Seconds
Guidance acceptance	80	10	70	90	%

Table 4.3 Calibrated model parameters

Simulation parameter	Unit	Initial value/version	Remarks
Global modelling parameters			
Simulation step	seconds	0.65	Calibrated value
Driver's reaction time	seconds	1.3	Calibrated value
Reaction time at stop	seconds	1.3	Calibrated value
Driver's behaviour models			
• Car-following model		Version 4.2	
• 2-lane car-following model		Applicable	
• Lane-changing model			
- Percent overtake	%	90	Default value
- Percent recover	%	95	Default value
Route choice model		Travel Time	With default parameters
Vehicle arrival type		Exponential	
Local modelling parameters			
Speed limits			
• Freeway	km/hr	110	As shown in model
• Service Roads	km/hr	70	As shown in model
Capacity			
• Motorway	veh/hr/lane	2100	Default value

• Service Road	veh/hr/lane	900	Default value
Visibility distance	metres	25	Default value
Distance Zone 1	seconds	20-25	Calibrated
Distance Zone 2	seconds	5-15	Calibrated

The motorway and service road model were calibrated using traffic counts from loop detector sites (traffic counting sites) on the motorway and using intersection counts at the roundabouts on the service road network. The calibration results are shown in Table 4.4. They show that the overall error of the models is less than 5 percent which is a good result considering the network under consideration.

Table 4.4 Calibration results

Period	% Error
am	5 % Northbound and 4 % Southbound

The calibrated motorway model was then validated using three methods. The average speeds were collected from loop detector sites on the motorway with the data being extracted from the STREAMS traffic management system. In addition, the length of real time incident-induced queues were also used to validate the model (refer discussion in Section 3.10). The use of this validation parameter could be questionable as the field data / console operator reports may have some inconsistencies. In any case, they provide useful data but may need to be used with caution. The travel times for the motorway were also used for validation. The validation results are presented in Table 4.5 and show that the freeway model's validation error was below 10 percent, which is a typical benchmark for error reporting. However, this is a small network and as such a very small variation in errors would typically be expected.

Table 4.5 Validation results for motorway model based on lengths of incident-induced queues

Period	% Error
am	8.3

The traffic counts, speed and travel time validation results are presented in Table 4.6. These results show overall travel time errors of around 1.2% percent and speed errors around 2.0% percent. All of these errors are reasonable and acceptable given the small scale of the model coverage and also given the random nature of traffic. It should also be mentioned here that the travel times and speeds for this validation were from the year 2004, as that was the latest available information on the Department of Main Roads Traffic Census CD. It is very likely that the results will be different if validated on similar data from 2006.

Table 4.6 Motorway model validation results

Period	Speed	Travel Time
am	2.0% Error	1.2% Error

It should be emphasised here that the calibration and validation results for the motorway and service roads are within the expected ranges. A number of studies in the literature have reported similar results and showed better accuracy for motorway models compared to arterial roads. This can be attributed to the controlled access characteristics of the motorway and the rather random nature of traffic on the service roads due to interruptions from property accesses, parking activity, different trip purposes and so on.

The results reported in this section show that the model provides an accurate representation of field conditions and its accuracy is consistent with findings reported for similar scale models. These results provide a very good degree of confidence in the model's ability to replicate field conditions and its suitability for modelling traffic management on the motorway and adjoining service roads under free flowing traffic and incident-induced traffic.

4.6 Choice of Car Vehicle Type

As part of the modelling process, an experiment can be made using the car vehicle types to determine if any parameters need to be changed. This is done in order to assist with calibration of the model and helps to determine if the standard default car vehicle type is sufficient. This is part of the calibration exercise and entailed the simulation of car vehicles running along a pilot test bed experiment and evaluating their particular performance.

There were three car vehicle types used for calibration in this research which were obtained from various sources. The three car vehicle types included the following:-

- Default car vehicle type from AIMSUN;
- Car vehicle type as used by the Department of Main Roads;
- Car vehicle type as used by NZ Transit in New Zealand.

The parameters for the individual properties of each of these car vehicle types are detailed in the following tables.

Table 4.7 Department of Main Roads car vehicle parameters

Name	Mean	Deviation	Min	Max	Units
Length	4.00	0.00	4.00	4.00	metre
Width	2.00	0.00	2.00	2.00	metre
Max Desired Speed	110.00	5.50	99.00	121.00	km/h
Max Acceleration	2.80	0.56	1.68	3.92	m/s2
Normal deceleration	4.00	0.40	3.20	4.80	m/s2
Max deceleration	6.50	0.65	5.20	7.80	
Speed Acceptance	1.05	0.05	0.95	1.16	
Min Distance Veh	2.00	0.10	1.80	2.20	metre
Give Way Time	30.00	3.00	24.00	36.00	seconds
Guidance Acceptance	0.00	0.00	0.00	0.00	%

Table 4.8 NZ Transit car vehicle parameters

Name	Mean	Deviation	Min	Max	Units
Length	4.00	0.00	4.00	4.00	metre
Width	2.00	0.00	2.00	2.00	metre
Max Desired Speed	110.00	20.00	90.00	160.00	km/h
Max Acceleration	2.80	0.20	2.40	3.20	m/s2
Normal deceleration	4.00	0.20	3.60	4.40	m/s2
Max deceleration	8.00	0.20	7.40	8.60	
Speed Acceptance	1.05	0.05	0.95	1.20	
Min Distance Veh	1.00	0.10	0.70	1.30	metre
Give Way Time	30.00	10.00	10.00	50.00	seconds
Guidance Acceptance	0.00	0.00	0.00	0.00	%

All the car vehicle parameter magnitudes are very similar, with only some minor differences. This is apparent in the area of the acceleration and deceleration data and some other standard deviations. The "Give Way Time" differences are interesting. This parameter is principally the time for gap-acceptance in a give way or stop situation at an intersection or lane changing with merging traffic situations with motorway on-ramps. When a vehicle has been at a standstill for more than this Give-way Time, it will become more aggressive and will reduce the acceptance margins. The AIMSUN default car vehicle is an average type car, meaning its parameters suit both urban, congested conditions and motorway free running conditions.

In addition, the model was calibrated using travel times and speed data. This was achieved by using documented Travel Time and Speed Survey data for the Motorway from Foxwell Road Interchange to Yawalpah Road Interchange (4.783 km) which were conducted in August 2004.

Table 4.9 Comparison of simulated vehicle travel time and speed with documented travel time and speed

Northbound am peak Coomera Interchange to Yawalpah Interchange	Documented Travel Time and Speed survey results – am peak	AIMSUN default standard car vehicle – simulated travel time and speed	Department of Main Roads car vehicle – simulated travel time and speed	Transit NZ car vehicle – simulated travel time and speed
Travel Time	170 seconds	169.4 seconds	167.3 seconds	168.6 seconds
Speed	102 km/h	102.5 km/h	103.7 km/h	103.0 km/h

Therefore, any of the chosen car vehicle types simulates the actual traffic conditions with a high degree of reliability and correlates well with actual recorded data for this scenario (that is, verifies Department of Main Roads data).

Another part of the calibration process looked at queue lengths caused by an incident. Documented queue lengths from data recorded by operators at the TMC provided this data. A similar incident is simulated in AIMSUN and queue lengths examined and compared with the documented data. This also assists with determining the type of car vehicle type to use.

Table 4.10 Comparison of simulated vehicle queue length with documented queue length for incident in am peak

Type of Incident and queue lengths for different car vehicle types	AIMSUN standard car – simulated queue length	Department of Main Roads car vehicle – simulated queue length	Transit NZ car vehicle – simulated queue length
2 lanes closed – am peak	3.431 km	4.701 km	3.535km

Again, the Department of Main Roads car vehicle type gives an excessive simulated queue length, whereas the AIMSUN default car vehicle type and the Transit NZ car vehicle type results in a queue length which aligns reasonably well with the documented data. Now, this simulated result for the am-peak period was compared with the actual queue length for the same incident scenario as shown in Table 4.11 below.

Table 4.11 Comparison of simulated queue length and actual queue length for incident in am peak using AIMSUN vehicle

Incident queues Simulated versus Actual	AIMSUN standard car - simulated queue length	Actual traffic data from TMC Actual queue length
2 lanes closed – am peak	3.431 km queue	approx 3.0 km – 4.0 km queue

The result of this exercise is that the standard AIMSUN default car vehicle type gives a good result using queue length as a calibration measure for the am-peak period. Although the limits of the actual queue lengths are quite sizeable, this result is acceptable for the purposes of this research. This experiment was conducted using just the default standard car vehicle and model parameters to see how the queue lengths might be generated for this time period and then compared with the actual queue lengths recorded from an incident.

4.7 The Use of "Route Based" Simulation

This terminology is part of the AIMSUN microsimulation software for the Route Choice simulation. There are two modes of Route-Based simulation. Fixed and Variable, depending on whether there is only one route from an origin to a destination, or more than one. In the fixed mode, no route choice is needed, as no alternative routes are available. In the variable mode, different parameters are set including assigning vehicles to paths and changing the motorist's behaviour to static or dynamic. In the fixed route mode, vehicles are generated at origins and then assigned to the shortest route to their destination. There are no alternative routes, so the route choice model is not needed. All vehicles follow the shortest path and no decisions about changing to another path can be made during the trip. The fixed-time model works by calculating initial paths during the warm up period and then when this warm up period is over, new initial paths are calculated and these same shortest path trees are used for the simulation.

The AIMSUN microsimulator uses the following steps for a variable route choice model:-

(a) Calculate initial shortest paths for each Origin / Destination (O/D) pair using defined initial costs, then;

(b) Simulate for a predefined time interval, assignment of path probabilities for each O/D pair, then;

(c) Recalculate shortest path considering experimental average link travel times and link cost functions and then identify, from shortest path tree, the new path for the O/D pairs, then;

(d) With guided vehicles, the above information is provided to the motorists (motorists being"guided") and they are allowed to dynamically re-route their trip;

(e) The "Compliance Level Percentage" stipulates that a particular proportion of the motorists may change their trip dynamically as they are "guided" by the shortest path giving a better travel time for their journey.

The variable route choice models were seen to be more complicated than what was needed for this research and therefore the fixed route mode, incorporating the fixed-time mode, was adopted for this research.

The "Compliance Diversion Rate" is a direct percentage of vehicles being diverted from the motorway to the diversion route and is based on many elements and parameters that form part of the microsimulation package, particularly cost, travel times and probabilities.

However, in this research, the diversion route is a much lower standard with a comparatively much lower level of service, leading to lower values of flows and other traffic parameters. This is why in some of the following graphs the results for the diversion route may not appear to be in the correct relationship with the Pacific Motorway results. In addition, the fixed route mode model suggests that at a particular time it is more beneficial to stay on the motorway and not to use the diversion route as the total travel time would be less by staying on the motorway. Thus, with the diversion route capacity restrictions and the workings of the AIMSUN route choice model both giving diverted traffic the lower travel time route, the traffic on the diversion route would be expected to be in close concurrence to the incident compliance diversion rate (that is, 10%, 20% and 30% of motorway traffic on diversion route).

4.8 Model verification by Transport Simulation Systems, Barcelona, Spain.

In order to complete the workings of the Lane Closure and Forced Turning components of the Traffic Conditions part of the fixed route mode part of the AIMSUN model, a copy of the model used for this research was sent to Transport Simulation Systems (TSS) in Barcelona, Spain. TSS is the producers of the AIMSUN microsimulation software suite. TSS Support examined the model, amended a few items, and made a few suggestions with my use of the Traffic Conditions part of the package. They also offered further assistance with the modelling of route choice by using the C-logit methodology, using slightly more complicated elements and parameters. However, the use of the C-logit route choice model is of a slightly higher order than what was needed for this research and the Traffic Conditions methodology was deemed sufficient. Indeed, any further modelling on incident traffic management and route diversions would be undertaken using the C-logit route choice elements.

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CHAPTER 5

Results

5.1 General Remarks

The results from various experiments conducted are presented in this section. The experimentation process consisted of two stages. The first consisting of examining basic motorway behaviour with some motorway experiments being staged (with AIMSUN documenting relevant statistics) and the second drilling down to examine the level of service with some finer detail on traffic incidents, lane closures and diversions (again with AIMSUN recording vital statistics). In addition, the provision of the first level of experiments provides a foundation on which to build the further detailed type experiments in order to deliver specific outcomes including measures of performance. The first level experiments consisted of examining the following scenarios:-

- The effects of a 30 minute incident blocking two motorway traffic lanes, and;
- The effects of a 60 minute incident blocking two motorway traffic lanes.

The experiments consisted of an examination of the following traffic parameters:-

- Average Traffic Speeds;
- Average Travel Time;
- Average Delay Time;
- Number of Stops per Vehicle;
- Average Queue length.

The experiments, of two hours duration, were conducted on the motorway with four traffic lanes in both directions, with the default vehicle types and other standard traffic type parameters. Incidents were then simulated and the effects on traffic noted. The 30 minute incident is from 7:15 am to 7:45 am and the 60 minute incident from 7:15 am to 8:15 am. The level of service of incident induced traffic flows is also examined. The incident site was on the northbound left two traffic lanes, approximately half way between Coomera Interchange and Yawalpah Interchange. The incident site was approximately 300 metres long (includes traffic merge, travel around incident site and then taper back to normal motorway traffic lane layout).

5.2 Basic Motorway Operations in Times of Incident

The first set of experiments looked at the basic motorway segment of four lanes (preliminary model) and staging the above types of incidents and documenting the effects.

- 30 minute incident blocking two motorway traffic lanes

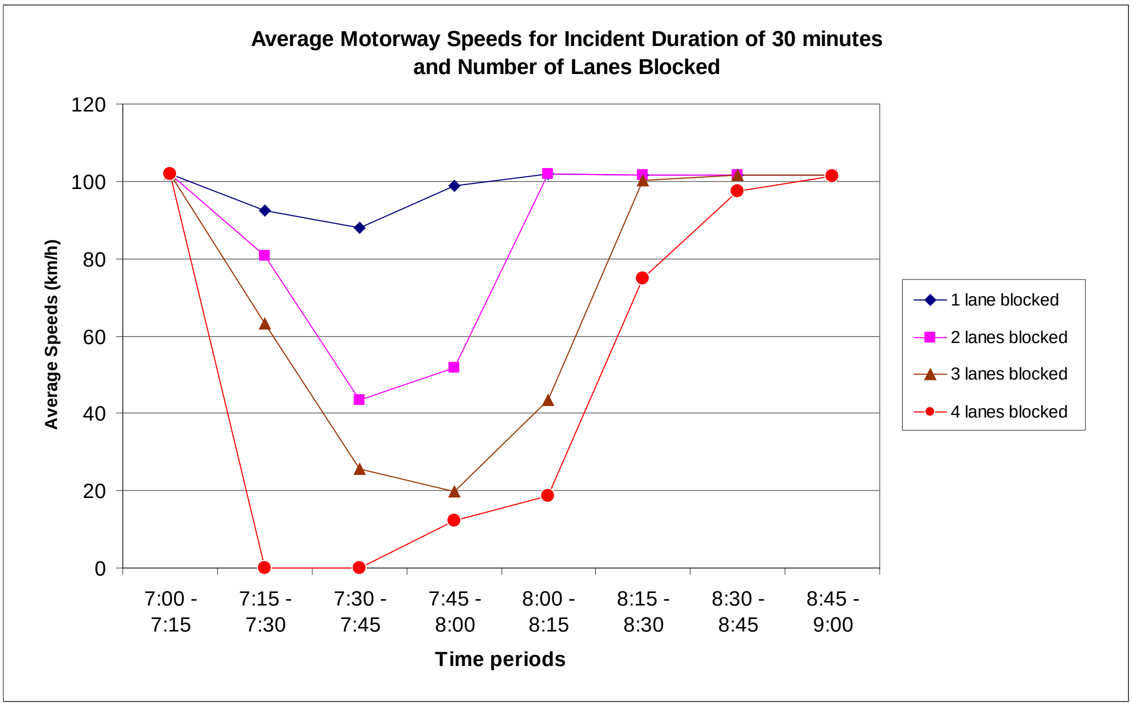

Figure 5.1 The effect of number of lanes blocked for an incident duration of 30 minutes on the average motorway speeds

The above figure shows the effects of a short duration incident on the number of lanes blocked and the average speeds. The effects of an incident on average speeds for the motorway get approximately 40% - 90% worst with the increase in the number of lanes blocked. One lane blocked shows a minimal effect, but from two to four lanes blocked, the effect on average speeds is most noticeable.

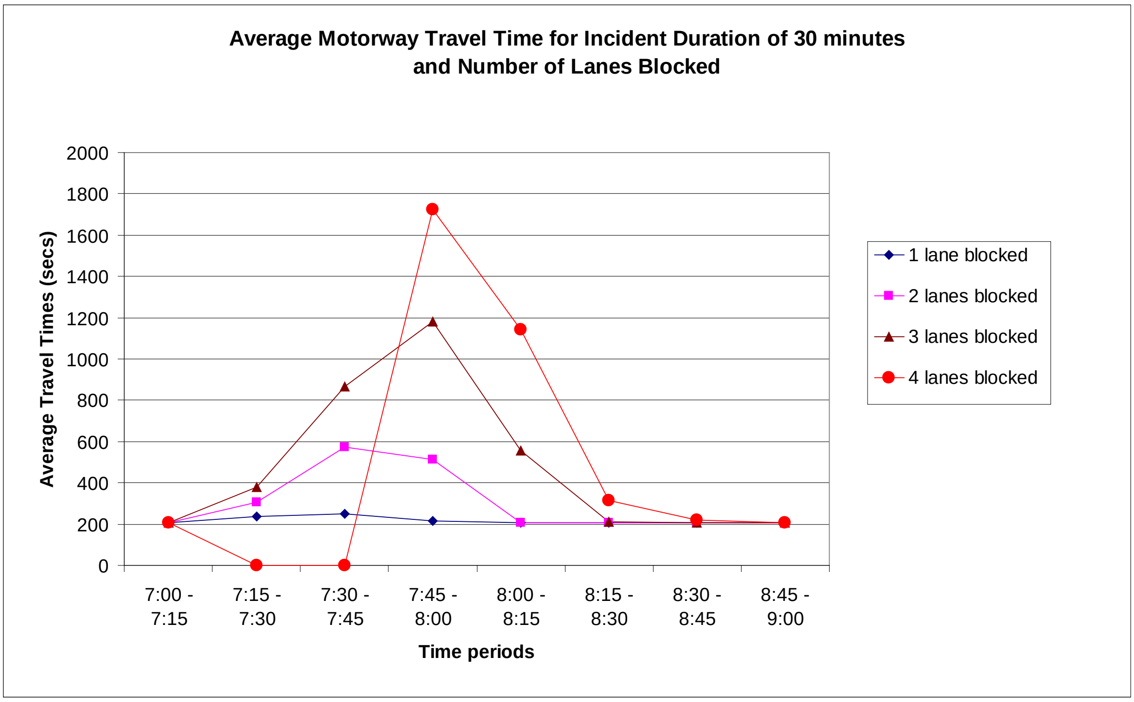

Figure 5.2 The effect of number of lanes blocked for an incident duration of 30 minutes on the average motorway travel time

In the above figure, average travel times for the motorway show a similar increase for each lane closure up to three lanes. The blockage of four lanes shows a negative "shock wave" effect (effectively average travel time slowly ceases to zero) before recovering to a maximum travel time at around 7:52 am. This is due to the incident ending and traffic flows then starting to return to normal with all traffic lanes open. Even with the incident finishing at 7:45 am, there is still an increase in travel times, showing that post-incident congestion remains until, say, 8:15 am (for three lanes blocked).

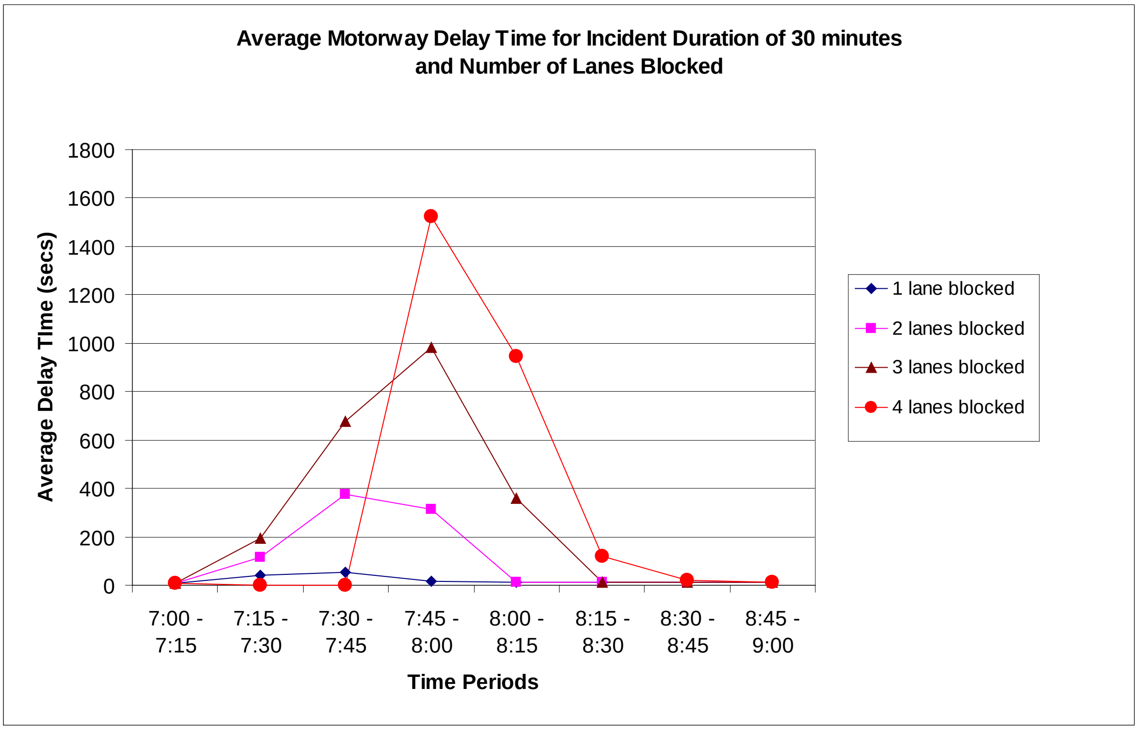

Figure 5.3 The effect of number of lanes blocked for an incident duration of 30 minutes on the average motorway delay time

The figure above shows a progressive increase in average delay time with a particular peak just after the motorway is opened after having four lanes blocked. The closure of four lanes again exhibits a dramatic effect on average delay time on the motorway. Delays for the closure of four lanes are around three times that of the closure of two lanes. Time for recovery (to zero delay time) appears to nearly "mirror" the time taken to reach the maximum average delay times, for all lane closure scenarios, although at a slightly faster rate.

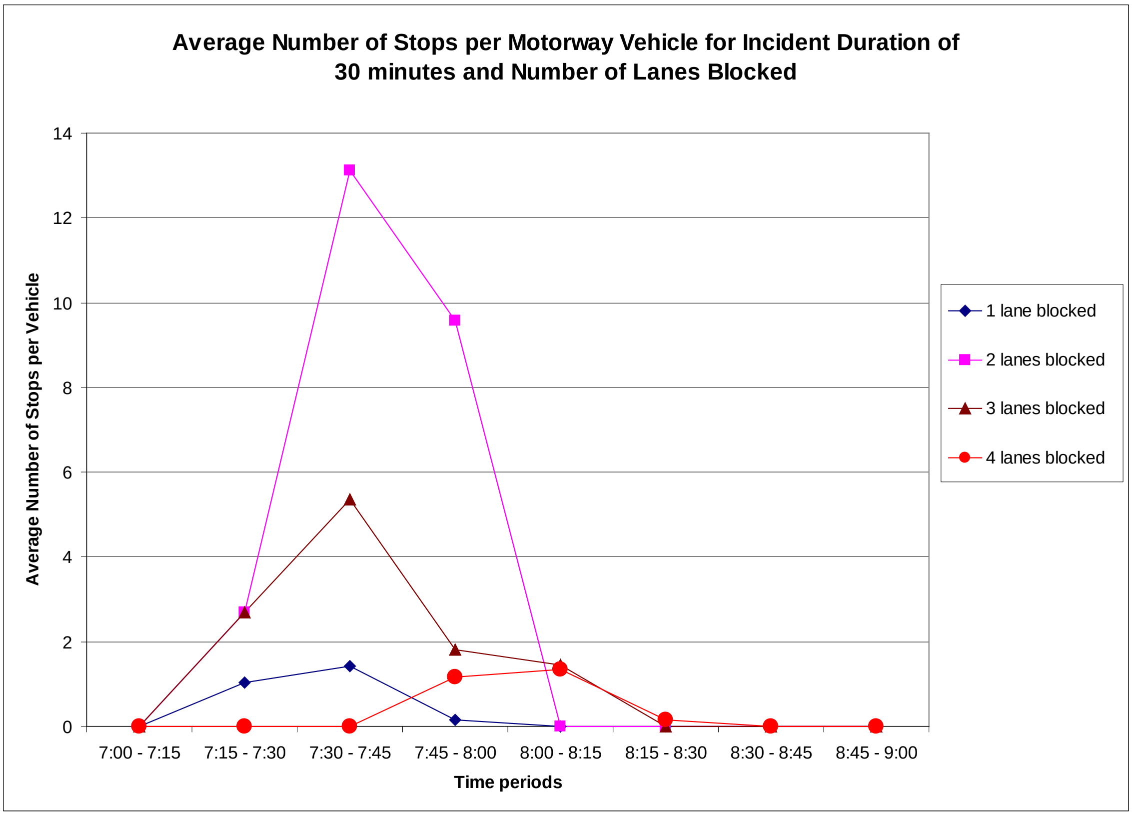

Figure 5.4 The effect of number of lanes blocked for an incident duration of 30 minutes on the number of stops per motorway vehicle

This figure is interesting in that the average number of stops per vehicle with one lane blocked is approximately the same as for four lanes blocked (around 1.8 stops per vehicle). The difference being in the time periods of this occurrence. The blockage of two lanes has around seven times the effect of a blockage of one lane with this traffic parameter. The average number of stops can be related to the lane change traffic manoeuvres made by the motorist and this is influenced by the number of lanes blocked and average speed of the traffic flows. This is shown with two lanes blocked, as the motorist can still change lanes and change his speed thus inducing this maximum average number of stops. With three lanes blocked, the motorist's behaviour changes and there are more opportunities to change lanes and average speeds, thus reducing average number of stops.

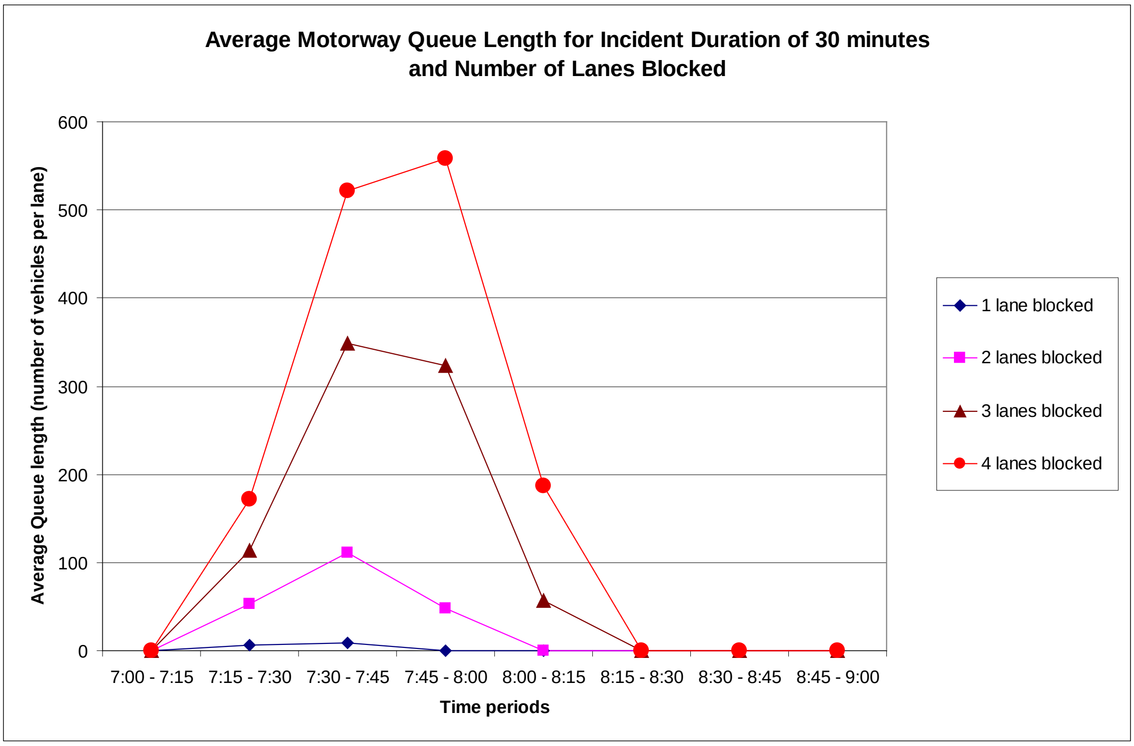

Figure 5.5 The effect of number of lanes blocked for an incident duration of 30 minutes on the average motorway queue length

In the above figure, the progressive increase in average queue length can be seen. AIMSUN reports average queue length in number of vehicles per lane, so a queue length has to be calculated taking into account variations in length and type of vehicles and headways. The rate of growth of the length of the queue is at a maximum, as expected, for a blockage of four lanes – growing to around 540 vehicles per lane in 30 minutes, compared with a closure of two lanes with around 120 vehicles in 30 minutes. There is around four times the increase in queue length from a blockage of two lanes to a blockage of four lanes.

- 60 minute incident blocking two motorway traffic lanes

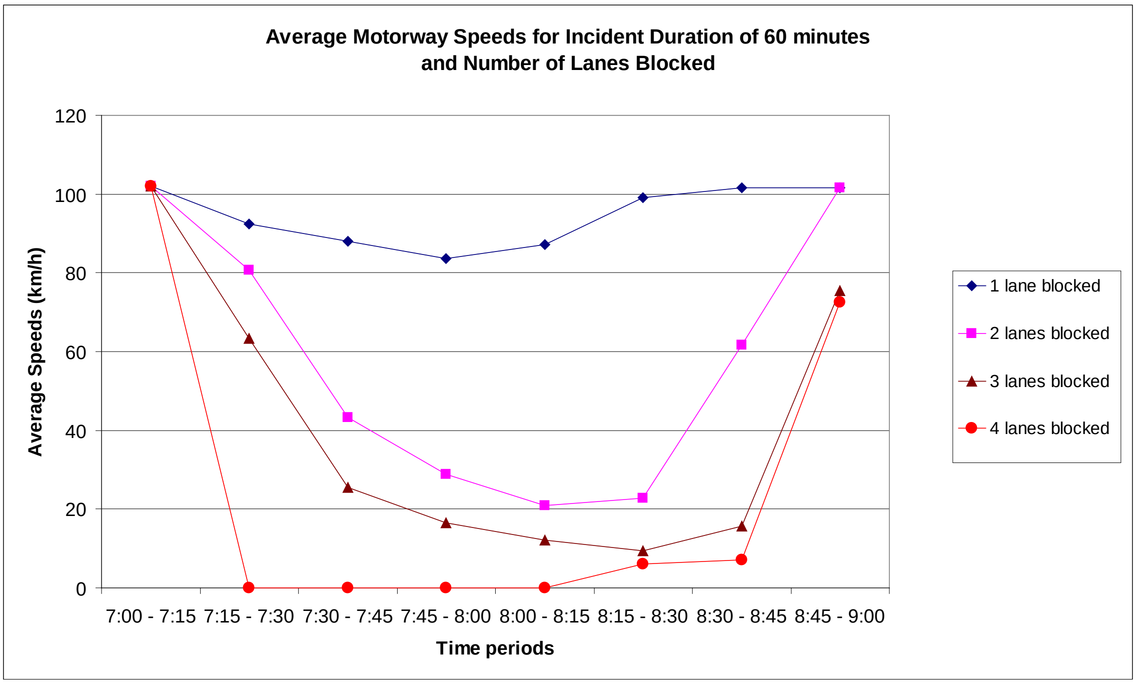

Figure 5.6 The effect of number of lanes blocked for an incident duration of 60 minutes on the average motorway speeds

This figure shows both the slow and rapid decline in average speeds on the motorway, depending on the number of lanes blocked. With an incident of 60 minute duration, the average speeds for the motorway are lower for a longer period, which is due to the incident having a more severe effect. The effects of a 60 minute incident over the 30 minute incident is around twice, with recovery times being around twice as long as well. The data for the particular number of lanes blocked do not appear to indicate a recovery within the two hour time period for the experiment, as shown above. This indicates that recovery back to "normal" pre-incident traffic conditions may take an additional 15 – 20 minutes, for the three and four lane blockages.

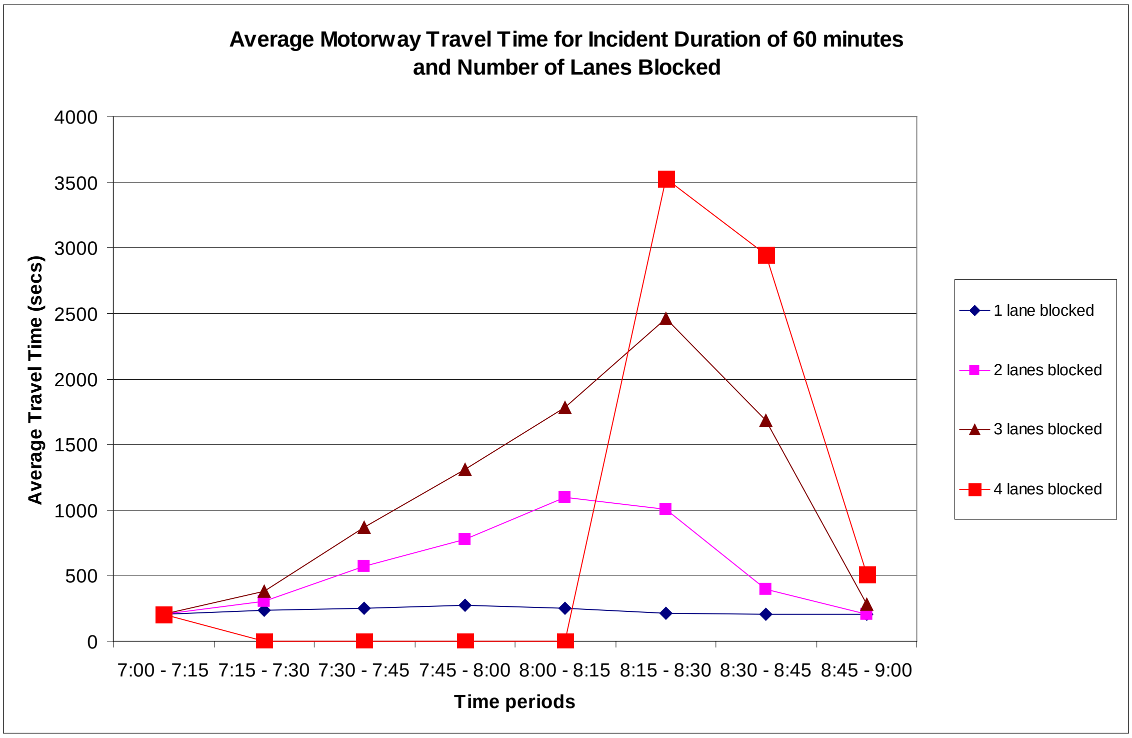

Figure 5.7 The effect of number of lanes blocked for an incident duration of 60 minutes on the average motorway travel time

The effects of a 60 minute incident can again be vividly seen on the above figure. The effects on the travel time just compounds with each successive time period and the number of lanes blocked. The rate of growth of average travel times for three lanes blocked (200 seconds to 1100 seconds) occurs in 36 minutes in a total time period of around one hour (incident duration in this case).

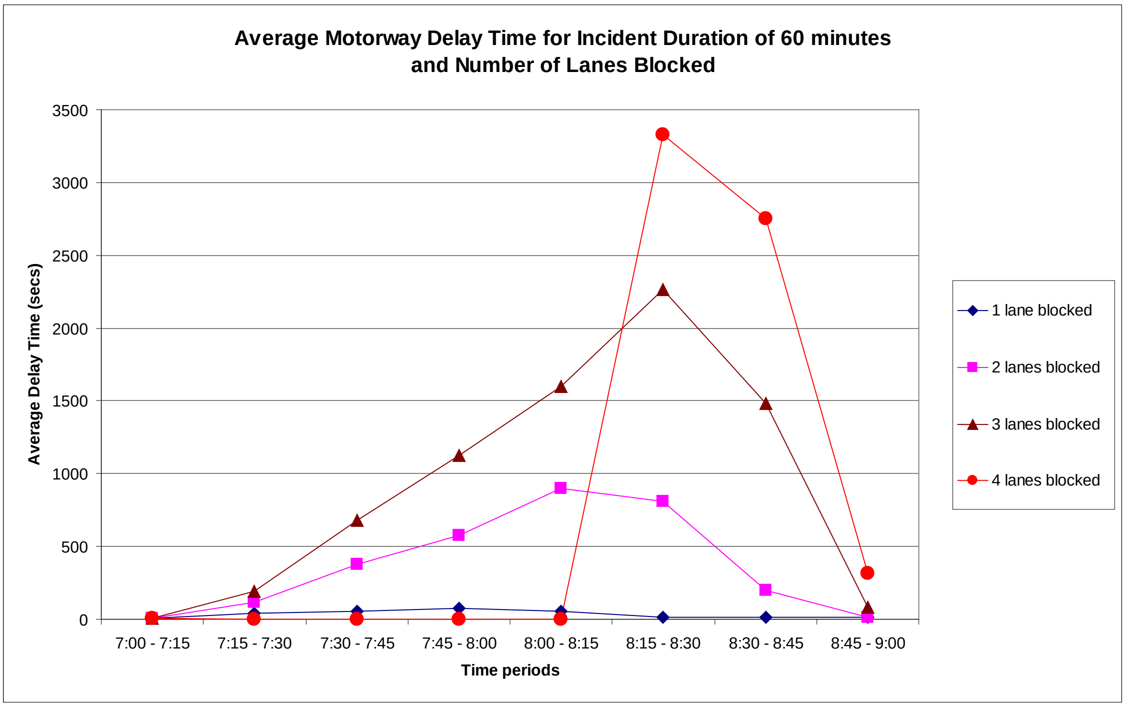

Figure 5.8 The effect of number of lanes blocked for an incident duration of 60 minutes on the average motorway delay time

Again, the figure above portrays the greatest increase in average delay time with the four traffic lanes blocked. The peak average delay time of four lanes blocked is around 58 minutes and is around twice that of the 30 minute incident. Having two lanes blocked exhibits a peak delay at around 8:15 am, which aligns to the end time of the incident. The blockage of three lanes exhibits the peak delay at around 8:30 am, which is approximately 15 minutes after the end time of the incident. This extra period of average delays is no doubt caused by the operations of just one traffic lane working. So the peak average delay time successively increases at a rate around a time period (15 minutes) per extra lane blocked.

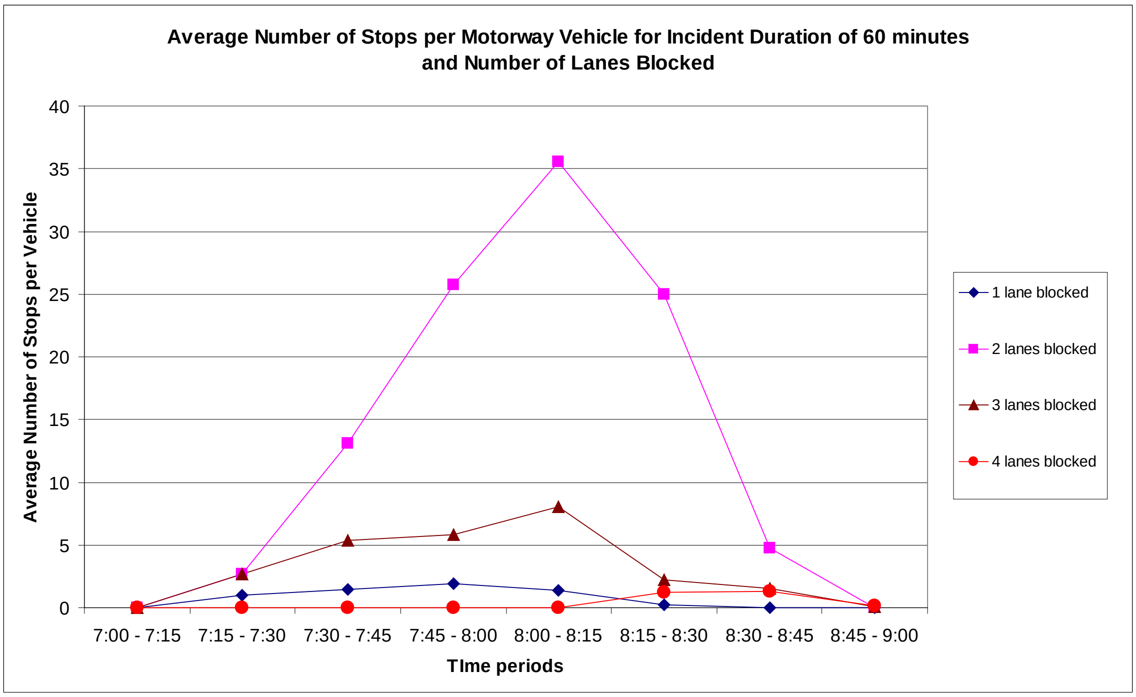

Figure 5.9 The effect of number of lanes blocked for an incident duration of 60 minutes on the number of stops per motorway vehicle

The effects of a 60 minute incident on average number of stops per vehicle is at a maximum with a blockage of two lanes with around 35 stops per vehicle. This is nearly three times the number of stops recorded for a 30 minute incident. Again, all maximums are around the end time of the incident (8:15 am), then the lanes open and the magnitude of different parameters improves. With more lanes open, there is more lane changing, differential speeds and an increasing number of stops. As with the 30 minute incident, having two lanes blocked appears to show similar behaviour – reaching the maximum average number of stops.

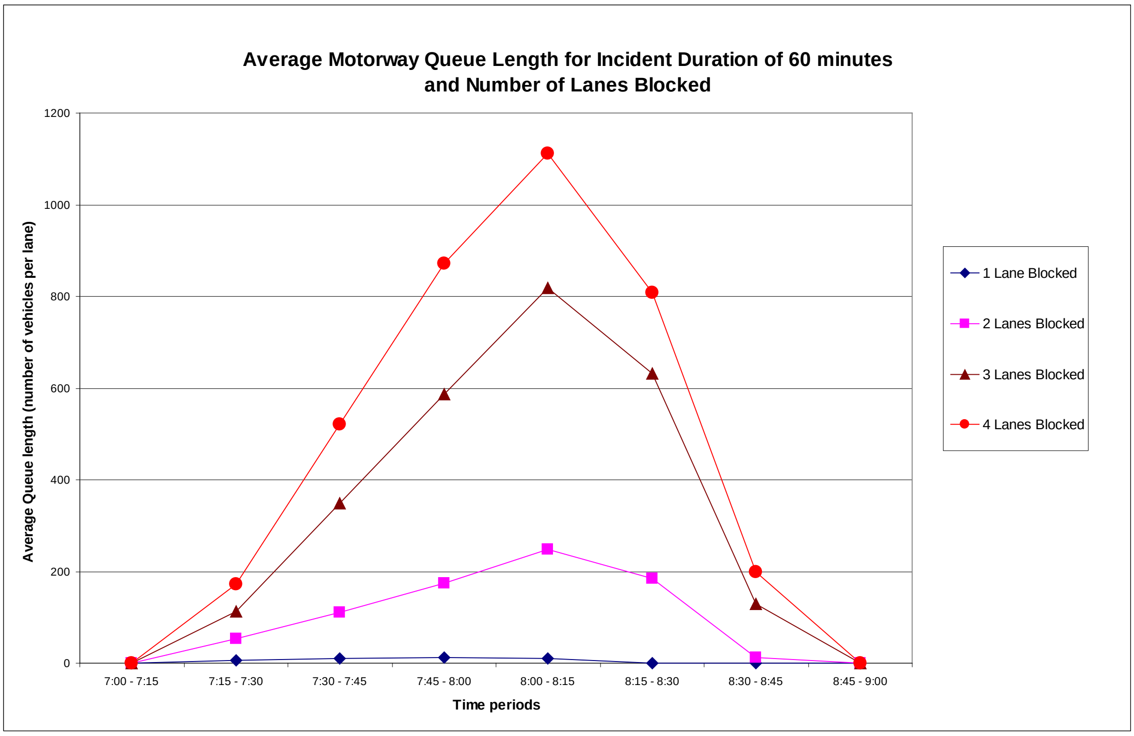

Figure 5.10 The effect of number of lanes blocked for an incident duration of 60 minutes on the average motorway queue length

The average queue length for an incident with a duration of 60 minutes is around 1100 vehicles per lane with blockage of four lanes. Again, this is around twice the effect of a 30 minute incident and takes longer to recover, taking an additional 30 minutes. The two lane blockage has around 250 vehicles per lane at its peak queue length.

5.2.1 Comparison of Incident Durations and Number of Lanes Affected

This section looks at a comparison of the different incident scenarios, number of lanes blocked and the various traffic parameters. It could be seen as a form of summary of the above data, presented in another way by examining the effects of a 30 minute incident and a 60 minute incident in a different way. As a reminder, all of the foregoing experiments were conducted on the preliminary "basic motorway segment" model.

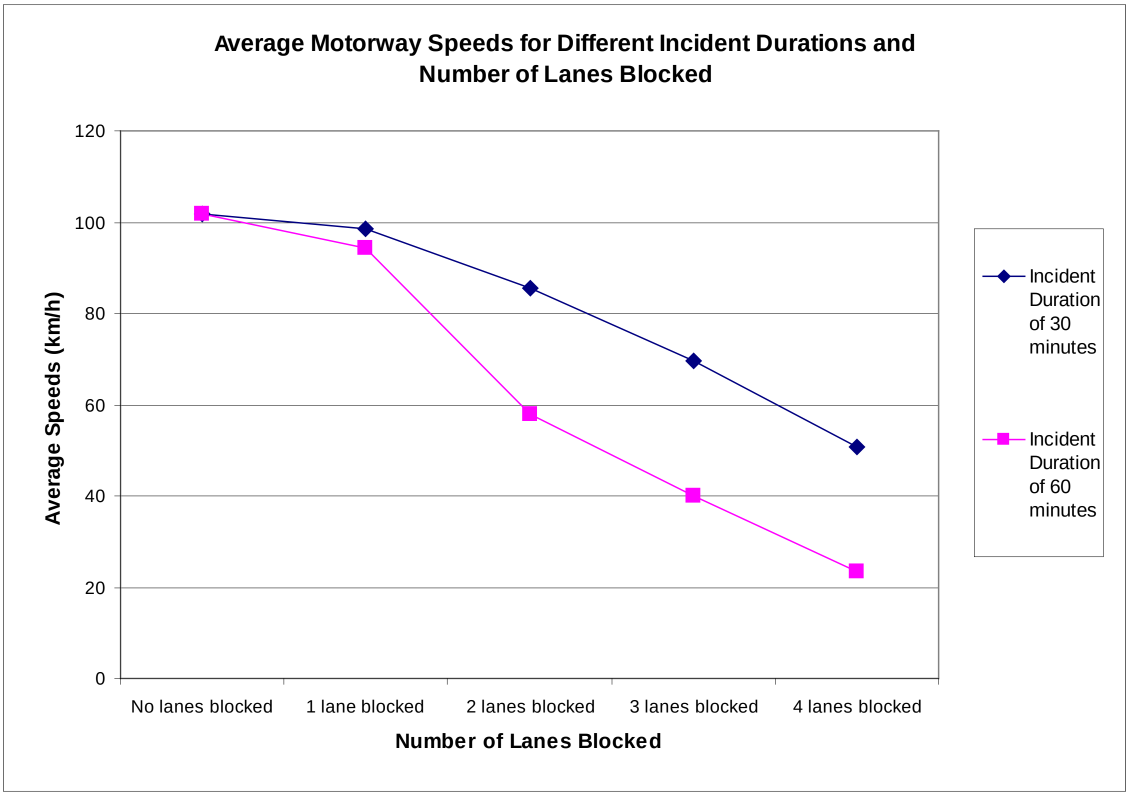

Figure 5.11 The relationship between different incident durations on average motorway speeds and number of lanes blocked

This figure shows a dramatic decline in average speeds, particularly after blocking one lane. The effects on average speeds for an incident duration of 60 minutes is around twice that of a 30 minute incident. Only in the blockage of four lanes does the average speeds halve from a 60 minute incident to a 30 minute incident. A maximum decrease in average speeds occurs at 3 lanes blocked with a decrease of around 70% from 30 minute incident to a 60 minute incident. Both incident scenarios exhibit similar behaviour with one lane blocked, after this point however, congestion worsens with the longer duration incident.

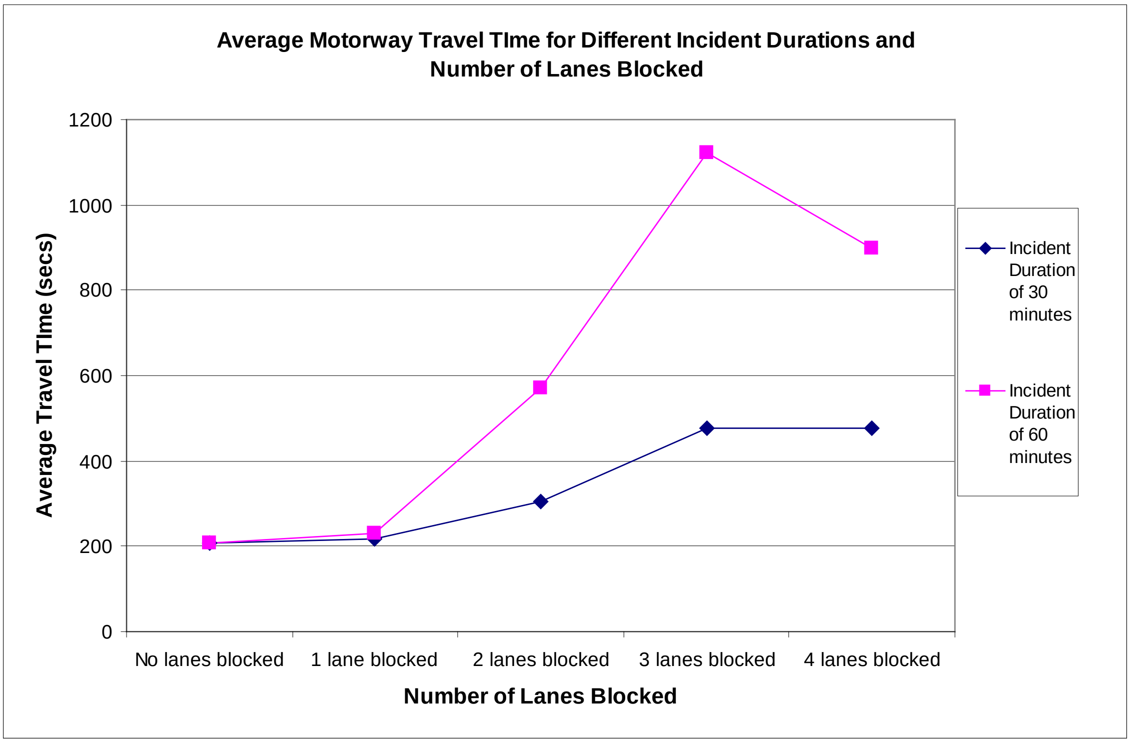

Figure 5.12 The relationship between different incident durations on average motorway travel times and number of lanes blocked

This figure again exhibits the marked effect of an incident of 60 minute duration over an incident of 30 minute duration. The effect of the larger duration incident is again sometimes more than twice that of the smaller incident duration. The average travel time for when the road is totally blocked (as in the blockage of four lanes) is immense, however, looking at the above figure, it may be hard to understand that having four lanes blocked as having a lower travel time than three lanes blocked in the longer duration incident (possibly more analysis needed).

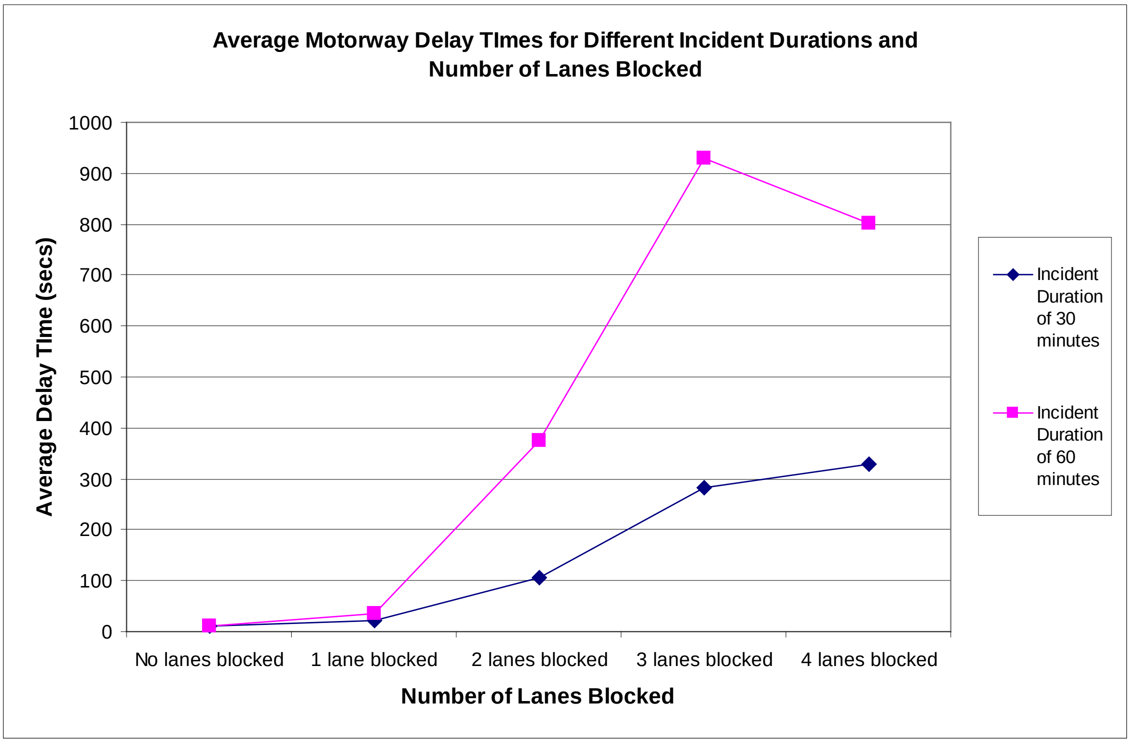

Figure 5.13 The relationship between different incident durations on average motorway delay times and number of lanes blocked

This figure is of similar format to the average travel time graph (Figure 5.12 above), with similar effects. The incident with a duration of 60 minutes peaks in average delay times at the blockage of three lanes. The explanation for this is outlined in the average travel time discussion. Again the blockage of four lanes induces big delays, especially for an incident with 60 minute duration. The average travel times (Figure 5.12) and the average delay times (Figure 5.13 above) exhibit a very similar relationship which may indicate a close relationship.

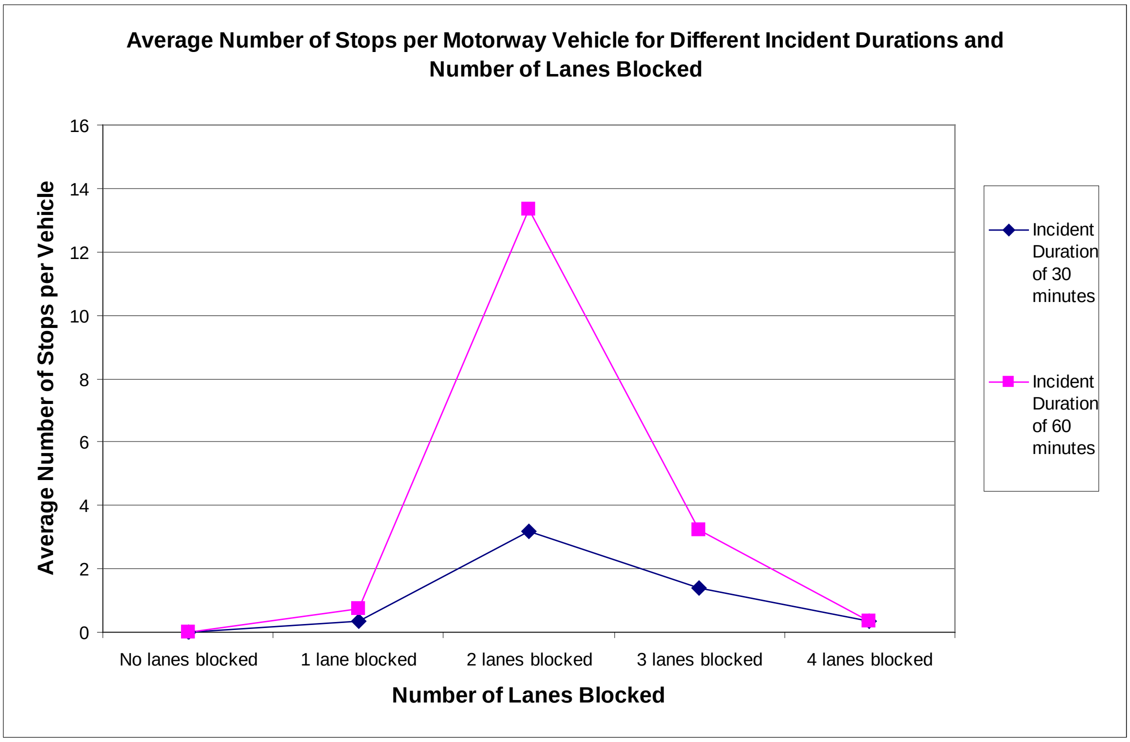

Figure 5.14 The relationship between different incident durations on average number of stops per motorway vehicle and number of lanes blocked

The average number of stops per vehicle for both types of incident has a similar shape, but the larger duration has more than twice the impact of the lower duration, especially around the blockage of two lanes. There would be some equation relating the two results to each other, as with all other relationships. Having two lanes blocked shows the most impact for both incident scenarios. At the peak number of average stops, the longer duration incident is around 4.5 times the peak number of stops for the smaller duration incident.

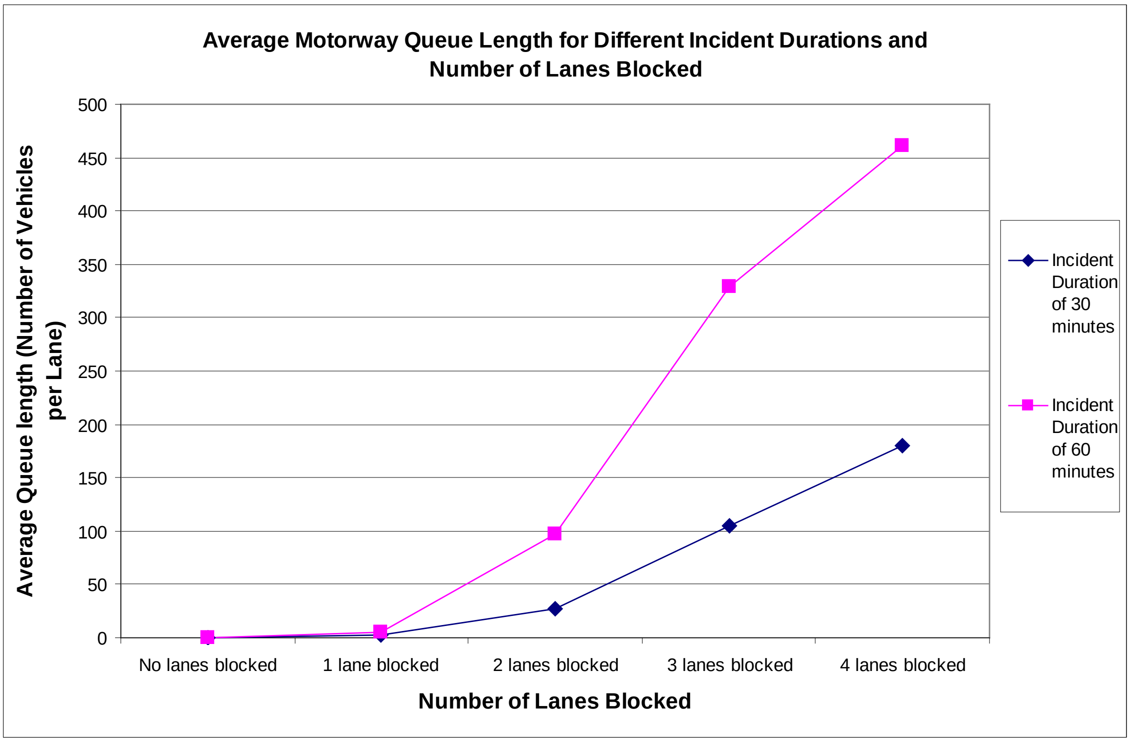

Figure 5.15 The relationship between different incident durations on average motorway queue length and number of lanes blocked

This figure again shows the dramatic effect of a 60 minute incident over a 30 minute incident, along with the steep rate of growth in queue length. The growth in queue length for the long incident takes place at a rate of around an average of 170 vehicles per lane for every one lane blocked or around 350 vehicles per lane for every two lanes blocked. The 30 minute incident average queue length grows at around 100 vehicles per lane for every one lane blocked.

5.2.2 Comparison of Impacts of a Motorway Incident

The above graphical results can be summarised in the tables below:-

Table 5.1 Traffic parameters for non-incident scenario and a 30 minute incident scenario

Scenario (Incident duration / blocked lanes)	Average Speeds	Mean Travel Time	Mean Delay Time	Number of Stops	Mean Queue Length
No Lanes Closed	101	208	11	0	0
30 min / one lane	98	217	21	0.3	2.0
30 min /two lanes	86	304	107	3.2	26.6
30 min / three lanes	69	477	282	1.4	105.4
30 min / four lanes	51	476	329	0.3	179.9

Table 5.2 Traffic parameters for a non-incident scenario and a 60 minute incident scenario

Scenario (Incident duration / blocked lanes)	Average Speeds	Mean Travel Time	Mean Delay Time	Number of Stops	Mean Queue Length
No Lanes Closed	101	208	11	0	0
60 min / one lane	94	231	34	0.7	4.8
60 min / two lanes	58	570	374	13.3	97.7
60 min / three lanes	40	1122	929	3.2	328.6
60 min / four lanes	23	899	800	0.3	460.7

The above tables demonstrate the effects in the severity of increasing the number of lanes blocked on the different traffic parameters. In Table 5.1 and Table 5.2 above, and in Table 5.3 and Table 5.4 below, the results are an average (or mean) of the eight time periods of 15 minutes each (giving a total duration for the experiment of two hours). All lanes blocked are on the left hand side in the direction of travel.

A percentage change comparison of the above data is shown in the tables below:-

Table 5.3 Traffic parameters for a non-incident scenario and a 30 minute incident scenario (% change)

Scenario (Incident duration / blocked lanes	Average Speeds	Mean Travel Time	Mean Delay Time	Number of Stops	Mean Queue Length
No Lanes Closed	0	0	0	0	0
30 min / one lane	-3%	4%	90%	30%	200%
30 min /two lanes	-15%	46%	872%	320%	2660%
30 min / three lanes	-32%	129%	2463%	140%	10540%
30 min / four lanes	-49%	128%	2890%	30%	17990%

Table 5.4 Traffic parameters for a non-incident scenario and a 60 minute incident scenario (% change)

Scenario (Incident duration / blocked lanes	Average Speeds	Mean Travel Time	Mean Delay Time	Number of Stops	Mean Queue Length
No Lanes Closed	0	0	0	0	0
60 min / one lane	-7%	11%	209%	70%	480%
60 min / two lanes	-42%	174%	3300%	1330%	9770%
60 min / three lanes	-60%	439%	8345%	320%	32860%
60 min / four lanes	-77%	332%	7172%	30%	46070%

All of the above tables and graphical representations have used section statistics generated by AIMSUN traffic microsimulator. Some of the percentage increases are immense with quite "unimaginable" type percentage increases. The definition of the various parameters is given below:-

- Average Speeds: Average speeds for all vehicles;
- Mean Travel Time: Average time a vehicle needs to cross a section inside the network;
- Mean Delay Time: Average delay time per vehicle per kilometre;
- Number of Stops: Average number of stops per vehicle per kilometre;

- Mean Queue Length: Average length of queue in that section, expressed as number of vehicles per lane. This is averaged over the duration of the incident and is not the maximum queue length attained for an incident-induced queue.

The way that AIMSUN reports on certain parameters needs to be examined closely, as they will not align with the reporting of similar type parameters from another traffic simulation (micro or macro) software. Each program will report in its own particular manner. The objective of the above % change measurements is to get an idea of the relative changes in the different parameters starting with a "base" case (i.e. comparing "apples with apples").

Network-wide traffic parameters clearly show that incidents caused motorway travel times to increase and motorway speeds to decrease. This is to be expected. Incidents blocking more traffic lanes had a greater impact on traffic parameters, for example, an increase of approximately 146% in travel time for a 30 minute incident blocking two lanes and a decrease in speed of around 17%. Looking further outside the scope of the study for a minute, incidents which blocked more lanes would produce the greatest environmental impacts (that is, increased fuel consumption and hydrocarbon emissions).

The rate of the decrease in average speeds between the different scenarios was also examined. In fact, of all the reported elements, speed is the only parameter, which decreases. Travel times, delay times, number of stops and queue lengths all increase in size, generally speaking. Average speeds decrease at the rate of around 19% for each successive lane blockage for a 30 minute incident.

5.2.3 Level of Service during a Motorway Incident

In order to gauge the rise and fall of the motorway level of service of incident queues, particular experiments were conducted on the preliminary model. This consisted of staging a motorway incident and recording average speeds and average flows at detector sites placed at 500 metre intervals up to 5000 metres from the incident site. Data was recorded in 15 minute interval time periods. The effects of a 30 minute incident and a 60 minute incident can clearly be seen (Figure 5.16 and 5.17). The 30 minute incident traffic queues spent 12% of the time at level of service D to F (88% of the time in "A" level of service) and the 60 minute incident traffic queues spent 37% of the time at level of service D to F (63% of the time spent in "A" level of service). Again this division of the level of service was based on two hour experiment duration. The speeds of the incident induced traffic streams was the main element in allocating the level of service. This parameter fluctuated around greatly and showed greater effects, which was in contrast to the constant motorway traffic flow levels during the duration of the incident.

Table 5.5 Level of service data for incident duration of 30 minutes blocking 2 lanes

Distance			T	I	M	E		
from	7:00 - 7:15		7:15 - 7:30		7:30 - 7:45		7:45 - 8:00	
Incident	Speed	Flow	Speed	Flow	Speed	Flow	Speed	Flow
500m	103	307	55	227	30	243	95	508
1000m	103	313	72	275	18	240	78	463
1500m	103	320	93	317	13	241	68	418
2000m	103	323	104	327	59	286	58	365
2500m	103	325	104	327	103	323	55	323
3000m	102	325	104	326	103	327	99	327
3500m	103	326	104	326	103	327	103	326
4000m	103	325	104	326	103	325	103	327
4500m	103	326	104	325	104	324	103	328
5000m	105	332	105	336	105	332	104	337

Distance		P	E	R	I	O	D	
from	8:00 - 8:15		8:15 - 8:30		8:30 - 8:45		8:45 - 9:00	
Incident	Speed	Flow	Speed	Flow	Speed	Flow	Speed	Flow
500m	103	327	103	324	103	328	103	326
1000m	103	326	103	326	103	326	104	324
1500m	103	327	103	326	103	326	103	326
2000m	103	327	103	327	103	327	104	325
2500m	103	326	103	327	103	326	104	324
3000m	103	327	103	326	103	327	103	323
3500m	103	328	103	326	103	327	103	326
4000m	104	326	103	327	103	327	103	324
4500m	104	327	103	326	104	326	103	325
5000m	105	334	104	334	105	333	105	332

Distance	 	 P	T E	I R	M I	E O	 D	
from	7:00 - 7:15	7:15 - 7:30	7:30 - 7:45	7:45 - 8:00	8:00 - 8:15	8:15 - 8:30	8:30 - 8:45	8:45 - 9:00
Incident								
500m	A	E	F	C	A	A	A	A
1000m	A	E	F	D	A	A	A	A
1500m	A	C	F	D	A	A	A	A
2000m	A	A	E	E	A	A	A	A
2500m	A	A	A	E	A	A	A	A
3000m	A	A	A	A	A	A	A	A
3500m	A	A	A	A	A	A	A	A
4000m	A	A	A	A	A	A	A	A
4500m	A	A	A	A	A	A	A	A
5000m	A	A	A	A	A	A	A	A

Figure 5.16 Level of service characteristics for incident duration of 30 minutes blocking 2 lanes

Table 5.6 Level of service data for incident duration of 60 minutes blocking 2 lanes

Distance			T	I	M	E		
from	7:00 - 7:15		7:15 - 7:30		7:30 - 7:45		7:45 - 8:00	
Incident	Speed	Flow	Speed	Flow	Speed	Flow	Speed	Flow
500m	103	307	54	227	30	243	33	247
1000m	103	312	72	275	18	240	21	244
1500m	103	321	93	317	13	241	13	241
2000m	103	323	103	327	59	286	10	241
2500m	103	326	103	327	103	323	20	251
3000m	103	325	104	326	103	327	75	301
3500m	103	326	104	326	103	327	103	326
4000m	103	325	104	326	103	325	103	327
4500m	103	326	104	325	104	324	103	328
5000m	105	332	105	336	105	332	104	337

Distance		P	E	R	I	O	D	
from	8:00 - 8:15		8:15 - 8:30		8:30 - 8:45		8:45 - 9:00	
Incident	Speed	Flow	Speed	Flow	Speed	Flow	Speed	Flow
500m	32	244	94	530	104	332	105	332
1000m	20	242	77	493	99	467	103	326
1500m	14	241	65	457	91	461	104	324
2000m	10	238	55	417	90	455	103	326
2500m	10	238	45	372	89	449	104	325
3000m	10	240	32	329	88	442	104	324
3500m	40	267	21	288	86	434	103	323
4000m	91	318	11	251	83	425	103	326
4500m	104	327	58	285	79	410	103	324
5000m	105	334	104	333	74	368	103	324

Distance		P	T E	I R	M I	E O	D	
from	7:00 - 7:15	7:15 - 7:30	7:30 - 7:45	7:45 - 8:00	8:00 - 8:15	8:15 - 8:30	8:30 - 8:45	8:45 - 9:00
Incident								
500m	A	E	F	F	F	B	A	A
1000m	A	D	F	F	F	D	A	A
1500m	A	C	F	F	F	D	B	A
2000m	A	A	E	F	F	E	B	A
2500m	A	A	A	F	F	F	B	A
3000m	A	A	A	F	F	F	B	A
3500m	A	A	A	D	F	F	B	A
4000m	A	A	A	A	B	F	C	A
4500m	A	A	A	A	A	E	D	A
5000m	A	A	A	A	A	A	D	A

Figure 5.17 Level of service characteristics for incident duration of 60 minutes blocking 2 lanes

A comparison of the two incident scenarios outlined above shows some trends in the traffic queue breakdown and recovery. As expected, an incident of shorter duration will have fewer effects and recover quicker. For comparison, typical level of service traffic conditions for the Pacific Motorway, just north of the Coomera River, for a normal weekday, is shown in Table 5.7 below.

Table 5.7 Typical level of service traffic conditions for Pacific Motorway

M1 motorway north of Coomera River									
TIME	NORTHBOUND					SOUTHBOUND			
HR END	Lane 1	Lane 2	Lane 3	Lane 4		Lane 4	Lane 3	Lane 2	Lane 1
1	Los A	Los A	Los A	Los A		Los A	Los A	Los A	Los A
2	Los A	Los A	Los A	Los A		Los A	Los A	Los A	Los A
3	Los A	Los A	Los A	Los A		Los A	Los A	Los A	Los A
4	Los A	Los A	Los A	Los A		Los A	Los A	Los A	Los A
5	Los B	Los A	Los A	Los A		Los A	Los A	Los A	Los A
6	Los F	Los B	Los B	Los A		Los A	Los A	Los A	Los C
7		Los F	Los C	Los B		Los A	Los B	Los C	Los F
8		Los F	Los C	Los B		Los B	Los C	Los D	
9		Los E	Los C	Los B		Los B	Los C	Los E	
10		Los D	Los B	Los B		Los B	Los B	Los D	
11		Los C	Los B	Los B		Los B	Los B	Los D	
12		Los C	Los B	Los A		Los B	Los B	Los D	
13		Los C	Los B	Los A		Los B	Los B	Los D	
14		Los C	Los B	Los A		Los B	Los B	Los D	
15		Los D	Los B	Los B		Los B	Los C	Los D	
16		Los F	Los C	Los B		Los B	Los C	Los E	
17		Los E	Los C	Los B		Los B	Los C	Los F	
18		Los E	Los C	Los B		Los B	Los C	Los F	
19	Los F	Los B	Los B	Los A		Los B	Los C	Los D	Los F
20	Los C	Los A	Los A	Los A		Los A	Los A	Los C	Los D
21	Los B	Los A	Los A	Los A		Los A	Los A	Los A	Los C
22	Los B	Los A	Los A	Los A		Los A	Los A	Los A	Los B
23	Los A	Los A	Los A	Los A		Los A	Los A	Los A	Los B
24	Los A	Los A	Los A	Los A		Los A	Los A	Los A	Los A

5.3 An Examination of the Impacts on the Network of a Motorway Incident

This section will detail the examination of just one part of the research, and this will also create a foundation from which to conduct further in-depth analysis. When an incident occurs on the Motorway, there are many impacts, both at a macro level and at a micro level. The immediate effects are those occurring directly within the incident precinct and these effects ripple out further into the outer part of the network. The incidents that are studied in this section include:

- 30 minute incident blocking two motorway traffic lanes, and;
- 60 minute incident blocking two motorway traffic lanes.

This is a continuation of the pattern established in the preceding sections on examining the type of incidents and adds to the understanding of the effects of these particular incidents. Other incident scenarios could be looked at, but then the specific learnings achieved by examining these particular cases could be compromised. The effects of an incident on the motorway and the diversion route traffic flows will now be studied by conducting experiments on the final small network model. The layout is shown in Appendix A2.

The particular traffic parameters (AIMSUN Stream Statistics) that will be examined in this section include:

- Average Traffic Flows;
- Average Speeds;
- Average Travel Times;
- Average Delay Times.

Again, this is a continuation of the parameters examined in the preceding sections, thus building upon a well-established base of knowledge gained from studying these similar scenarios. But now an examination will be done looking from a network wide perspective. Experiments were conducted and results will be given looking at the average values for the above parameters on various replication runs of the experiments.

5.3.1 Compliance Diversion Rates for Incident Induced Traffic

With the occurrence of an incident on the Pacific Motorway, motorists will inevitably look for a suitable alternative travel route, depending on the perceived incident severity. Every motorist has a different trip purpose. In conjunction with this, each motorist has a preconceived notion of what parameters are important to him/her for the successful execution of this trip. They could include such things as a good travel time for the trip, low average delays for the trip or maintaining a good, average speed for the trip. While bearing these particular interests in mind in order to achieve a good trip outcome, motorists will need to make a decision about whether to divert from the Motorway or not. This decision is influenced also by the motorist's knowledge of the network, influencing traffic conditions, other external information (VMS message, radio traffic report, SMS message), weather conditions and so on.

Previous research points to compliance diversion rates of around 5% - 60% (Hidas, 2000) as being optimal for a diversion rate for incident-induced traffic queues. This is a very wide variation and does not really point to a particular good, usable diversion rate for use in research. However, also of relevant importance is that the capacity of the diversion route needs to be assessed and then a diversion rate can be applied that will meet this capacity criteria. AustRoads (2007) has used compliance diversion rates of 15% and 30%, in incident cases, for their urban freeways with closely spaced interchanges with high peak traffic demand.

5.3.2 Diversion Route Fundamentals – Western Diversion Route and Eastern Diversion Route

The particular diversion route used in this research consists of a two way, two lane rural type road. It is basically the western service road of the Motorway from Coomera Interchange north to Yawalpah Interchange. This would most likely be the preferred diversion route for northbound motorway incident-induced traffic queues. The eastern side service road from the Coomera Interchange up to the Yawalpah Interchange is also an optional diversion route. However, unless the western diversion route became very congested or an incident occurs here, then this eastern diversion route would not be used to any degree. Also, motorists would use whichever route they perceive to lead them to their destination more efficiently. This would point to the diversion traffic using the western service road. Very few would cross the motorway to use the eastern service road as an alternative diversion.

There are residential developments occurring along the length of the western service road diversion route with junctions being created with roundabouts and intersections where the developments access the service road. This road is Council owned and maintained and is in good order. It is of a 60km/h and 70 km/h standard and also is in rolling terrain. There are five intersections along this particular diversion route consisting of two roundabouts and three intersections. This general area is rapidly developing with increasing residential development and associated traffic generation. In addition, the Coomera Anglican College is also accessing this road, generating school morning and afternoon traffic volumes and movements. These movements combined with general morning peak traffic generation from the residential developments will add considerable traffic to this small network.

All of these factors will inhibit the operation of a good diversion route from the motorway in the times of an incident. Blocking or inhibiting access from the adjoining collector roads and the school in order to assist with good traffic diversion operations may not really be an option. However, it could be possible with good police resources and positive communications between different emergency service personnel. This could be an area for further discussion with emergency services to assist with traffic management in times of incidents on the motorway. In addition with a constant major traffic flow continually having "right-of-way" at different roundabouts, the other minor adjoining legs may not receive many opportunities to enter the roundabout. This may not be that detrimental to the immediate roundabout traffic operations and the network diversion route traffic flows.

5.4 Results of Comparison of Motorway Traffic and Western Diversion Route Traffic

There were numerous experiments conducted to ascertain the type of relationship between Motorway incident-induced traffic operations and the western diversion route incident-induced traffic operations. There is a point at which the traffic parameters, for a particular incident scenario, for the motorway and diversion route appear to be in equilibrium, where not one particular route is favoured. The incident scenarios examined will again be:-

- 30 minute incident blocking two motorway traffic lanes, and;

- 60 minute incident blocking two motorway traffic lanes.

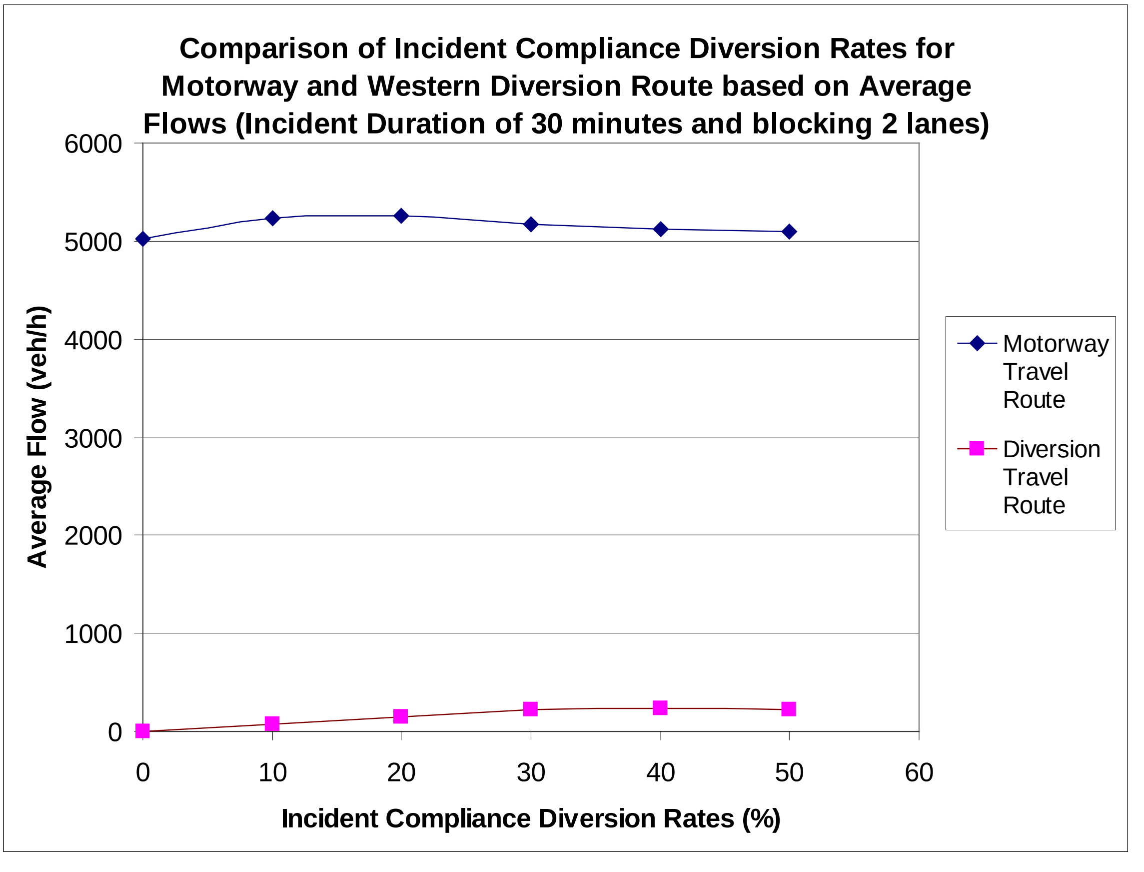

Figure 5.18 Average flows on motorway and western diversion route for a particular diversion rate (30 minute incident)

The above figure shows the relationship of the different flows on each route. The capacity of the diversion route (at LOS C) is achieved at around 30% diversion rate (about 300 veh/h) while the maximum motorway flow (around 5300 veh/h) is around 15% diversion rate for this incident. As the motorway flow decreases, the diversion route flow increases (slowly due to increase in traffic flow from the motorway). Motorway flow decreases with high diversion rates as vehicles are queueing up for the off ramp to divert, thus lowering the average motorway flows. Also, the diversion route is at capacity and cannot receive any additional traffic at around 30% diversion rate.

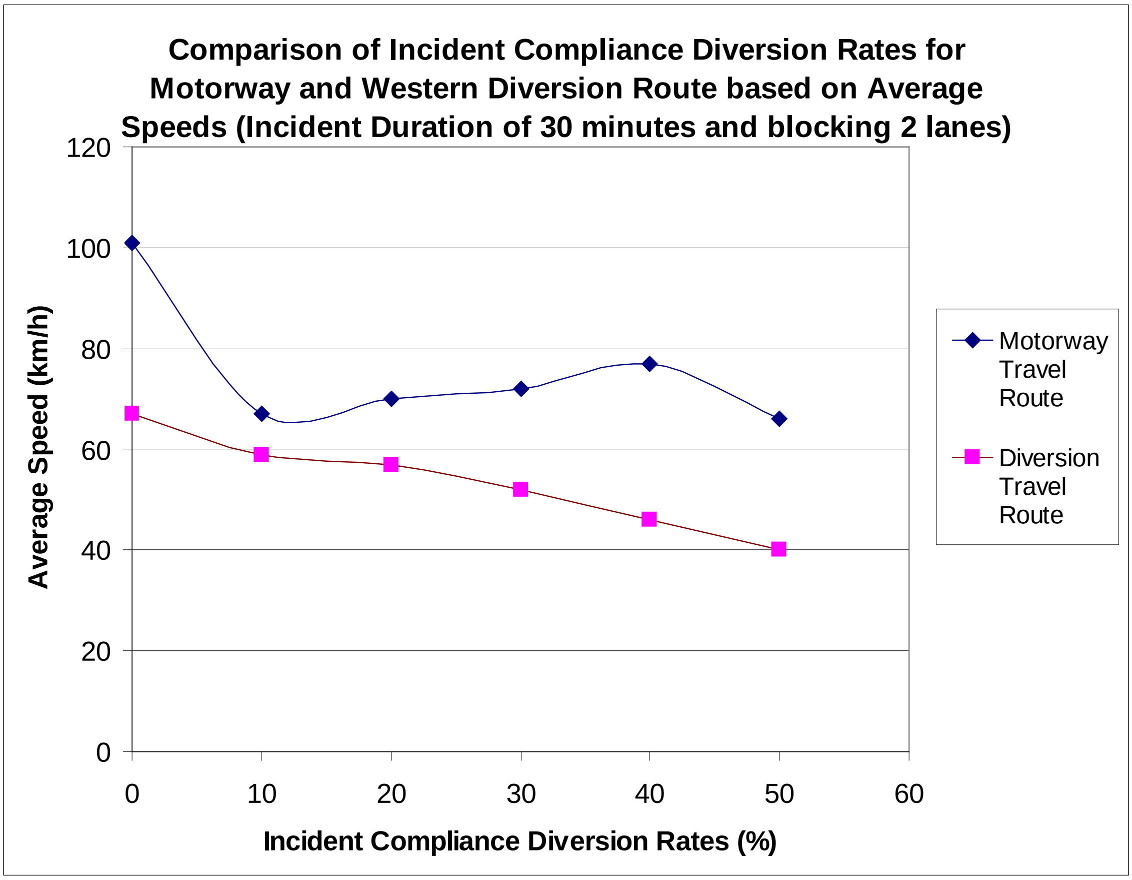

Figure 5.19 Average speeds on motorway and western diversion route for a particular diversion rate (30 minute incident)

Looking at figure 5.19 above, it can be seen that motorway speeds are lowest at around 12% diversion rate, with diversion route speeds also decreasing from this point as well. The sharpest fall in motorway speeds is in the lower diversion rates (up to 10%). However, the motorway speeds increase again due to more traffic going onto the diversion route, thereby letting the motorway traffic increase speeds. At a high diversion rate (50%) guided diversion route traffic is starting to queue for the off-ramp to divert, thus slowing the average speeds for that motorway section.

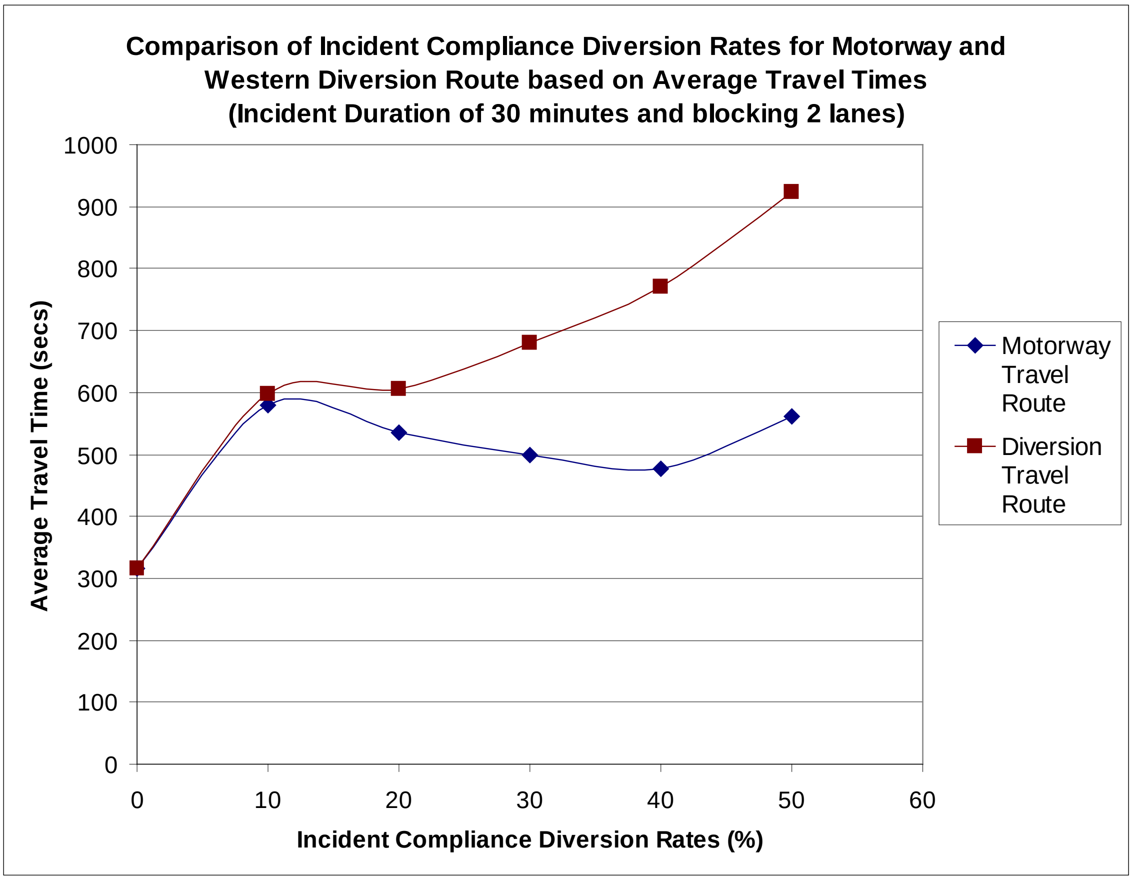

Figure 5.20 Average travel times on motorway and western diversion route for a particular diversion rate (30 minute incident)

From the similar pre-incident starting point, the average travel time for the different routes diverges dramatically. Again, at a point around 13% diversion rate, the average travel time for both the diversion route and motorway plateaus, as more traffic is diverted (guided). Then at around 18% diversion rate, the diversion route average travel time starts to increase, meaning that capacity is being reached. The motorway average travel times decrease to a point around 40% diversion rate, due to motorway traffic flows travelling at a slightly faster pace. Again, at around 40% diversion rate, motorway average travel times increase because of vehicles queueing up to exit onto the off-ramp (to divert around the incident site), thus increasing the average travel time for the motorway section. In addition, at the end of the incident, with traffic returning back to pre-incident conditions, the northbound on-ramp traffic at the Coomera Interchange slightly congests the northbound motorway traffic, also lowering the average motorway traffic speeds and increasing the motorway average travel time for that section.

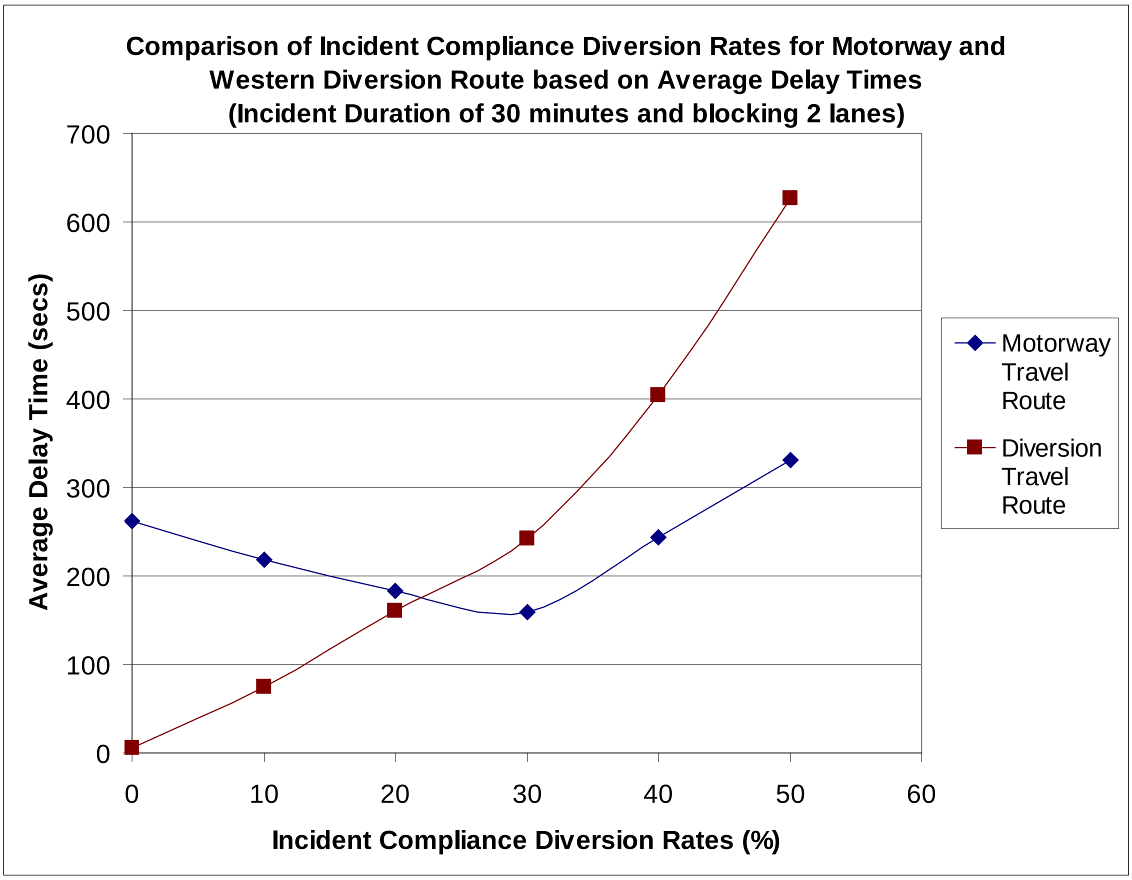

Figure 5.21 Average delay times on motorway and western diversion route for a particular diversion rate (30 minute incident)

This figure shows that at a particular point, the average delay times for the motorway and diversion route appear to converge, giving both the motorway and diversion route approximately the same average delay time of around 180 seconds at around 22% diversion rate. Before this point, the motorway has a delay of around 260 seconds at the start of the incident before diversions are introduced. After this equilibrium point, the motorway average delay times decrease further and then increase with increasing diversion rates. Again, with the high diversion rates, motorway traffic is queueing up to use the northbound off-ramp, thus increasing the average delay time for that section. The diversion route average delay times are increasing as it reaches capacity with decreasing vehicle speeds. The diverted traffic using the northbound on-ramp at Yawalpah interchange, to access the motorway, again induces congested traffic conditions as traffic attempts to re-enter northbound motorway traffic flows.

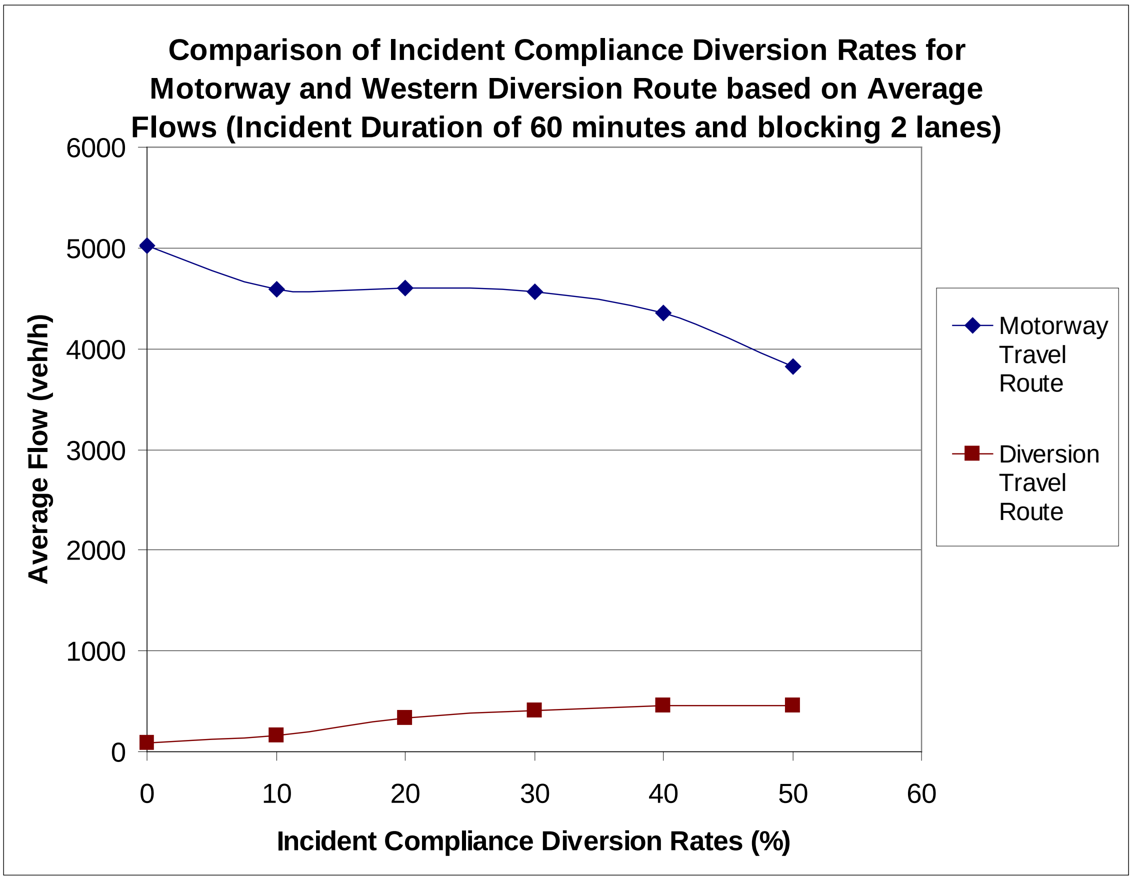

Figure 5.22 Average flows on motorway and western diversion route for a particular diversion rate (60 minute incident)

Turning to an incident with a longer duration, the average flows appear similar to the shorter duration incident. The capacity of the diversion route (at LOS C) is achieved at around 20% diversion rate (about 320 veh/h) while the motorway average flow (around 4700 veh/h) plateaus around 10% diversion rate for this incident. As the motorway average flow decreases, the diversion route average flows increase (slowly due to capacity being reached). Motorway average flow decreases with high diversion rates as vehicles are exiting onto the off ramp to divert, thus lowering the average motorway flows. The effects of a longer incident duration can be seen as having a more severe effect.

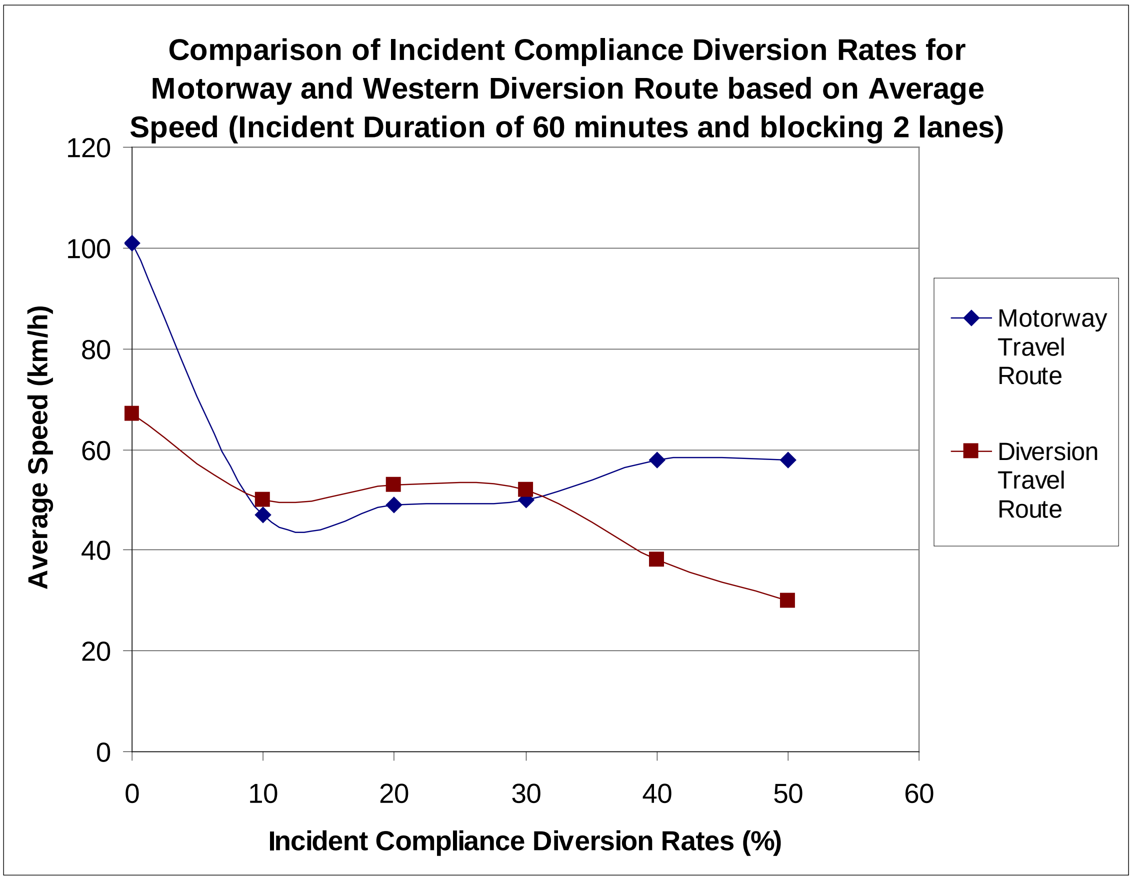

Figure 5.23 Average speeds on motorway and western diversion route for a particular diversion rate (60 minute incident)

Looking at Figure 5.23 above, it can be seen that average motorway speeds are lowest at around 12% diversion rate, with diversion route average speeds also decreasing to around 12%. The sharpest fall in average speeds is in the lower diversion rates (up to 10%). However, the motorway average speeds increase again due to more traffic going onto the diversion route, decreasing the flows on the motorway. At around 30% diversion rate, the average speed for the diversion route decreases noticeably. Capacity is reached and the flows breakdown. At around 9% and again at 31% diversion rate, the average speeds appear to be the same for both the motorway and the diversion route (~50 km/h). At a high diversion rate (50%) guided diversion route traffic is starting to queue for the off-ramp to divert, thus slowing the average speeds for that motorway section to around 30 km/h.

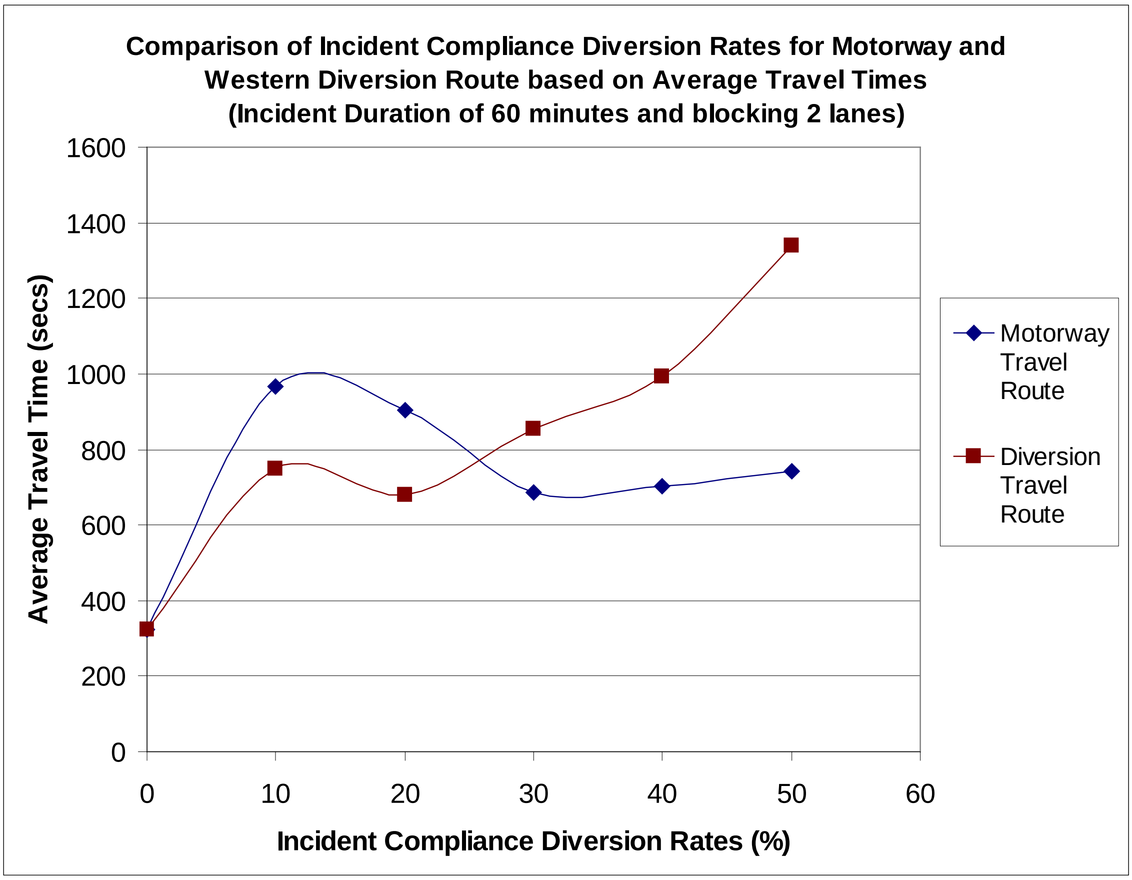

Figure 5.24 Average travel times on motorway and western diversion route for a particular diversion rate (60 minute incident)

From the similar pre-diversion starting point, the average travel time for the different directions diverges dramatically, similar to the 30 minute incident. At a point around 12% diversion rate, the average travel time for the diversion route and motorway is at its highest, tapering off after this. The motorway average travel times decrease to a point around 30% diversion rate due to lower motorway traffic flows travelling at a slightly faster pace. From this point, motorway average travel times increase slightly because of vehicles queueing up to exit onto the off-ramp to divert around the incident site, thus lowering the average speed for the motorway section. From about the 20% diversion rate, the diversion route average travel times increase due to increased diversion traffic volumes. In addition, at the end of the incident, with traffic slowly returning back to pre-incident conditions, the northbound on-ramp traffic at the Coomera Interchange slightly congests the northbound motorway traffic, also lowering the average motorway traffic speeds and increasing the average motorway travel time for that section. The average travel times for the motorway and diversion route are about the same at around 26% diversion rate.

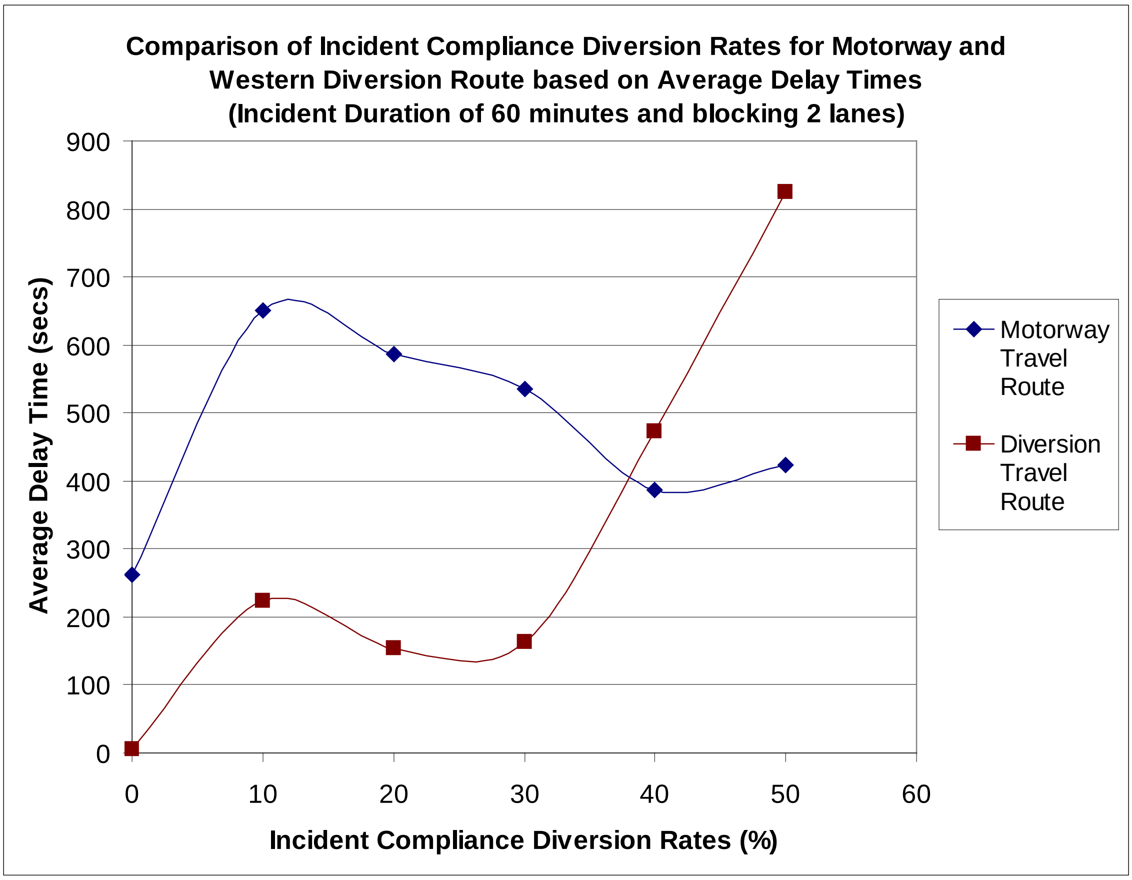

Figure 5.25 Average delay times on motorway and western diversion route for a particular diversion rate (60 minute incident)

This figure shows that at a particular point, the average delay times for the motorway and diversion route appear to converge, giving both the motorway and diversion route approximately the same average delay time of around 400 seconds at around a 38% diversion rate. Before this point, the motorway average delay times peak at around 12% diversion rate, similar to the diversion route. After this they both decrease slightly but then the diversion route average delay times increase with increasing diversion rates (adding more traffic). Again, motorway traffic is queueing up to use the northbound off-ramp with the high diversion rates, thus lowering average travel times to a particular point. The diversion route average delay times are increasing as it reaches capacity.

5.4.1 Discussion on Motorway and Western Diversion Route Experiments

By looking at the graphical figures and by reading the short discussions of the results, the traffic parameters can be dynamic (like average speeds and average delay times). The 60 minute incidents appear to be more dynamic than the 30 minute incidents regarding the actions of incident-induced traffic queues. A two lane, two way diversion route on undulating terrain, with residential development, schools and intersections will have a low capacity. This minor service road becomes a major diversion route with different motorway incidents. In any case, the overall movement of network traffic in times of incident is a priority for any transport authority.

An operational Level of Service of C for the diversion route utilising this service road is used as a "datum" point for all experiments above. This gives a reasonable diversion route traffic flow situation. High diversion rates (say above 40%) could also be seen as a problem, mainly because motorists queue up on the motorway to divert. This causes extra congestion on the motorway and needs to be monitored and controlled by changing the incident diversion rate. The road authorities' procedure for incident management should document the diversion rates and durations for particular traffic flows on the motorway and diversion route. Therefore, taking all of the above into account, with a 30 minute motorway incident blocking two lanes, the network appears to operate as best as possible using a diversion rate of between, say 15% to 22%. Conversely, with a 60 minute motorway incident, blocking two lanes, the network appears to operate as best as possible using a diversion rate of between, say 12% to 20%.

5.4.2 Comparison of Western Diversion Route Level of Service with Compliance Diversion Rates

In order to achieve a reasonable level of operation for diversion route operations, capacity, flows, speeds, delays and other criteria would need to be closely scrutinised. As outlined in Chapter 3, Materials and Methods, the documented level of service includes the parameters of both traffic speed and traffic flow. For this particular diversion route to operate at level of service C, a traffic flow of approximately 603 vehicles per hour (total both ways) or around 301 vehicles per hour, and with a typical speed of around 58 km/h (AustRoads Guide Part 2).

Many experiments have been conducted on the network with varying configurations of lane closures, incident duration and diversion rates for management of incident induced traffic queues. The results of these experiments have been detailed in the sections above. The object of this short section is to suggest a suitable incident and diversion configuration which would meet these experimental diversion route level of service requirements (based on average traffic flow and average traffic speed). A short summary of the different scenarios is presented below in Table 5.8.

Table 5.8 Incident type, motorway compliance diversion rate and western diversion route statistics and level of service

Incident type	Compliance Diversion Rate for Motorway traffic	Western Diversion Route Average Traffic Flow (one way) (veh/hour)	Western Diversion Route Average Traffic Speed (one way) (km/h)	Western Diversion Route Level of Service based on Speed and Flow
30 minute incident blocking two lanes	10%	69	59	B
	20%	144	59	B
	30%	217	51	C
	40%	235	46	D
	50%	228	39	E
60 minute incident blocking two lanes	10%	160	49	D
	20%	329	53	D
	30%	413	52	D
	40%	453	38	E
	50%	454	30	E

Therefore, looking at the modelling aspect, in the event of a 30 minute incident blocking two lanes on the motorway and with motorists receiving good driver information and wanting to minimise their travel time on their trip, then at a particular point, these drivers will decide to use the diversion. This actual number of motorists will be some proportion of the modelled 20% compliance diversion rate. However, at this point, the diversion route is operating at capacity with an average level of service B. At the peak 15 minute time period interval in the modelled morning experiment, there is around 1 vehicle in every 3 vehicles diverting (not the average). The average for the whole two hour experiment (which contains the incident duration) is around 1 vehicle in 5 diverting.

The situation with a 60 minute incident blocking two motorway lanes will naturally have more severe effects on incident induced traffic congestion. Again looking at the diversion route operating at a level of service C with a total capacity of 603 vehicles / hour (giving 301 vehicles /hour in each direction with a 50 / 50 directional assignment), the matching compliance diversion rate would be approximately 17%. Again the modelled speed parameter does not completely align with the accepted level of service parameter – a similar scenario to the 30 minute incident. This approximate percentage represents a diversion route level of service C. As expected, this is achieved at a slightly lower compliance diversion rate and with longer incident duration, the effects of congestion are compounded, thus giving the lower average value for the experiment. The average for the whole two hour experiment (which contains the incident duration) is around 1 vehicle in 6 diverting, compared with 1 vehicle in 4 diverting in the peak 15 minute time period. This can be easily monitored on the CCTV at the Traffic Management Centre and VMS messages adjusted accordingly to attain the desired diversion rate.

5.5 Results of Comparison of Motorway and Western and Eastern Diversion Route Traffic

The effects of increasing capacity of a two lane diversion route for management of incident-induced traffic queues would be expected to be reasonably optimistic. This section will examine exactly to what extent the western and eastern diversion route configuration will assist with incident traffic management. As shown in Appendix A3, there is both a western diversion route and an eastern diversion route for use to disperse motorway incident-induced traffic queues. However, these diversion routes can be utilised to a particular point and then after this point they may become a hindrance to good incident traffic management. Their use could prove to be most productive depending on the individual incident circumstances.

The eastern diversion route is similar in road and traffic characteristics to the western diversion route and is 7.08 km in length (compared to the western diversion route at 5.14 km in length). Both diversion routes are two lane, two way roads in rolling terrain with speed limits of 60km/h or 70km/h. At the start of both the diversion routes, the diverted traffic was assigned as 50% diverted to the western diversion route and 50% diverted to the eastern diversion route. This assignment of traffic was intended to give some indication of the performance of the motorway and the diversion routes. However, this would need to be refined to give equitable performance of traffic parameters for each diversion route. The results from these experiments can be seen in the following short sections.

- 30 minute incident blocking two motorway traffic lanes.

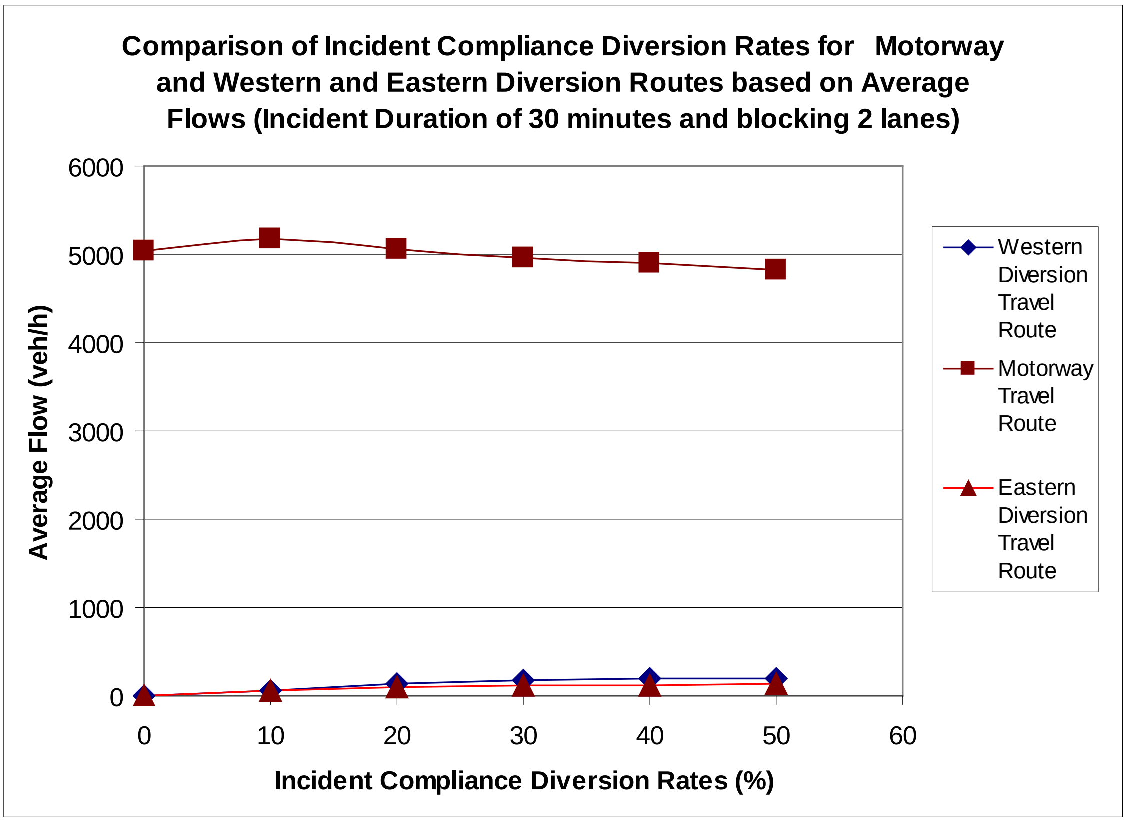

Figure 5.26 Average flows on motorway and western and eastern diversion routes for a particular diversion rate (30 minute incident)

This figure is very similar to the other average flow graphs in the previous sections. Probably the only difference is that there are extra traffic flows due to the addition of the eastern diversion route (additional capacity). Due to the longer length of the eastern diversion route, less traffic flow was getting through. At around 10% compliance diversion rate, maximum average flows occur on the motorway. However, at around 40% compliance diversion rate, the average flows on the diversion routes are at a maximum with this traffic parameter. Motorway average flows slightly decrease as more traffic is diverted to diversion routes.

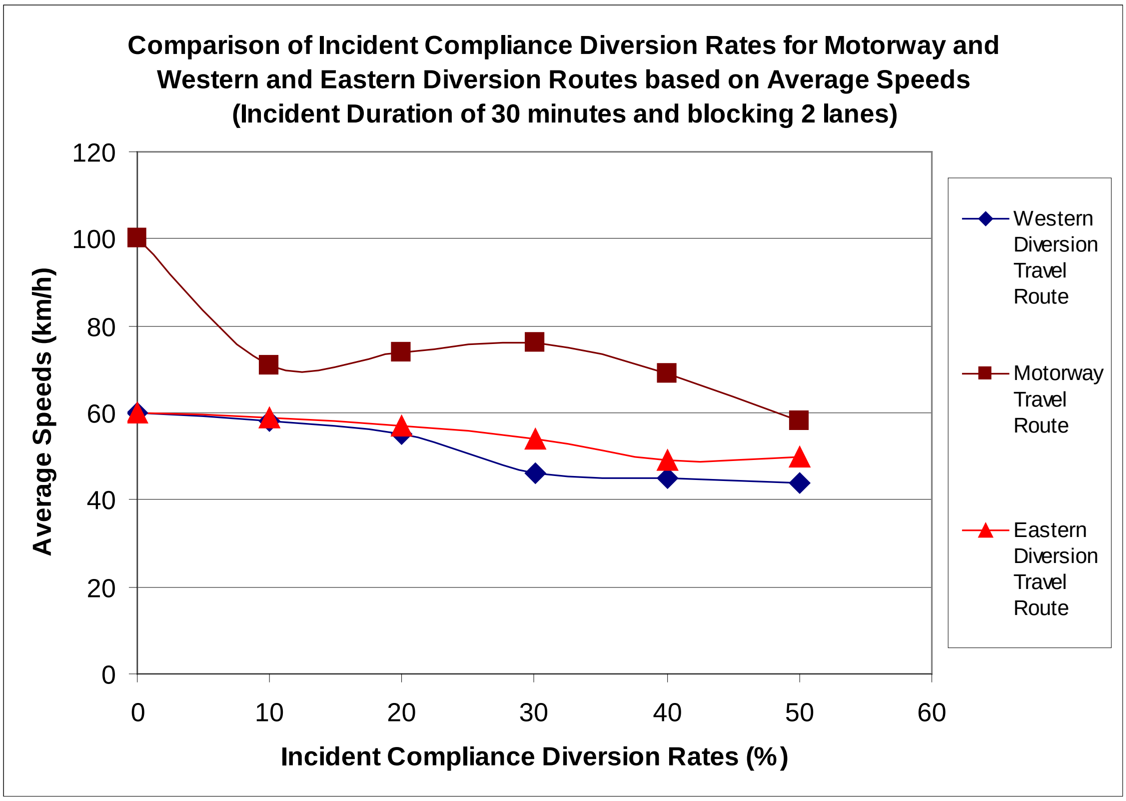

Figure 5.27 Average speeds on motorway and western and eastern diversion routes for a particular diversion rate (30 minute incident)

The trend for diversion route average speeds generally show a decrease to around 30% compliance diversion rate, at which point motorway average speeds reach a maximum. They drop again after this point as there is extra congestion introduced on the motorway due to diversion route traffic accessing the motorway again at the northbound on-ramp at the Yawalpah Interchange. The eastern diversion route average speeds drop slightly as the compliance diversion rate increases, as expected. However, the western diversion route, where it meets the western roundabout at the Yawalpah Interchange has to give way to the eastern diversion route traffic coming over the overpass to the roundabout. This causes further congestion on the western roundabout at the Yawalpah Interchange and a subsequent drop of average speeds. The eastern diversion route performs better than the western diversion route at any compliance diversion rate (higher average speeds).

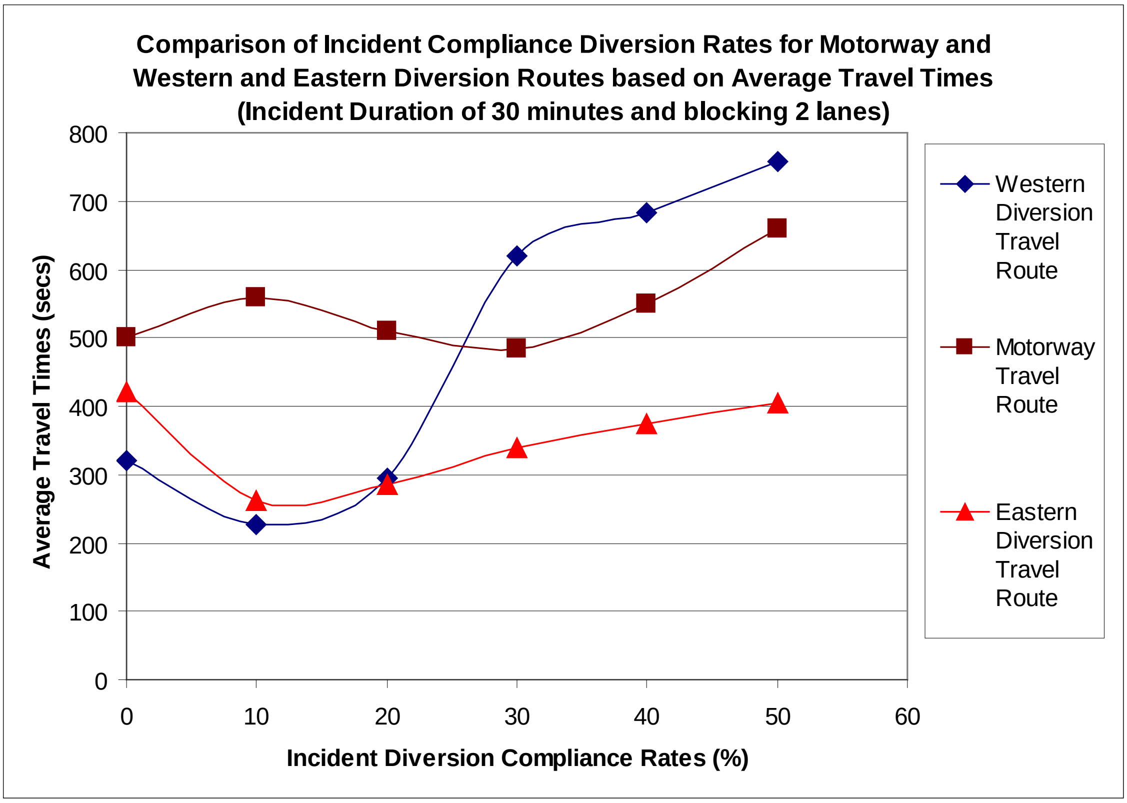

Figure 5.28 Average travel times on motorway and western and eastern diversion routes for a particular diversion rate (30 minute incident)

This figure shows the motorway average travel times decreasing to a minimum at around 30% compliance diversion rate. The motorway average travel times increase after this due to the extra congestion of diversion traffic from both the western and eastern diversion routes entering the motorway to travel north again. Average travel times for the diversion routes however, decrease to a minimum at around 12% compliance diversion rate. The increase in average travel time for the western diversion route is due to the congestion and queueing at the western roundabout of the Yawalpah Interchange where they must give way to eastern diversion route traffic entering the roundabout. This is more pronounced at around 30% compliance diversion rate. This shows the eastern diversion route having much better average travel times, despite carrying a similar volume of diversion traffic and being nearly two kilometres longer in length. They also have a critical roundabout operating in their favour also giving a further advantage. At around 20% compliance diversion rate, the motorway and eastern diversion route have a similar travel time (290 seconds), and at about 26% compliance diversion rate, the motorway and western diversion route have a similar travel time (about 490 seconds).

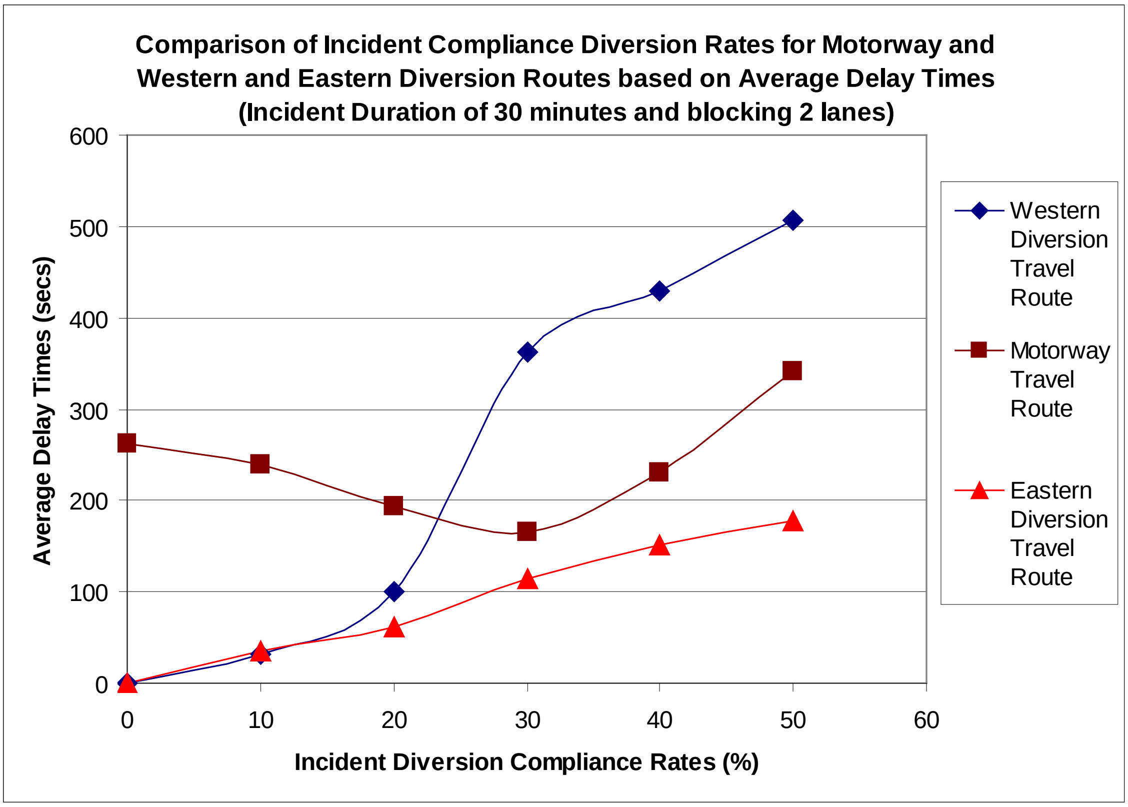

Figure 5.29 Average delay times on motorway and western and eastern diversion routes for a particular diversion rate (30 minute incident)

The conclusions from this figure are nearly similar to those drawn from Average Travel Times (Figure 5.28). The parallel comes from the higher the average travel time the higher the average delays. The motorway average delay times decrease slowly to a minimum at around 30% compliance diversion rate before increasing again. This shows a compliance diversion rate of around 30% to achieve minimum motorway average delays. However, at this point (30% compliance diversion rate), the western diversion route shows huge average delays and increasing from that point. This is due to the extra congestion at the western roundabout at the Yawalpah Interchange as explained prevoiusly. The eastern diversion route shows again to be better performing with lower average delays, despite being longer and having the same amount of diversion traffic. As stated above, the assignment of the incident-induced traffic queues to the western and eastern diversion routes need to be further refined to result in both diversion routes performing to an equitable standard of operation (level of service).

- 60 minute incident blocking two motorway traffic lanes.

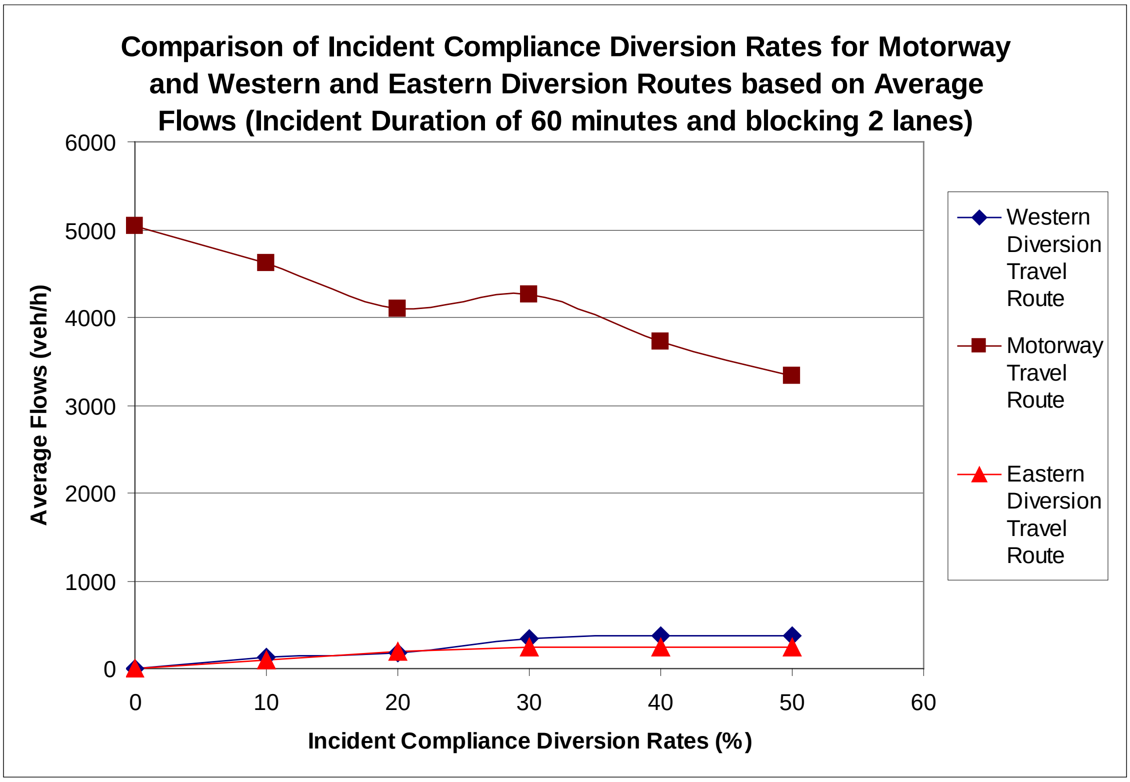

Figure 5.30 Average flows on motorway and western and eastern diversion routes for a particular diversion rate (60 minute incident)

Again, the difference in the ability of the motorway and diversion routes (by using the existing service roads) to handle incident induced traffic queues and flows can be observed. The subject of capacity of the routes has been addressed previously. It would appear that at around 30% compliance diversion rate, motorway average flows are at a maximum and the western diversion route carrying slightly more diverted traffic than the eastern diversion route. However, the level of service on the diversion routes could be compromised with increasing diversion traffic flows.

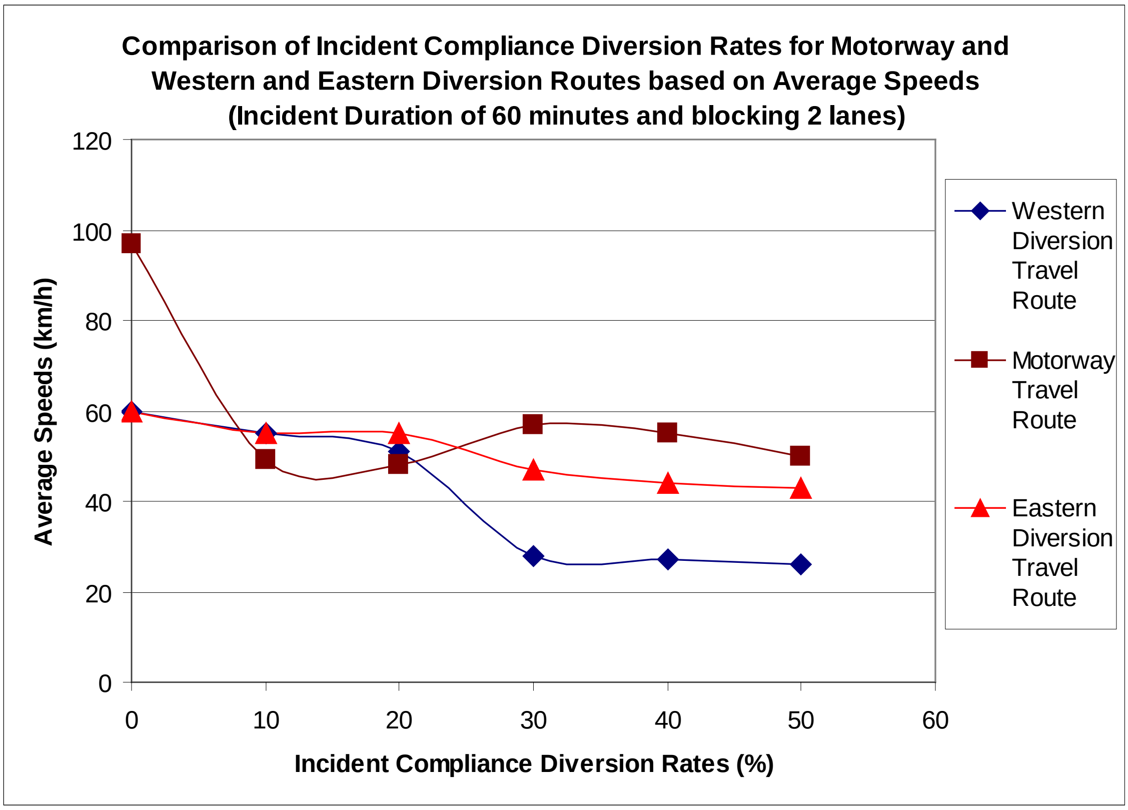

Figure 5.31 Average speeds on motorway and western and eastern diversion routes for a particular diversion rate (60 minute incident)

This figure vividly shows the "breakdown" in the average speeds for the western diversion travel route. The motorway average speeds drop to a minimum around 14% compliance diversion rate, but increase again after this point to a maximum at around 30% compliance diversion rate. At this point also, the western diversion route in particular suffers severe drop in average speeds and remains there. The eastern diversion route performs better – but still has a drop in average speeds to around 42 km/h. At around 23% compliance diversion rate, the average speeds for the three travel routes appear to be close to each other, around, say, around 50 km/h.

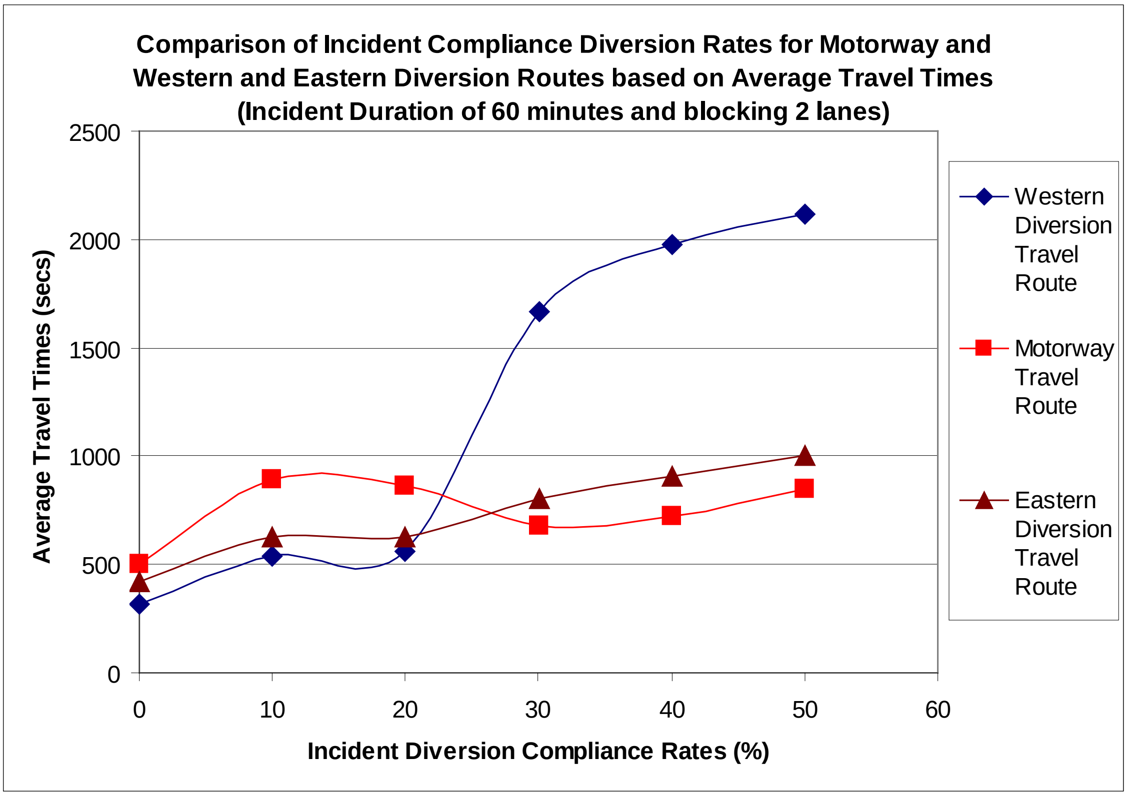

Figure 5.32 Average travel times on motorway and western and eastern diversion routes for a particular diversion rate (60 minute incident)

This figure shows that the average travel times for the motorway increasing to a maximum at around 13% compliance diversion rate before decreasing to a minimum at around 30% compliance diversion rate. They increase after this point primarily due to the congestion caused by diverted traffic re-joining the motorway at the northbound on-ramp from the western roundabout at the Yawalpah Interchange. Again, average travel times on the western diversion route reach a minimum at around 17% compliance diversion rate, but increases dramatically after this point, to about 30% compliance diversion rate. The eastern diversion route maintains a steady increase in average travel times, with the largest increase in the transition from 20% to 30% compliance diversion rate. For this incident situation, at around, say, 22% compliance diversion rate, the average travel times for the three travel routes appear to be close to each other, around, say, 740 seconds.

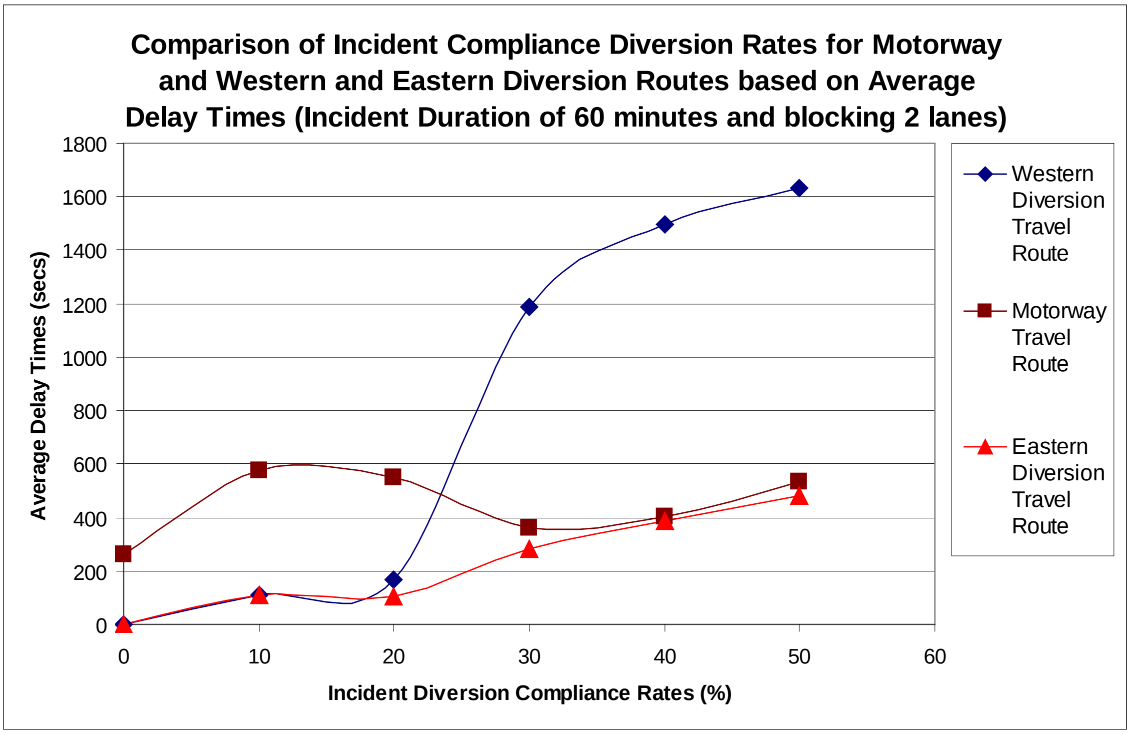

Figure 5.33 Average delay times on motorway and western and eastern diversion routes for a particular diversion rate (60 minute incident)

Here, the average delay times for the motorway increase to around 600 seconds for a 13% compliance diversion rate before decreasing to around 380 seconds at around 30% compliance diversion rate. The western and eastern diversion routes have a similar average delay time of around 100 seconds at around 18% compliance diversion rate. Average delays for the western diversion route and the motorway are similar at around 490 seconds at around a 24% compliance diversion rate. The sudden increase in average delay times for the western diversion route can be seen from a 20% to 30% compliance diversion rate. Motorway average delays decrease after a 15% compliance diversion rate.

5.5.1 Discussion on Western and Eastern Diversion Route Experiments

The addition of extra capacity assists with the dispersion of incident-induced traffic queues, but to what extent is not totally known. The above discussion gives some idea of the extent of the support given by this extra capacity. With these incident scenarios and traffic assignments, the decrease in the level of performance of the western diversion route can be seen. The eastern diversion route performs reasonably well. This diversion route methodology would require a good deal of education to the public and emergency services' on its deployment. However, static signs and appropriate messages on the Variable Message Signs which detail how the diversion routes operate would be of assistance. The travelling public therefore would have three travel route options for reaching their northern destination in times of an incident occurring on the northbound motorway traffic lanes between Coomera Interchange and Yawalpah Interchange.

As previously stated, the assignment of the diverted traffic to go to each diversion route was modelled as 50% to the western diversion route and 50% to the eastern diversion route. This assignment gave some good results and shows that with the majority of traffic parameters, the western diversion route performs slightly worse than the eastern diversion route. This occurs despite being around two kilometres shorter and carrying a similar amount of diverted traffic. However, from these results, for both diversion routes, further refinement on traffic assignment can be done to achieve some equitable results between all three travel routes. So, with more rationalised re-assignment of diverted traffic, the performance of the three travel routes could be about the same and the benefits and operations of this small network are possibly as good as they could be in times of an incident on the motorway.

5.5.2 Comparison of Level of Service of Both Diversion Routes with Compliance Diversion Rates

The diversion operations involving the two diversion routes would be expected to show a reasonably good outcome, regarding level of service, caused by aligning with the good results for the various traffic parameters. However, this is not really the case as indicated by Table 5.9 below. Congestion at different points in the network give rise to an overall low performing network – and the fact that two diversion routes are used which begin and end together at the same locations also introduces a further point of interest. In addition, the motorway flows around the incident site also need to be considered. An overall incident management traffic plan which integrates all these considerations and balances all the traffic parameters on the three travel routes would be valuable.

Table 5.9 Incident type, western and eastern diversion route average flows and average speeds and level of service for 50% / 50% traffic assignment

Incident type	Compliance Diversion Rate for Motorway traffic	Western Diversion Route Average Traffic Flow (one way) (veh/hour)	Western Diversion Route Average Traffic Speed (one way) (km/h)	Western Diversion Route Level of Service based on Speed and Flow	Eastern Diversion Route Average Traffic Flow (one way) (veh/hour)	Eastern Diversion Route Average Traffic Speed (one way) (km/h)	Eastern Diversion Route Level of Service based on Speed and Flow
30 minute incident blocking two lanes	10%	67	60	B	51	60	B
	20%	140	58	B	94	59	B
	30%	177	55	C	124	57	C
	40%	191	45	E	127	49	D
	50%	195	44	E	131	50	D
60 minute incident blocking two lanes	10%	124	56	C	95	58	B
	20%	178	51	D	202	55	C
	30%	343	28	F	243	47	D
	40%	369	27	F	250	44	E
	50%	377	26	F	249	43	E

Some notes of the above tables (Table 5.8 and Table 5.9):-

- Duration of Incident = Time of diversion for Incident;

- Start time of incident = Start time of Diversion;

- Data presented above is reported for one direction only as diversion route traffic flow would principally be northbound one way on the western and eastern service road diversion route;

- Combination of Highest Traffic Flow and Lowest Traffic Speed gives worst level of service.

For a 30 minute incident blocking two lanes, both the west and east diversion routes exhibit a really good level of service, particularly for a low motorway compliance diversion rate. Both routes have similar average flows and average speeds. Bear in mind that the flows and speeds recorded below are averages for the period of the experiment. The flow and speed parameters would vary in a positive way and in a negative way for each 15 minute time period. The average of all these is reported in this table. There is also the dispersion of traffic queues after the end of the incident and when the diversion route ceases to function. Traffic has to suddenly jump out of the incident diversion route scenario and back to their normal travel routes to reach their destinations.

The 60 minute incident scenario appears to operate with slightly worse with fair levels of service. The average flows are higher and average speeds are slightly lower. The incident has a longer duration with the time period for the diversion being the same as the time period for the incident. This means higher throughput of traffic for each route and the eastern diversion travel route appears to travel at a reasonable speed, given the incident traffic diversion situation. For the 30 minute incident scenario, the traffic volumes on each diversion route is approximately the same. Whereas with the 60 minute incident scenario, the traffic volumes on the eastern diversion route are approximately 50% to 70% less than the traffic volumes on the western diversion. The average speeds for the lower duration incident scenario are approximately the same for each diversion route. For the higher duration incident scenario, the average speeds for the eastern diversion route are approximately 30% to 40% higher that the western diversion route at high compliance diversion rates.

As a general type conclusion to this discussion, just looking at the level of service criteria (based on diversion route speed and flow), it would appear that the adoption of both a western and eastern diversion route offers some benefits and leads to a better performing network. However, looking at the overall performance of all the traffic performance parameters (average flows, average speeds, average travel times and average delays) and in particular the average travel time parameter, the performance of this network can be improved during times of incidents. With some refinements of the traffic assignments of the incident-induced traffic queues, good performance can be achieved on all three travel routes. This shall be examined in the next section, in order to gain the most performance with limited capacity of this small network.

5.6 Results of Traffic Re-Assignment to Western and Eastern Diversion Routes

The task of achieving equitable magnitudes of particular traffic parameters for each travel route (and for each incident type) is a matter of considered experimentation. However, the data above gives an indication of where to start with this task. Traffic flows can be highly variable, but this research could hopefully be seen to represent the real situation in times of incidents. In addition, the traffic management procedures for incident induced traffic queues for the 30 minute incident duration may be much different to those of 60 minute incident duration.

The experiments conducted so far have basically concluded that the motorway and the diversion routes are to be treated as two distinct elements. In this part of the research, the experiments will use a motorway diversion compliance rate of 25% for all scenarios, but with different re-assignments of the traffic queues to the western and eastern diversion routes. The re-assignment of incident-induced traffic queues to the western and eastern diversion routes, which will be used in the experiments in this section, consisted of the following:-

- 50% to the western diversion route and 50% to the eastern diversion route;
- 45% to the western diversion route and 55% to the eastern diversion route;
- 40% to the western diversion route and 60% to the eastern diversion route;
- 35% to the western diversion route and 65% to the eastern diversion route;
- 30% to the western diversion route and 70% to the eastern diversion route.

In order to arrive at a reasonable result, only some of the traffic parameters were examined. The traffic parameters used to arrive at a suitable traffic re-assignment were average speed and average travel time. These two parameters were seen to show most potential in delivering a suitable outcome. Average flows and average delays, for this particular exercise of refining traffic re-assignments, could provide a secondary role for this exercise. However, as seen above, trying to get the average flows to equate on the three travel routes is fairly well impossible, given the magnitudes of the different flows and the functional class and capacity of the three travel routes. The motorway has large flows and large capacity and is at the top of the hierarchical tree regarding functional class. Whereas the service roads (diversion routes) normally have low flows with low capacity and are somewhat lower in the hierarchical tree regarding functional class.

Achieving reasonably equitable magnitudes of each of the traffic parameters for the diversion routes and letting the motorway function as best it can will rate as the best result that can be achieved for this situation (and network). The diagrams below highlight these points. The experiments which generated these results all used a Motorway Compliance Diversion Rate of 25% with varying directional traffic re-assignments for the western and eastern diversion routes.

- 30 minute incident blocking two motorway traffic lanes.

The output from these experiments is shown below. The diagrams present a condensed version of the various outputs from average speeds and average travel times for the three travel routes. As can be seen from close examination of this output, there is little variation. They all appear to work the same and give similar results. Even though the western diversion route is shorter in length, it has problems with the operations of the western roundabout at Yawalpah Interchange with the diverted traffic on the eastern diversion route accessing the roundabout to re-join the motorway to go north. The eastern diversion route performs better than the western diversion route.

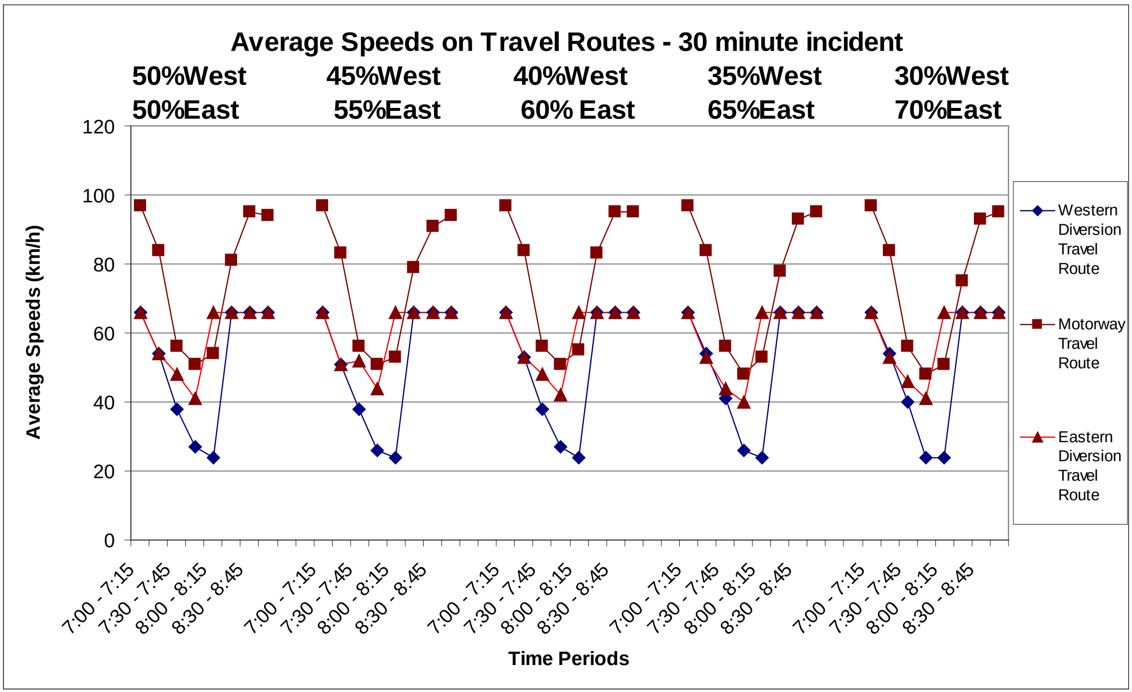

Figure 5.34 Average speeds on travel routes for various re-assignments of diversion traffic queues (30 minute incident)

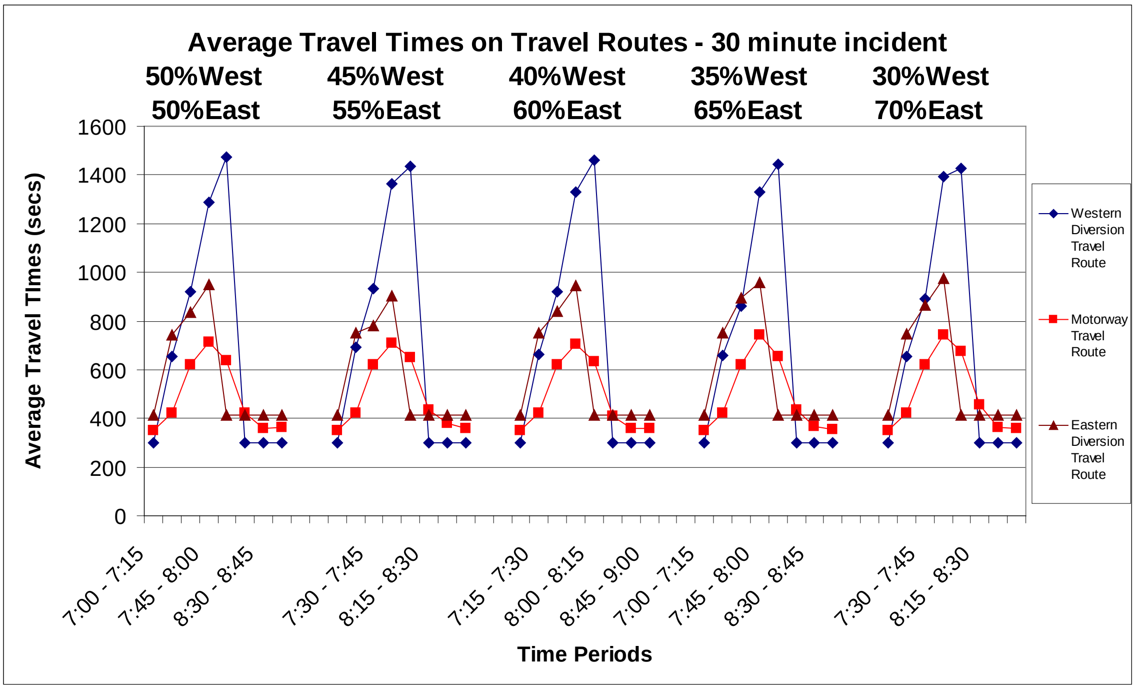

Figure 5.35 Average travel times for travel routes for various re-assignments of diversion traffic queues (30 minute incident)

As can be seen from these figures, there is not really that much variation in the results from the different traffic re-assignments for the diversion traffic diverting to the western and eastern diversion routes. This is odd, as it would have been expected that at a particular point, the performance measures for the re-assignment of the diversion traffic between the western and eastern diversion routes would have been equal. However, for both the average speeds and average travel times traffic parameters, the optimum performance for the diversion routes is around 45% of diverted traffic to the western diversion route and 55% of diverted traffic to the eastern diversion route.

- 60 minute incident blocking two motorway traffic lanes.

The results from these experiments are shown in the figures below. As mentioned previously, an incident of 60 minute duration does have more severe impacts on network operations than a 30 minute duration incident. Again, a condensed version of the outputs is presented to enable a quick synopsis to be made from just one figure. The presentation of each individual diagram of output for average speeds and average travel times would be much more cumbersome. Again, for these experiments, the motorway compliance diversion rate is 25%.

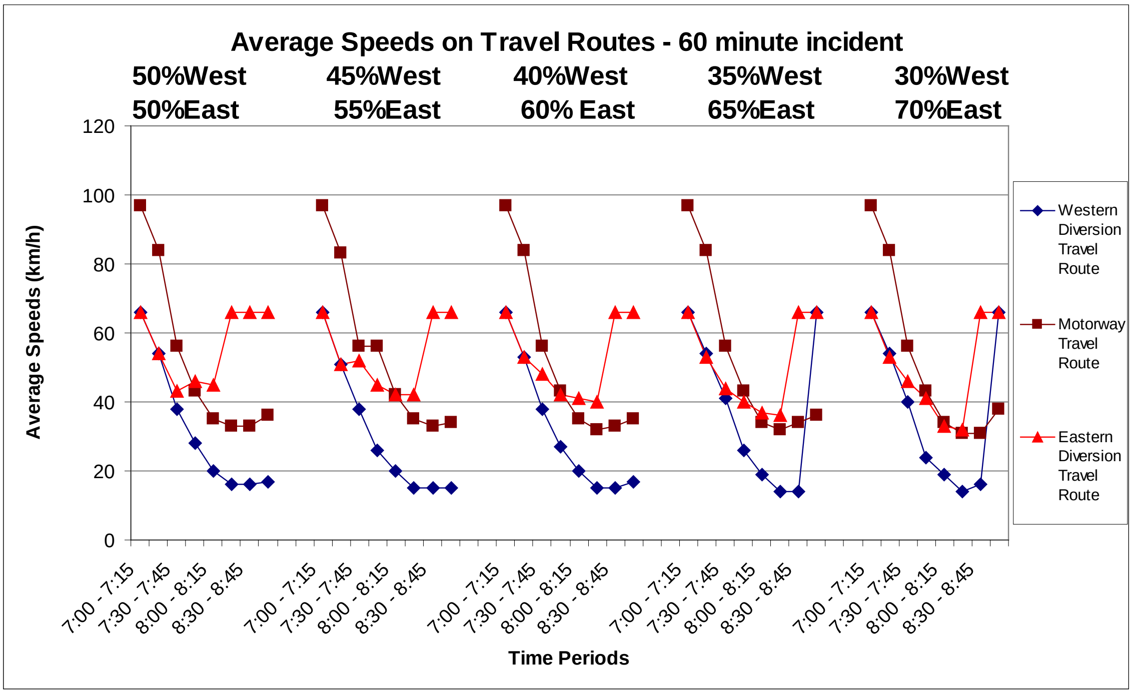

Figure 5.36 Average speeds on travel routes for various re-assignments of diversion traffic queues (60 minute incident)

An examination of the above figure concludes that the trends for the average speeds of the motorway and diversion routes remains fairly consistent. The western diversion route appears to operate effectively around, say, 35% of diversion traffic to the west and 65% of diversion traffic to the east diversion traffic re-assignment. This is where the average speed recovers to pre-incident levels. The impacts on the eastern diversion route are that the average speeds get lower and lower with more traffic being diverted to it. Again, the western diversion route performs badly due to capacity issues and the operations of the western roundabout at the Yawalpah Interchange. But it does recover somewhat with the 35% of diversion traffic to the west and 65% of diversion traffic to the east traffic re-assignment.

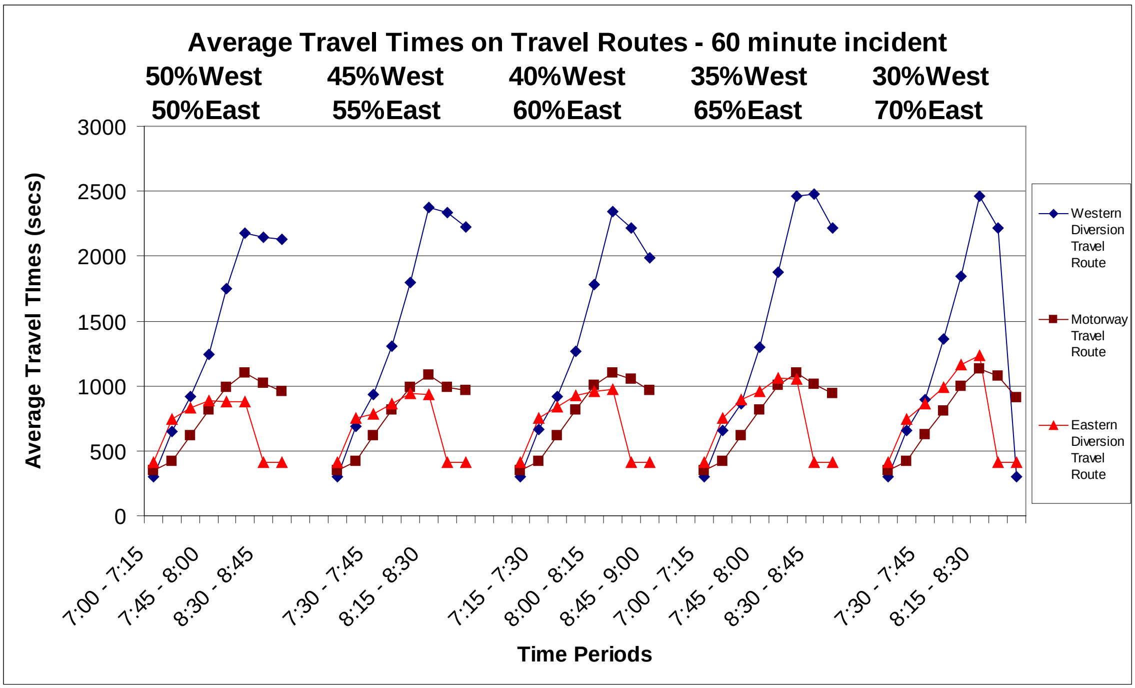

Figure 5.37 Average travel times for travel routes for various re-assignments of diversion traffic queues (60 minute incident)

Both the motorway travel route and the eastern diversion route perform well. However, at about the 50% diversion traffic to the west and 50% diversion traffic to the east traffic re-assignment, the average travel time for the western and eastern diversion route appears to be lowest in this diversion percentage range. Therefore, at around, say, 43% diversion traffic to the west and 57% diversion traffic to the east traffic re-assignment, for a 60 minute incident, blocking two lanes on the motorway, with a 25% motorway compliance diversion rate, the network performs at an optimum. This is the mean of the average speeds and average travel times results.

5.6.1 Summary of Diversion Route Traffic Re-assignment Experiments

As a summary of the above data, a table is presented below.

Table 5.10 Traffic re-assignment percentages to the western and eastern diversion routes which gives optimum network performance

Type of Experiment	% Re-assignment of Incident Induced Traffic Queue for Optimum Operations for Western Diversion Route	% Re-assignment of Incident Induced Traffic Queue for Optimum Operations for Eastern Diversion Route
30 minute incident blocking two lanes of motorway, 25% motorway compliance diversion rate	45%	55%
60 minute incident blocking two lanes of motorway, 25% motorway compliance diversion rate	37%	63%

Associated with the above traffic re-assignments is a traffic flow parameter for this optimum diversion rate percentage. The average speed and average traffic flow will give a magnitude of the level of service for diversion route operations. This is presented below for the Western Diversion Route and the Eastern Diversion Route.

Table 5.11 Level of service for western diversion route with 25% motorway compliance diversion rate – 30 minute incident

Type of Experiment	Western Diversion Route at 45% Traffic Re-assignment – Average Speed (km/h)	Western Diversion Route at 45% Traffic Re-assignment – Average Traffic Flow (veh/h) (one way)	Western Diversion Route at 45% Traffic Re-assignment – Level of Service
30 minute incident blocking two lanes of the motorway	51	156	D

Table 5.12 Level of service for eastern diversion route with 25% motorway compliance diversion rate – 30 minute incident

Type of Experiment	Eastern Diversion Route at 55% Traffic Re-assignment – Average Speed (km/h)	Eastern Diversion Route at 55% Traffic Re-assignment – Average Traffic Flow (veh/h) (one way)	Eastern Diversion Route at 55% Traffic Re-assignment – Level of Service
30 minute incident blocking two lanes of motorway	60	119	B

Table 5.13 Level of service for western diversion route with 25% motorway compliance diversion rate – 60 minute incident

Type of Experiment	Western Diversion Route at 37% Traffic Re-assignment – Average Speed (km/h)	Western Diversion Route at 37% Traffic Re-assignment – Average Traffic Flow (veh/h) (one way)	Western Diversion Route at 37% Traffic Re-assignment – Level of Service
60 minute incident blocking two lanes of the motorway	34	261	F

Table 5.14 Level of service for eastern diversion route with 25% motorway compliance diversion rate – 60 minute incident

Type of Experiment	Eastern Diversion Route at 63% Traffic Re-assignment – Average Speed (km/h)	Eastern Diversion Route at 63% Traffic Re-assignment – Average Traffic Flow (veh/h) (one way)	Eastern Diversion Route at 63% Traffic Re-assignment – Level of Service
60 minute incident blocking two lanes of the motorway	52	261	C

5.7 Further Discussion of Level of Service, Diversion Traffic Volumes with Diversion Route Capacity

With the average diversion route traffic flows and traffic speeds at a level of service around level B, there would be some variance around this level during the duration of the incident and also then when the motorway starts returning back to normal traffic conditions. Depending on these traffic parameters, the level of service could fluctuate between level A and level C. In fact, as an example, looking at the 20% compliance diversion rate (for incident duration of 60 minutes, blocking two lanes), the highest traffic flow rate is 660 veh/hr (total two way) at the lowest traffic speed of 58 km/h. This could be equivalent to a D type level of service. At virtually every 15 minute time interval during the experiment, the flow and speed parameters change enough to warrant the next level of service – either improving or declining the diversion route level of service.

Therefore, in the event of any incident blocking lanes on the motorway, motorists may want to divert in order to minimise the travel time for their trip. As noted a figure of 25% compliance diversion rate has been used for all experiments relating to modelling of diversion route operations. However, the actual assignment of traffic to the individual diversion routes varies in order to achieve an optimum outcome for the network. Looking at the 30 minute incident scenario, a traffic assignment of around 50% to each of the two diversion routes gives optimal network outcomes. This could be seen as being a fairly reasonable result. The 60 minute incident scenario has a slight bias to more traffic being assigned to the eastern diversion route to achieve optimum results for the network. The traffic control methods in order to achieve these assignments would need to be examined and then executed by emergency agencies and transport authorities.

5.8 Application of this Methodology to other similar areas of the Motorway

Looking at the Pacific Motorway from Smith Street to the Logan River, there are a total of fourteen grade-separated interchanges, each consisting of an overpass, on and off ramps and roundabouts or signalised intersections linking to the urban arterial road network. On the eight lane part of the motorway, there are twelve interchanges in this district, with two being on the six lane part of the motorway. There is a system of service roads running parallel to the motorway linking up most, if not all, of the interchanges. In conjunction with this system of service roads is a mix of residential and commercial development, all bringing different traffic characteristics to the operations of this small network.

The application of this diversion route capacity strategy, as discussed in previous sections, could be made to other parts of the motorway. By having an examination of the particular elements and parts of the motorway and aligning these to the subject area as discussed above, some consistencies can be found in the application of this methodology. Table 5.15 below gives a brief overview of the motorway interchanges and their suitability for use of this diversion route strategy. However, the main point to note is that its application is only to the eight lane section of the motorway. Its application to the six lane section of the motorway is limited, but with some modifications, it could be used.

Table 5.15 Connectivity of interchanges on Pacific Motorway and suitability for use of research methodology

Interchange location	Distance between Interchanges	Interchange Connectivity by Western Service Road	Interchange Connectivity by Eastern Service Road	Western Service Road link / diversion route suitability assessment	Eastern Service Road link / diversion route suitability assessment
Beenleigh North					
	1.963 km	Fair	Fair	N.A.	N.A.
Beenleigh South (Distillery Road)					
	2.200 km	N.A.	Good	N.A.	Good
Yatala North (Jacobs Well Road)					
	2.934 km	Good	Good	Good	Good
Yatala South (Computer Road)					
	3.533 km	N.A.	Very good	N.A.	Very good
Ormeau (Peachey Road)					
	2.359 km	Very good	Very good	Very good	Very good
Pimpama (Mirambeena Road)					
	2.860 km	N.A.	Good	N.A.	Good
Yawalpah (Yawalpah Road)					

	4.783 km	Good	Very good	Good	Very good
Coomera (Foxwell Road)					
	3.150 km	N.A.	Fair	N.A.	Fair
Oxenford (Hope Island Road)					
	2.491 km	Good	Good	Fair	Fair
Helensvale (Helensvale Road)					
	2.458 km	Good	N.A.	Good	N.A.
Gold Coast Highway					
	3.016 km	Good	Good	Good	Good
Smith Street					
	3.912 km	Fair	N.A.	Fair	N.A.
Nerang North (Nerang – Broadbeach Road)					
	1.521 km	N.A.	N.A.	N.A.	N.A.
Nerang South (Pappas Way)					

Note:- Very Good = Direct connectivity, no intersections, excellent capacity potential;
Good = Some direct connectivity, few intersections, good capacity potential;
Fair = Indirect connectivity, numerous intersections, driveway accesses, urban type environment, low capacity, commercial development;
N.A. = Not applicable, non existent.

Therefore, by examining the above table, it can be concluded that this research methodology can be applied to approximately four motorway locations (with a location consisting of a motorway section with an interchange on each end). This means that the methodology could be used for both traffic directions, using the interchanges and service road layouts efficiently. In addition, depending on the exact location and nature of the incident, this methodology could be productively applied to a particular part of a motorway location and only to one traffic direction.

5.8.1 Alternative Northbound Diversions

With regard to the motorway incident scenario, the hard shoulders of the northbound off ramp could be utilised to achieve two traffic lanes, thus achieving a higher capacity diversion route around the incident on the northbound motorway lanes. Then, with this dual traffic lane off ramp leading to the two lane entry leg to the western roundabout at the Coomera Interchange, the operations of the diversion route could be improved. In particular, the left hand roundabout approach lane could be for traffic using the western diversion route – by turning left at the roundabout. The right hand roundabout approach lane could turn right at the roundabout, cross over the motorway, turn left at the eastern roundabout and proceed north on the eastern diversion route / eastern service road. This leads to the eastern roundabout at the Yawalpah Interchange, where traffic can again cross westbound over the motorway to the western roundabout, turn right, then onto the northbound on ramp to join the motorway.

The eastern diversion route again consists of a rural type, two lane, two way type road. It has a very similar layout and configuration to the western diversion route, but the eastern service road layout does not currently have residential developments adjoining the road. In addition, this service road is not in rolling terrain, and has slightly better horizontal and vertical alignments with a nice smooth asphalt pavement and good visibility. All of these factors point to an increased capacity and level of service over the western diversion route. However, an approximation could be that the diversion traffic volume could be increased by using both the western and eastern diversion routes. This would reduce congestion and improve the level of service for diversion route traffic operations. However, the successful deployment of this would depend on positively addressing incident management operations, emergency services, driver behaviour and available resources.

Both the western and eastern side service roads / diversion routes are two lane, two way rural type roads, as discussed. However, there may be scope, in times of becoming diversion routes, as a consequence of motorway incidents, that these service roads could be made to operate as one way, two lane roads to cope with incident-induced traffic queues. However, while this would have the potential to nearly double the capacity of the diversion route layout, the logistics of operating this would not really be possible. This is mainly due to the resources needed to control the numerous intersections, junctions and accesses onto the roads to ensure that traffic flows are maintained in the correct direction. There is a large amount of risk to be monitored and managed and may not be seen to be an economical outcome for this diversion route methodology.

An additional factor that may assist with management of incident – induced traffic queues could be to approach the service centre, which is located just off the northbound off-ramp of the Coomera Interchange, about assisting the incident management strategy. This could be in the form of offering some "special deals" to incident bound traffic queues. This could include half price meals, free rides for children or cheaper fuel for a particular time period. This would involve enticing traffic to leave the eastern diversion route traffic queue to stay at the service centre for a while until the incident – induced queues have reduced and the incident close to finishing. Perhaps the length of time to run the "special deals" could align to the duration for the diversions. However, independent research would be needed to put together a "Memorandum Of Understanding" with Management of the Service Centre complex which will benefit all stakeholders involved. This may or may not be successful.

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CHAPTER 6

Discussion

6.1 General Remarks

Looking at the proceedings of the research from an overall perspective, it could be said that this incite into another side of incident traffic management has provided much useful information. This includes making a positive contribution to understanding traffic flows especially in times of incidents and traffic diversions. Results and learnings from the experiments conducted could also prove useful in application to other areas of the Pacific Motorway, and possibly to other motorways in other districts in Queensland. Aligning the modelled incident to actual incidents is also useful in endeavouring to make all the results more meaningful (by using calibration and validation of AIMSUN model). Each element of the experiment was examined and checked for completeness and how it interacted with other elements to give a high-quality result.

As detailed in the chapters "Modelling" and "Materials and Methods", the construction and execution of the experiments is exacting. Given the fact that traffic conditions can alter minute by minute or even second by second, they still generally maintain a presence around some type of broad general average or band of performance (that is, for example, peak times and off peak times) and tend to follow a general trend.

At a broad network wide level, this research could be seen to assist with the management of the far reaching effects of an incident and also on how to manage the impacts that may be experienced on the rest of the network, particularly the urban network. Then, conversely, at the micro level, the management of the inner core incident area is needed as these effects can ripple out to the outer cordon part of the incident scene. Each topic in this chapter contains an examination of two parts of the results. This includes discussion on analytical (quantitative) processes and results and level of service (qualitative) processes and results.

6.2 Motorway Incident (Simple Network Section) – Traffic Analysis

- 30 minute incident blocking two motorway traffic lanes.

The experiments for examining this case gave some interesting outcomes (as described in the section "Results"). As expected, with the worsening of traffic flow conditions (as caused by an incident), congestion increases. As an example, the effects on average motorway speeds get approximately 40% - 50% worst with the each additional lane closed. The complete closure of all four lanes has a dramatic effect on traffic parameters as traffic flow is fundamentally stopped and a "shockwave" is sent back through the traffic. Again, with some traffic parameters, the effects of a particular number of lanes closed can be compounded to as much as seven times the effect from the initial lane closed. The rate of increase of the negative compounding effects of some traffic parameters, especially average motorway traffic speeds, is nearly linear over the time periods. The first time period (15 minutes) of the incident duration shows the greatest rate of any negative effects in all experiments. Also, time and type of recovery back to "normal" traffic conditions tends to vary, depending on which traffic parameter is being examined and the lower the number of lanes blocked, then the quicker the recovery. Looking at average delays only can give a time for recovery that is different than looking at, say, average travel times.

- 60 minute incident blocking two motorway traffic lanes.

Generally, these results show far worse effects for the different traffic parameters than the 30 minute incident scenario. The negative effects are generally worst and for a longer duration. The magnitude of some parameters are two to three times worse than the 30 minute incident scenario. Some time durations for traffic returning back to pre-incident conditions falls outside the two hour experiment time period (like average travel speeds). In addition, it appears that the worst effects of some traffic parameters peaks after the duration of the incident has ended (like average delays). As with most of the traffic parameter graphs, there is a steep climb in the rate of growth showing the worse effect. This is the initial "shock" that the incident has on the traffic flows, but then after this peak, the effect lessens as traffic is diverted onto diversion routes or goes around the incident site.

The most dramatic item that stands out here is the rate at which particular traffic parameters decrease (or increase). Probably the quickest growing parameter is queue length for both the 30 minute and 60 minute incident scenarios. The 30 minute incident scenario displays reasonable decreases in performance for the increasing number of lanes blocked. Average speeds, average travel times, average delay times, number of stops and queue length show this trend. However, with the blockage of three lanes to four lanes, some of the parameters appear to display a similar trend and magnitude, showing that the severity of a three lane blockage is similar to a four lane blockage. This occurs with average speeds, average travel time and average number of stops.

6.3 Incident Durations and Number of Motorway Lanes Affected

The most prominent point here is the way in which the severity of the impacts increases with increasing number of traffic lanes affected. In some cases it is quite severe. The impacts of an incident affecting one to three lanes are severe, but when the fourth lane is affected, the effect is indeed quite noticeable. This is most likely due to the fact that at this point, the motorway traffic lanes cease to operate, indeed the motorway ceases to function. This compounding effect is immense. Also, generally the effects of a 60 minute incident are around twice that of a 30 minute incident, but for the longer duration incident, the network takes longer to recover back to pre-incident traffic conditions, sometime around 15 minutes longer (that is, 25% longer).

Average traffic speeds decrease approximately 45% for each additional lane closed for a 30 minute incident and about the same for a 60 minute duration incident. There is a dramatic decrease in average speed particularly after the closure of one lane. The average travel time for a 30 minute incident shows an immediate effect of a negative "shock wave" with the closure of all four lanes. Even with one traffic lane operating, there are some positive effects on all traffic parameters. Looking at average delays, the impacts of a 60 minute incident are much greater than a 30 minute incident. In addition, the rate at which the delay times increase for a 60 minute incident is much greater than the 30 minute incident (for example, 500 seconds average delay for a 60 minute incident going from two lanes blocked to three lanes blocked and 200 seconds average delay for a 30 minute incident going from two lanes blocked to three lanes blocked).

The average number of stops for the incident scenarios is interesting. It shows that this number peaks with the blockage of two lanes and then decreases with the blockage of all four lanes. This would most probably be due to lane changing of the motorists with one and two lanes open as lane changing induces stop / start behaviour. With three or four lanes blocked, vehicles are more or less "restrained" in their lanes (that is, no lane changing) which reduces the stop rate (change of behaviour). Also the magnitude of the 60 minute incident is far greater than the 30 minute incident. Average queue lengths exhibits expected behaviour, with large queue length growth rates occurring for the 60 minute incident. The queue grows at around 350 vehicles per lane for a time period (15 minutes) for the 60 minute incident. It also portrays a worse picture than the 30 minute incident (230 vehicles per lane per 15 minute time period).

6.4 Motorway Incident (Simple Network Section) – Level of Service

The term level of service refers to the use of average speed and average flows as a measure of the operating conditions encountered by traffic. The AustRoads (1999) Guide Part 2 "Road

Capacity" refers to a maximum rate of service flow as a measure of traffic volume. An experiment was conducted with simple incidents and average speed and average flow data was recorded for each time period (15 minutes) and at intervals of 500 metres up to a total of 5000 metres (5 kilometres) from the incident site. The output (Table 5.5 and 5.6 in the Section "Results") gives these quantities for average speed and average flows. These tables display the level of service for the time period and distance from the incident site and gives an indication on how the level of service changes and in which particular areas (that is, the distance from the incident site). The two usual motorway incident scenarios were examined. These consisted of:-

- 30 minute incident blocking two motorway traffic lanes, and;

- 60 minute incident blocking two motorway traffic lanes.

As with all the other foregoing discussions and conclusions, the effects of a 60 minute incident compound much more intensely over a 30 minute incident.

However, on examining the 30 minute incident scenario (Figure 5.16) (incident start time is 7:15am), the worst level of service for the motorway, level F, occurs at around the 7:30am to 7:45am time period and for a distance of approximately 1500 metres extending from the incident site. LOS F is below a speed of 48 km/h and with traffic flow above 2200 vehicles / hour / lane (or above 270 vehicles / 15 minutes / lane with two blocked and two lanes operational - from Table 3.9). The "jump" to a LOS F from C occurs in the next time interval, however, when the incident has finished, the return to pre-incident conditions is more "gradual". The effects of the "shock wave" of congestion can also be seen with a particular LOS occurring at a particular distance from the incident site and the rate at which this worsening effect grows. This scenario has traffic at a LOS A for around 88% of the time and then for 12% of the time at levels other than A. As mentioned in section 5.2.3, motorway speed governed the choice of level of service.

The incident of 60 minute duration (Figure 5.17) shows further effects as compared with the 30 minute incident scenario (Table 5.5 and 5.6 in Results). The immediate first impression is that the motorway flow stays at LOS F for a longer duration and over a longer distance from the incident site. Again, a particular "shock wave" of congestion has developed and is much more pronounced than the 30 minute incident scenario. At the worst point, the LOS F chiefly occurs at the time period 7:30am to 8:30am, just after the incident has ended. This is an interesting time period, for as the LOS F occurs for up to around 4000 metres away from the incident site, the front of the incident-induced queue has started to disperse, showing LOS of around B / C for a distance of up to 1000 metres or so. Once traffic gets going, the LOS A returns in a quick manner and by the last time period (8:45am to 9:00am) LOS A has been re-established again.

This scenario has motorway incident-induced traffic queues at a level of service A for around 63% of the time and around 37% of the time at levels other than A.

6.5 Motorway Incident with Western Diversion Route – Traffic Analysis

There has been some brief discussion on the results of experiments from these scenarios in the previous sections. However, by examining the data presented in the section "Results", some conclusions can be made with regard to the different diversion rates of traffic from the motorway in the two incident scenarios. Table 6.1 below details the best case for each traffic parameter for both incident scenarios and summarises the "best result" for each traffic parameter (highest flows, highest speeds, lowest travel times, lowest delay times).

Table 6.1 Comparison of motorway compliance diversion rates for different traffic parameters and incident scenarios

Traffic Parameter	30 min incident – Western Diversion Route (Motorway Compliance Diversion Rate giving best result)	30 min incident – Motorway (Motorway Compliance Diversion Rate giving best result)	60 min incident – Western Diversion Route (Motorway Compliance Diversion Rate giving best result)	60 min incident – Motorway (Motorway Compliance Diversion Rate giving best result)
Average Flows	30%	15%	20%	10%
Average Speeds	12%	40%	20%	40%
Average Travel Times	19%	38%	20%	32%
Average Delay times	12%	29%	27%	42%

The table above (Table 6.1) gives an indication of what magnitude of diversion rate would appear to give the optimum traffic solution given the particular incident scenario and travel route. As would be expected, high compliance diversion rates gives the best results for the motorway operations (but bad for diversion route), and the lower magnitude diversion rates gives best results for the diversion route. While the diversion route operates well (at whatever diversion rate to give the best result for the chosen traffic parameter above), the motorway will continue to operate well (relatively speaking), only with a minimal decease in level of service (with a small "squeeze point" at the incident site). This is due to the motorway having such large capacity – even if reduced to two traffic lanes operating for a short section.

The priority road for the road manager needs to be established at the time of the incident and this decision should be made as part of the Incident Management Plan. Many factors need to be considered in order to arrive at a correct decision and this subject is not in the scope of this research. Therefore, from Table 6.1 above, if the road manager has a 30 minute incident, blocking two traffic lanes on the motorway, and their priority is to attain the best travel time for motorway traffic, then a diversion rate of 38% to the western diversion route needs to be implemented and achieved. The effect of this is that this diversion route will obviously suffer badly, resulting in a fairly low level of service. Again, if the chosen diversion route becomes the priority road, and good travel times need to be achieved for diversion route traffic, then a diversion rate of 19% of motorway traffic needs to be done (again to the western diversion route). The motorway traffic will not suffer that much from a decision like this as the motorway has good capacity.

The level of service of the western diversion route operating solely is presented in Table 6.2 below. The western diversion route appears to operate well, especially given the fact that the longer duration incident compounds the effects on the network (25% compliance diversion rate).

Table 6.2 Summary of level of service for western diversion route using 25% motorway compliance diversion rate

Type of Experiment	Western Diversion Route Level of Service (using traffic re-assignments which give optimum operations)
30 minute incident blocking two lanes of motorway	B
60 minute incident blocking two lanes of the motorway	D

6.6 Motorway Incident with Western Diversion Route – Level of Service

For this particular diversion route to operate at level of service C, a traffic flow of approximately 603 vehicles per hour (total both ways) or around 301 vehicles per hour (one-way), at a typical speed of around 58 km/h (AustRoads Guide Part 2) is required. This is with the previously calculated directional break up of normal service road traffic flows to be 50% northbound direction and 50% southbound direction. The table of data (Table 5.8 in "Results") details the relationships between incident type, compliance diversion rate and level of service from average speed and average flows. The level of service for the diversion routes is worked out from the formulas in the AustRoads Guide Part 2 (as shown in "Materials and Methods").

Typically, the diversion route level of service decreases with increasing diversion rates from the motorway. With the lower incident duration, at the start of the incident, the level of service is reasonable at B, but increases to E for a 50% diversion rate. The 60 minute incident duration, however, starts off at a severe level of service of D and worsens to E for a 50% diversion rate. This encompasses a smaller increase in the scale of the severity, but begins at a poorer level. This is due to the more severe effects of an incident with 60 minute duration. In both cases, there is a high compliance diversion rate at which the average speeds and average flows get worse, but at around 30% compliance diversion rate, the rate for the worsening of the average speeds and average flows tend to plateau slowly to reach the worse level of service.

6.7 Comparison of Motorway and Western and Eastern Diversion Routes – Traffic Analysis

The addition of extra capacity for diverted traffic (in the form of another diversion route) could be seen to assist with management of incident-induced traffic queues. In this small network, there is scope for diverted traffic to use the eastern service road (between Coomera Interchange and Yawalpah Interchange) as a diversion route. This eastern diversion route is around 37% longer than the western diversion route but is very similar in road geometry, alignments and other general characteristics. The eastern diversion route also encompasses two additional roundabouts which diverted traffic needs to negotiate in order to rejoin the motorway traffic stream to proceed north. Also of note was that in the experiments, diverted traffic was assigned as 50% to the western diversion route and 50% to the eastern diversion route.

In this scenario, there are, in effect, three travel routes for motorway traffic to use when an incident occurs. This assists with the congestion management induced by the incident. Another very relevant point is the actual management of the three travel routes. This would require immense time and resources to manage but this cost would be small compared to the cost of delays suffered by the travelling public on the network.

Table 6.3 Comparison of western and eastern diversion rates for 50% / 50% traffic assignment to each diversion route

Traffic Parameter	30 min incident – Western and Eastern Diversion Routes (Diversion Rate giving best result for both)	30 min incident – Motorway (Diversion Rate giving best result)	60 min incident – Western and Eastern Diversion Routes (Diversion Rate giving best result for both)	60 min incident – Motorway (Diversion Rate giving best result)
Average Flows	40%	10%	30%	30%
Average Speeds	20%	30%	10%	30%
Average Travel Times	12%	30%	21%	30%
Average Delay times	12%	30%	18%	33%

6.8 Comparison of Motorway and Western and Eastern Diversion Routes – Level of Service

The addition of another diversion route may assist with dispersion of incident-induced congestion and queues generated by an incident. For the 30 minute incident blocking two lanes on the motorway, the diversion route levels of service display a slightly increasing trend. There appears to be a reasonable difference in magnitude of values for flows, and the difference in magnitudes for the speeds is also noticeable, covering a smaller difference percentage-wise for the values (Referring to Table 5.9 in "Results"). The western diversion route starts with a level of service B and finishes with E. The eastern diversion route starts with a level of service B and finishes with D. This shows that for a 30 minute incident, the eastern diversion route performs slightly better than the western diversion route as it does not go to a level of service E.

For the 60 minute incident blocking two lanes on the motorway, the diversion route levels of service exhibit slightly different behaviour. There appears to be a wider magnitude of values for flows than the shorter duration incident, and the difference in magnitudes for the speeds is also less, covering a smaller scale for the values. Also the final level of service (at the end of the incident), and the rate at which it worsens, is, as expected, worse than the 30 minute incident scenario. The western diversion route starts with a level of service C and finishes with F. The eastern diversion route starts with a level of service B and finishes with E. This shows that for a

60 minute incident, the productive use of both western and eastern diversion routes can give fair results with incident traffic queue management.

However, the level of service (with average speeds and average flows) is just a particular performance measure for network operations. As discussed elsewhere, the overall performance of all the traffic parameters (average flows, average speeds, average travel times and average delays) and in particular the travel time parameter, can the performance of this network can truly be monitored and managed. The level of service though can be used to give a fair indication of the driveability and operating conditions as perceived by the average motorist.

6.9 Traffic Re-Assignment to Western and Eastern Diversion Routes – Traffic Analysis

Leading on from the above discussion, some experiments were conducted to examine the effects of using some different diversion traffic re-assignments for the western and eastern diversion routes. All the experiments done so far, using both the western and eastern diversion routes, have sent 50% incident traffic to the western diversion route and 50% to the eastern diversion route. Also the motorway compliance diversion rate was set at 25%. Again, this was seen as an optimum value based on previous experiments.

Recent documentation by Morcombe (2005) on modelled traffic movement in times of motorway incidents has said that a typical diversion rate of 20% can be used with due regard for the rest of the immediate adjacent network. This figure was used to generate some data on the amount of the cost of delays to the community due to motorway incidents. In this report incident duration was 50 minutes with an initial total motorway blockage. However, for this research the adopted figure of 25% is appropriate. This conclusion also comes after examination of much data and many numerous field trips to the actual western and eastern diversion routes.

The diversion route traffic re-assignment percentages, used for the diversion route experiments, ranged from 30% to 50% for the western diversion route and from 50% to 70% for the eastern diversion route. There is a slight bias to the use of slightly higher percentages going to the eastern diversion route mainly due to the better travel and operational conditions that the eastern diversion route has. As mentioned before, with the use of both the western and eastern diversion routes for dispersion of incident-induced traffic queues, the eastern diversion route appears to operate better. Therefore, three travel routes are in use for traffic to negotiate around the incident – the western diversion route, the motorway itself proper and the eastern diversion route.

For the analysis of the re-assignment of diverted traffic to western and eastern diversion routes, it was elected to use only a couple of performance measures to gauge the effectiveness of the particular strategies. The performance measures chosen were average speed and average travel time. This was deemed to be appropriate for this short analysis without using the whole gambit of measures as used for other experiments. However, for further detailed analysis, average delay times and average flows could be used. But as discovered in this section, the results from the experiments conducted using the various combinations of diversion route percentages gives close ranging results with relatively little variance.

With the low capacity issues surrounding both the diversion routes as opposed to the motorway with a greater capacity, certain compromises need to be made. Achieving reasonably equitable magnitudes of each of the traffic parameters for the diversion routes and letting the motorway function as best it can will rate as the best result that can be achieved for an incident situation.

For a 30 minute incident blocking two lanes of the motorway, the performance measures of average speed and average travel time seem to indicate similar magnitudes for all permutations of the different percentage diversion rates. The shape of the graph data for all the experiments over the time periods is nearly the same shape with similar rates of increase and decrease of average speeds and average travel times for each travel route. However, with a traffic re-assignment of 45% to the western diversion route and 55% to the eastern diversion route, the network operates in an optimal fashion.

The 60 minute incident blocking two lanes of the motorway shows similar results for the performance measures of average speed and average travel time. However, there are some noticeable trends in the data presented in the graphs. Looking at the average speeds, the data for the motorway and western diversion route tend to be very similar. Only the shape of the data curve for the eastern diversion route exhibits a noticeable trend to decreasing average speeds with the increasing percentage of incident-induced traffic allocated to it. There are similar trends with the graph showing the average travel time data. The motorway and western diversion route are more-or-less the same with the eastern diversion route showing noticeable trends according to the amount of incident-induced traffic allocated to it. However, with a traffic re-assignment of 43% to the western diversion route and 57% to the eastern diversion route, the network operates in an optimal fashion.

6.10 Traffic Re-Assignment to Western and Eastern Diversion Routes – Level of Service

The level of service for the operations of the western and eastern diversion routes was calculated using average traffic flows and average speed parameters. The resultant level of service is worked out from the data presented in section 3.6.1 (Materials and Methods) on the calculation of level of service for the two lane, two way service road / rural road type scenario. The Table 6.4 below shows the magnitudes for the level of service for the western and eastern diversion routes for a particular incident scenario. Again, the eastern diversion route shows a much better level of service in both incident scenarios than the western diversion route. As expected, the western diversion route operates adequately in the 30 minute incident scenario, but for the 60 minute incident scenario, the western diversion route operates at a much worse level of service.

Table 6.4 Summary of level of service for western and eastern diversion routes using optimum percentage traffic re-assignment

Type of Experiment	Western Diversion Route Level of Service (using traffic re-assignment percentage for optimum operations)	Eastern Diversion Route Level of Service (using traffic re-assignment percentage for optimum operations)
30 minute incident blocking two lanes of motorway	D	B
60 minute incident blocking two lanes of the motorway	F	C

It is interesting that solely examining the level of service criteria, for a 30 minute incident blocking two lanes on the motorway, that if only the western diversion route is used, the Level of Service is B. However, if both the western and eastern diversion routes are used, the level of service for the western diversion route is compounded to a level of service D, but the level of service for the eastern diversion route is a B. This shows that for a 30 minute incident blocking two lanes on the motorway, just the implementation of the western diversion route is sufficient for optimum operations (based on level of service criteria).

6.11 Motorway Traffic Flows and Level Of Service

Virtually all of the above conclusions have not mentioned the operations of the motorway during these incident times. Discussion has centred around just letting the motorway operate as best it can and addressing the issue of the operations of the western and eastern diversion routes. This is a short discussion, as the results are already fairly well known. The motorway still manages to push the traffic through, albeit at a slightly lower average speed. The LOS criteria for the motorway is sought from Table 4.1 of the AustRoads (1999) Guide "Roadway Capacity". This is different to the diversion route LOS and is to be considered to be a totally separate exercise.

However, generally the experiments have reported the levels of service as outlined in Table 6.5 below.

Table 6.5 Motorway average speeds and average flows for a 30 minute incident duration

Type of Incident	Motorway Average Speeds (km/h)	Motorway Average Flows (veh/h)	Motorway Level of Service
30 minute incident blocking two lanes of motorway with deployment of western diversion route only	71	5245	D
30 minute incident blocking two lanes of motorway with deployment of both western diversion route and eastern diversion route	73	5000	D

Table 6.6 Motorway average speeds and average flows for a 60 minute incident duration

Type of Incident	Motorway Average Speeds (km/h)	Motorway Average Flows (veh/h)	Motorway Level of Service
60 minute incident blocking two lanes of motorway with deployment of western diversion route only	51	4655	E
60 minute incident blocking two lanes of motorway with deployment of both western diversion route and eastern diversion route	51	4230	E

6.12 The Value of Deployment of Both the Western and Eastern Diversion Routes

The value of using both the western and eastern diversion routes in motorway incident times may be debateable. This statement is made after considering all the fore mentioned data and conclusions. There may be value alone in just using the western diversion route for both the shorter and longer duration type incidents or indeed, just the western diversion route for all motorway incident traffic diversions. The advantage of using both the western and eastern diversion routes together is that there is more capacity for diverted traffic flows.

An examination of the results reveals that for a 30 minute incident, blocking two lanes on the motorway, the deployment of the western diversion route only gives an average speed of 55 km/h and an average flow of 181 veh/h. A 60 minute incident, blocking two lanes of the motorway, with the deployment of the western diversion route only gives an average speed of 52 km/h and an average flow of 371 veh/h.

Now, for a 30 minute incident, blocking two lanes of the motorway, the deployment of both the western and eastern diversion routes could be used. This gives an average speed of 49 km/h and an average flow of 159 veh/h for the western diversion route and an average speed of 56 km/h and an average flow of 109 veh/h for the eastern diversion route. Thus the total flow of both the diversion routes is 268 veh/h. This is a increase of 48% for traffic flows using both diversion routes against the single diversion route.

However, the average speeds are good but are unsustainable. The maximum length queue is around 857 metres northbound on the western diversion route coming up entering the western roundabout at the Yawalpah Interchange. The clearance of the motorway flows just after the incident is finished tend to "flood" the northbound motorway carriageway with traffic and this leads to a problem with merging traffic at the on-ramp from the western roundabout at the Yawalpah Interchange. These circumstances lead to congestion at the northern Yawalpah Interchange part of the research area.

For a 60 minute incident, blocking two lanes of the motorway, the deployment of both the western and eastern diversion routes could show more potential to better manage traffic flows. This conclusion shows that the western diversion route sustained an average speed of 41 km/h and an average flow of 261 veh/h and the eastern diversion route had an average speed of 51 km/h and average flow of 223 veh/h. Therefore, the total flows using both the diversion routes is 484 veh/h at an average speed of 46 km/h. This is a good result. This represents an increase of around 30% over solely just using the western diversion route and at a good average speed, even with a decrease of this parameter of around 12%.

Therefore, the use of just the western diversion route for both the 30 minute incident and 60 minute duration appears to be the most useful, and the deployment of both the western and eastern diversion routes for the 60 minute incident providing better results, based on average speeds and average flows. These performance measures are chosen to align with the calculation of level of service. A minimum type diversion route average speed, in times of motorway incidents, which would be acceptable to the general public would be around, say, 45 km/h, with around 40 km/h as a very minimum. Any lower would not be acceptable by the public and would damage the credibility of any future incident traffic management plans. This aligns to around a level of service E, which is not great.

6.13 Additional Thoughts on Provision of Extra Diversion Capacity in Times of Motorway Incidents

The ability to increase capacity of the diversion for incident-induced queues will assist to some degree with incident traffic management. As discussed previously, there are some other ways to achieve this within the defined research area. These include the following:-

- Reconfiguring the two lane, two way diversion route / service road, just west of the motorway, to operate as a two lane, one way diversion route. In addition, the eastern diversion route could also be "converted" to operate as a two lane, one-way road carrying northbound diversion traffic. However, there would be big problems with the logistics of carrying out such diversion plans with resources and materials and other elements. Also, the motorists would need education in their driving behaviour and then understand how the diversion traffic routes would work.

- The utilisation of the motorway shoulders, either on the median side (2.4 metres) or on the outside (3.0 metres) of the through traffic lanes, to provide an additional traffic lane does have some merits. The main advantage in providing another "lane" is reducing the incident-induced queues by guiding traffic around the incident site. In addition, the other advantage, which could also be significant, is that motorists would not have to leave the main travel route and get tangled up with diversion routes. This is particularly relevant with motorists not familiar with roads off the motorway. Also, there would be a crucial need for no vehicle breakdowns if traffic is to use the shoulders as traffic lanes to circumvent the incident site. Also, this initiative could hinder emergency services operations and would therefore need to be managed carefully.

- More diversion route capacity could be made by utilising the opposing motorway traffic lanes on the other side of the median. With this concept, an existing "Emergency Crossover" point could be used to channel incident-induced traffic across onto the other opposing traffic lanes and then maybe use one or two traffic lanes for traffic to move around the incident. The impacts of this procedure on the carriageway with opposing traffic flows would be immense; in effect a separate traffic management plan would be needed for this exercise. Of particular interest would the messaging needed on the variable message signs to portray the traffic flow layout that is ahead. This is in addition to the incident management messages which would be displayed for the incident diversion / traffic management plan.

The recent accident (between four trucks and three cars) on 23rd March 2007, and subsequent fire in the Burnley Tunnel in Melbourne, which killed three people, has again brought the topic of traffic operations and road rules in incident times to be again examined in more detail. Some of these outcomes could be utilised in Queensland on any roads which have a major incident. Even though the amended road rules particularly refer to tunnel incidents, they could equally be applied to other types of road incidents. The changes to the road rules in times of incidents could include the following:-

- All heavy vehicles to travel at 10km/h less than the allowable speed;
- All heavy vehicles to travel in the left hand traffic lane;
- Ban any lane changes;
- Increase of traffic fines and demerit points for motorists who ignore the new rules.

In addition to these measures, there could be other changes to the traffic element of the incident management strategy that may be introduced in times of motorway incidents. This could possibly centre around a particular vehicle type being directed to use a particular route. Thus if there was a particular incident that required the use of both the western and eastern diversion route, heavy vehicles could be directed to only use the western diversion route and cars be directed to only use the eastern diversion route, or vice-versa. This may or may not be a good strategy, but is worthy of consideration to improve traffic flows.

6.14 Other Thoughts on Motorway Traffic Operations

The provision of an additional highway, with three or four traffic lanes in each direction, which runs parallel to, and has connections to the motorway, would provide the optimal diversion route. This is indeed the case in the United States where they have a large, diverse road and highway network. This initiative was launched a few years ago, but was not carried out due primarily to an issue regarding fauna (koalas). However, a new initiative (Intra Regional Transport Corridor) was launched which again includes a highway running parallel with the motorway, but it is very much in the concept planning stages of development.

Another thought which could be raised is that of how to get some validation and calibration of all the aspects for the different elements of all the models produced in this research. The only ideal way for this to happen is to "stage" an actual incident which replicates the actual conditions for a selected experiment as used in this research. This idea is most definitely frowned upon and would be immoral, unethical and illegal. This idea or notion will not be expanded upon and only mentioned for the sake of completeness. However, if an incident did happen under normal circumstances (with no "assistance" or control) then there may be scope to use or invoke some of the methodologies as concluded above. Systems, resources and materials would need to be ready to be pressed into productive use immediately. This is very hard to achieve in reality.

Another aspect also worthy of mentioning is outside uncontrollable events or resources. Reference is made in this regard to the media reporting back to their television and radio stations with reports and updates on newsworthy motorway incidents. Of particular concern are media reporters in helicopters. In the 30 minute incident scenario, there would probably be minimal coverage by reporters and small reports on the media. However, with a 60 minute incident, there is potential for media coverage and this may involve reporters in a helicopter. This creates unnecessary distractions for the public and emergency services and other road users leading possibly to secondary accidents and other unnecessary traffic diversions. However, if the Police declare the incident a Major Incident or Disaster then entry into all airspace above / around the site is restricted. This would prohibit helicopters with reporters. This declaration by Police would not probably happen unless there were many fatalities or all four motorway traffic lanes were blocked for a reasonable amount of time (say more that 30 minutes).

With the costs of delays induced by incidents on the motorway, currently in the range of around, say $1000 to $1300 per minute (Valentine, 2003), any measures that can reduce delays and restore pre-incident traffic conditions will result in benefits for many parties. The use of diversion routes has many benefits as detailed in this study. The benefits derived from a good incident traffic management diversion plan will extend from the highest level of government all the way down to a member of the public.

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CHAPTER 7

Conclusions

7.1 General Remarks

The study presented in this thesis has provided an insight into incident traffic management together with relevant and useful information. This includes making a positive contribution to understanding traffic flows especially in times of incidents and traffic diversions. The conclusions from the experiments conducted could also prove useful in applications to other areas of the Pacific Motorway, and possibly to similar motorways in other districts in Queensland. Aligning the simulated data to actual data is also useful in endeavouring to make all the results more meaningful (by using calibration and validation of AIMSUN model). Each element of the experiment was examined and checked for completeness and also how it interacted with other elements to give a reliable outcome. In conclusion, there are no gaps in the understanding of incident traffic management methodology involving traffic diversions and capacity (quantitative) and the operating conditions with level of service (qualitative) analyses.

7.2 Summary of Research Outcomes

The present study led to four major conclusions:

1. From a level of service perspective, an incident of 60 minutes duration, blocking two motorway traffic lanes, is approximately three times worse than an incident of 30 minutes duration blocking two motorway traffic lanes. This conclusion is from an examination of average speeds and average flows resulting from these incidents on a simple section of motorway. Average speeds appear to be the most variable.

2. With a 30 minute incident blocking two motorway traffic lanes, the study network appears to operate in an effective manner using a compliance diversion rate (to the western diversion route) of approximately 24%. Conversely, with a 60 minute

incident blocking two motorway traffic lanes, the motorway and the western diversion route appear to operate adequately using a compliance diversion rate (to the western diversion route) of approximately 26%. These outcomes come from an examination of these traffic parameters: the average flow, average speed, average travel time and average delay time. The qualitative level of service effects for these incident scenarios for the western diversion route is "B" and "D" respectively, which is reasonable. High compliance diversion rates (>35%) cause excessive queueing on the motorway and therefore increases the risks of secondary incidents.

3. Looking at the deployment of both the western and eastern diversion routes, for a 30 minute incident, blocking two motorway traffic lanes, a compliance diversion rate of 21% is best for the operation of both the western and eastern diversion routes, and around 25% compliance diversion rate is best for the operation of the motorway. For a 60 minute incident, blocking two motorway traffic lanes, a compliance diversion rate of 20% is best for the operation of both the western and eastern diversion routes, and around 31% compliance diversion rate is best for the operation of the motorway. This is based on the incident-induced traffic queues being assigned as 50% to the western diversion route and 50% to the eastern diversion route. The option of three travel routes (western diversion route, motorway and eastern diversion route) gives further flexibility in managing traffic queues. The compliance diversion rate of 21% gives optimal operations of both western and eastern diversion routes for both incident scenarios and for this traffic assignment.

4. Using a motorway compliance diversion rate of 25% (% traffic diverted from the motorway onto diversion routes) and re-assigning this diverted traffic 45% to the western diversion route and 55% to the eastern diversion route, the 30 minute incident scenario (blocking two motorway traffic lanes) is being managed to give an optimum outcome. A re-assignment of diverted traffic of 43% to the western diversion route and 57% to the eastern diversion route gives optimal performance with the 60 minute incident scenario (using a motorway compliance diversion rate of 25% and blocking two motorway traffic lanes). These traffic re-assignment values are based on achieving the optimal average speeds and average travel times for these diversion routes. However, the final traffic re-assignment percentage values are nearly similar for both incident scenarios.

7.3 Directions for Future Study

The present research has achieved several significant outcomes. However, there are some areas which could benefit from further study and these are presented below:

1. Different incident scenarios could be further explored. The two incident scenarios examined in this research were the two most common occurrences. As traffic volumes and compositions change, the type of incidents will change and will require further investigation. Other points, such as incidents occurring on the right hand traffic lanes (as opposed to incidents occurring on the left hand traffic lanes as in this research) are other avenues to explore.

2. The effects of heavy vehicles on the traffic streams and their involvement in incidents is another area for further study. This will become important particularly if there is legislation introduced which will restrict certain classes of vehicles to only use particular motorway traffic lanes. What will be the effect of such action on incident traffic management?

3. Further analysis using traffic microsimulation packages also needs to be mentioned. The AIMSUN microsimulation package has some detailed route choice models with a lot of traffic parameters (cost, delay, time, speed) which can be altered to give many different results. As the use of microsimulation increases, the variablility of incident elements (for example, a particular decrease in average motorway speeds to initiate a diversion) can be examined in finer detail.

4. The influence of messaging on VMS also needs to be further researched. Many studies have been conducted over the years on this topic but it is still changing and evolving, especially with the increased number of elderly motorists using the network. This will also require possibly some comments from psychologists as well on how motorists perceive different messages and how they will react.

5. Concept planning for roads can benefit from incident traffic management examples. Planning a motorway with interchanges will need to further consider the implications of incidents, particularly when diversions are needed. If diversion routes can be modelled and incidents can be simulated, then knowledge can be gained on suitable motorway, interchange and service road (diversion route)

layouts. This aspect needs to be considered along with capacity, safety and efficiency of the layout of future transport infrastructure.

6. Looking further at the surrounding road network, some thought could be given to incident traffic management when special events are on at locations close to the motorway. This will include Music Festivals at Parklands Showgrounds, Football Games at Carrara Stadium and Robina Stadium. Special events at these locations may induce non-incident related congestion on the motorway. This is an abnormal traffic condition and the preparation of a special incident traffic management plan when an incident occurs would be viewed favourably by stakeholders.

7. Validation of the different model-predicted performances presented in this research could also be an area of further study. Validation is a crucial element of the complete modelling task in order to give a particular degree of confidence in the models' outputs. It primarily involves checking the models' predictions to the field measurements of traffic performance and would include an analysis of errors. A framework, strategy and operational requirements would need to be established together with agreement through consultation with targeted stakeholders.

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Appendix A

Table A1 Travel time survey and speed survey results Pacific Motorway 2004

Route GC4 - Pacific Motorway (Beenleigh-Nerang)
Average by route section August 2004

Car Inbound	AM peak		Off-peak		PM peak	
	07:00:00-09:00:00		10:30:00-12:30:00		15:30:00-18:30:00	
Section end point	Avg Time (seconds)	Avg Speed (km/hour)	Avg Time (seconds)	Avg Speed (km/hour)	Avg Time (seconds)	Avg Speed (km/hour)
Southport-Nerang Road	12	53			13	51
Smith Street (north bridge)	148	96			148	96
Gold Coast Highway	111	96			111	96
Helensvale Road	88	104			89	103
Oxenford-Southport Road	89	101			91	99
Foxwell Road	113	103			114	101
Yawalpa Road	170	101			173	99
Mirambeena Road	103	100			104	99
Peachey Road	84	101			86	99
Computer Road	126	101			126	101
Stapylton-Jacobs Well Road	104	100			104	100
Beenleigh South	81	100			82	100
Beenleigh North	67	98			67	98
Logan River (north abutment)	54	107			54	107
Total route	**1350**	**107**			**1362**	**98**

Car Outbound	AM peak		Off-peak		PM peak	
	07:00:00-09:00:00		10:30:00-12:30:00		15:30:00-18:30:00	
Section end point	Avg Time (seconds)	Avg Speed (km/hour)	Avg Time (seconds)	Avg Speed (km/hour)	Avg Time (seconds)	Avg Speed (km/hour)
Beenleigh North	54	98			52	102
Beenleigh South	68	104			66	106
Stapylton-Jacobs Well Road	84	95			81	98
Computer Road	107	99			103	103
Peachey Road	129	99			125	102
Mirambeena Road	88	97			85	101
Yawalpa Road	103	101			101	102
Foxwell Road	173	100			170	102
Oxenford-Southport Road	111	100			111	102
Helensvale Road	90	101			89	101
Gold Coast Highway	89	100			87	103
Smith Street (north bridge)	109	100			107	101
Southport-Nerang Road	146	97			142	99
Nerang River (north abutment)	11	65			11	70
Total route	**1363**	**99**			**1332**	**101**

Table A2 Travel time survey and speed survey results Pacific Motorway 2005

Route GC4 - Pacific Motorway (Beenleigh-Nerang)
Average by route section June 2005

Car Inbound *Section end point*	AM peak 07:00:00-09:00:00 Avg Time (seconds)	Avg Speed (km/hour)	Off-peak 10:30:00-12:30:00 Avg Time (seconds)	Avg Speed (km/hour)	PM peak 15:30:00-18:30:00 Avg Time (seconds)	Avg Speed (km/hour)
Southport-Nerang Road	7.4	88.1			7.6	86.1
Smith Street (north bridge)	147.5	95.6			146.4	96.3
Gold Coast Highway	111.4	97.9			112.2	97.2
Helensvale Road	87.8	100.2			89.4	98.5
Oxenford-Southport Road	90.4	100.2			92.5	98.0
Foxwell Road	153.7	73.8			135.6	83.7
Yawalpa Road	182.9	93.6			176.8	96.8
Mirambeena Road	106.2	97.1			107.4	96.1
Peachey Road	86.5	98.0			86.8	97.6
Computer Road	131.8	96.6			132.2	96.3
Stapylton-Jacobs Well Road	109.7	95.8			109.8	95.7
Beenleigh South	86.0	96.2			89.3	92.5
Beenleigh North	69.7	94.2			70.1	93.7
Logan River (north abutment)	53.7	97.5			53.6	97.7
Total route	**1424.9**	**94.1**			**1409.7**	**95.1**

Car Outbound *Section end point*	AM peak 07:00:00-09:00:00 Avg Time (seconds)	Avg Speed (km/hour)	Off-peak 10:30:00-12:30:00 Avg Time (seconds)	Avg Speed (km/hour)	PM peak 15:30:00-18:30:00 Avg Time (seconds)	Avg Speed (km/hour)
Beenleigh North	63.3	79.5			64.4	78.2
Beenleigh South	68.8	96.3			68.0	97.4
Stapylton-Jacobs Well Road	85.2	98.2			85.6	97.7
Computer Road	108.8	96.2			107.9	96.9
Peachey Road	130.2	98.5			132.1	97.1
Mirambeena Road	88.1	95.9			88.5	95.4
Yawalpa Road	104.8	97.7			105.0	97.5
Foxwell Road	176.0	97.8			177.9	96.7
Oxenford-Southport Road	117.3	97.3			118.2	96.6
Helensvale Road	94.1	96.1			94.4	95.7
Gold Coast Highway	92.8	94.7			94.1	93.4
Smith Street (north bridge)	116.4	93.9			114.7	95.3
Southport-Nerang Road	155.9	90.4			154.7	91.1
Nerang River (north abutment)	8.3	88.8			8.9	82.5
Total route	**1409.8**	**95.2**			**1414.5**	**94.9**

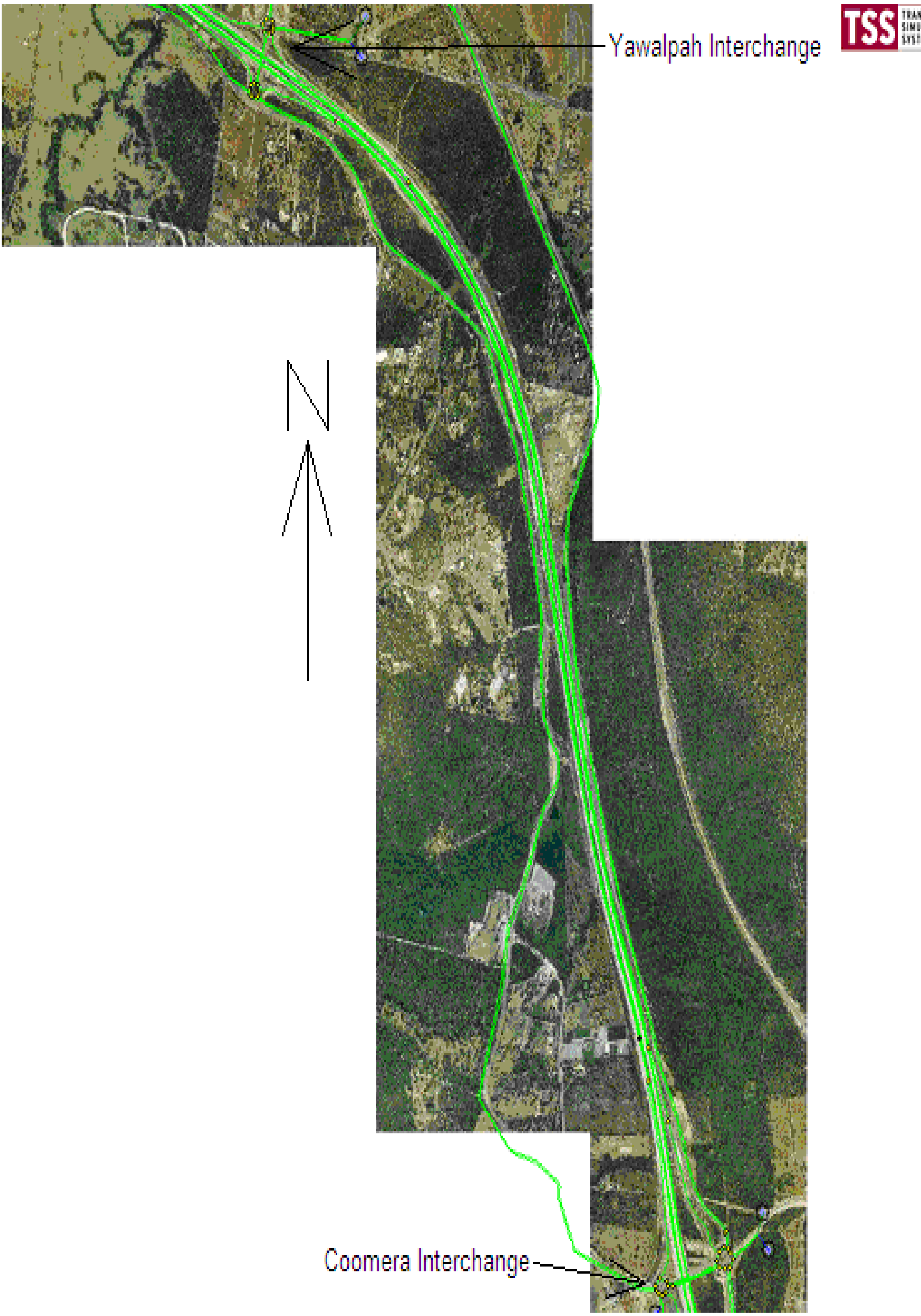

Figure A1 Research model overlayed on raster images

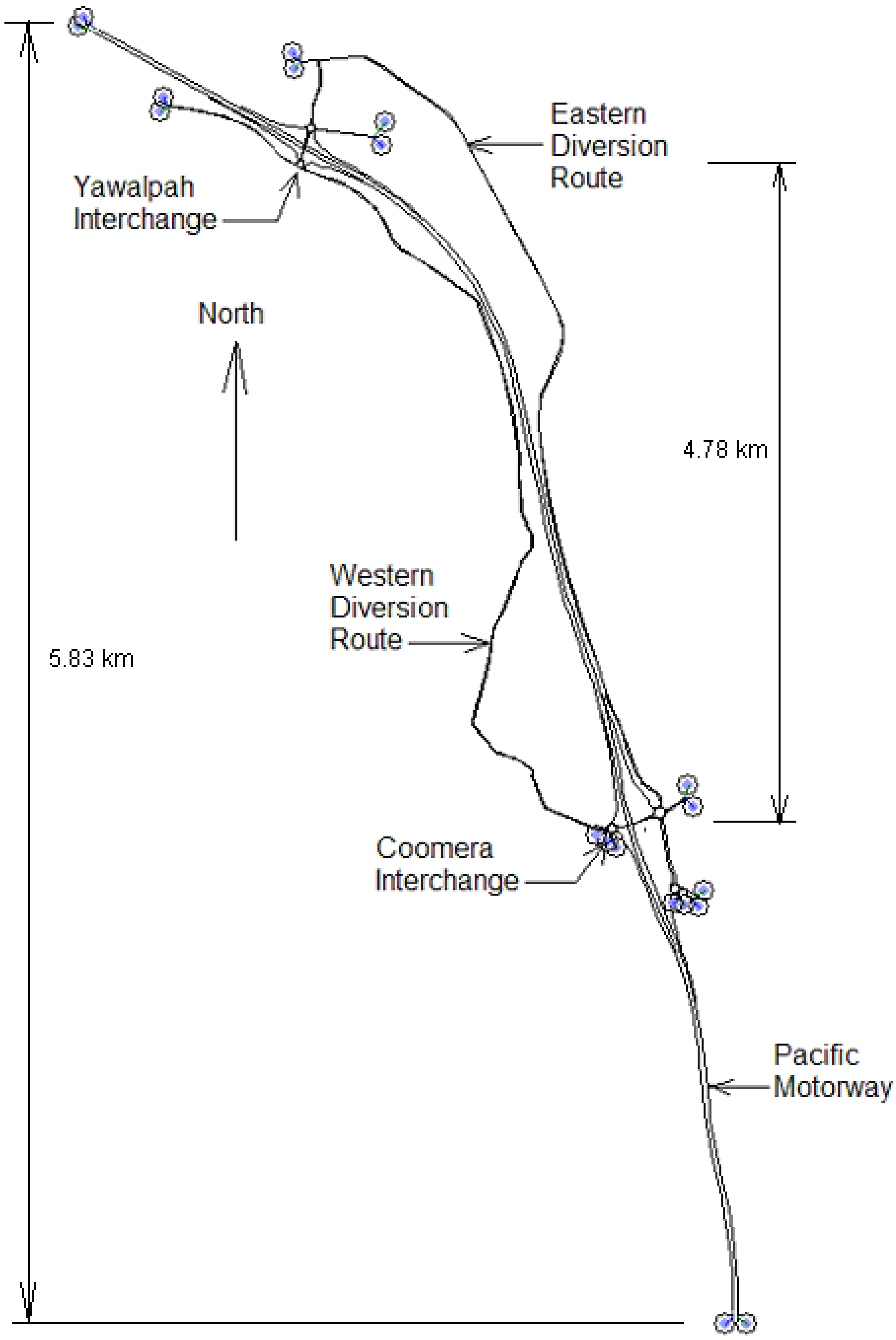

Figure A2 Research area showing eastern and western diversion routes

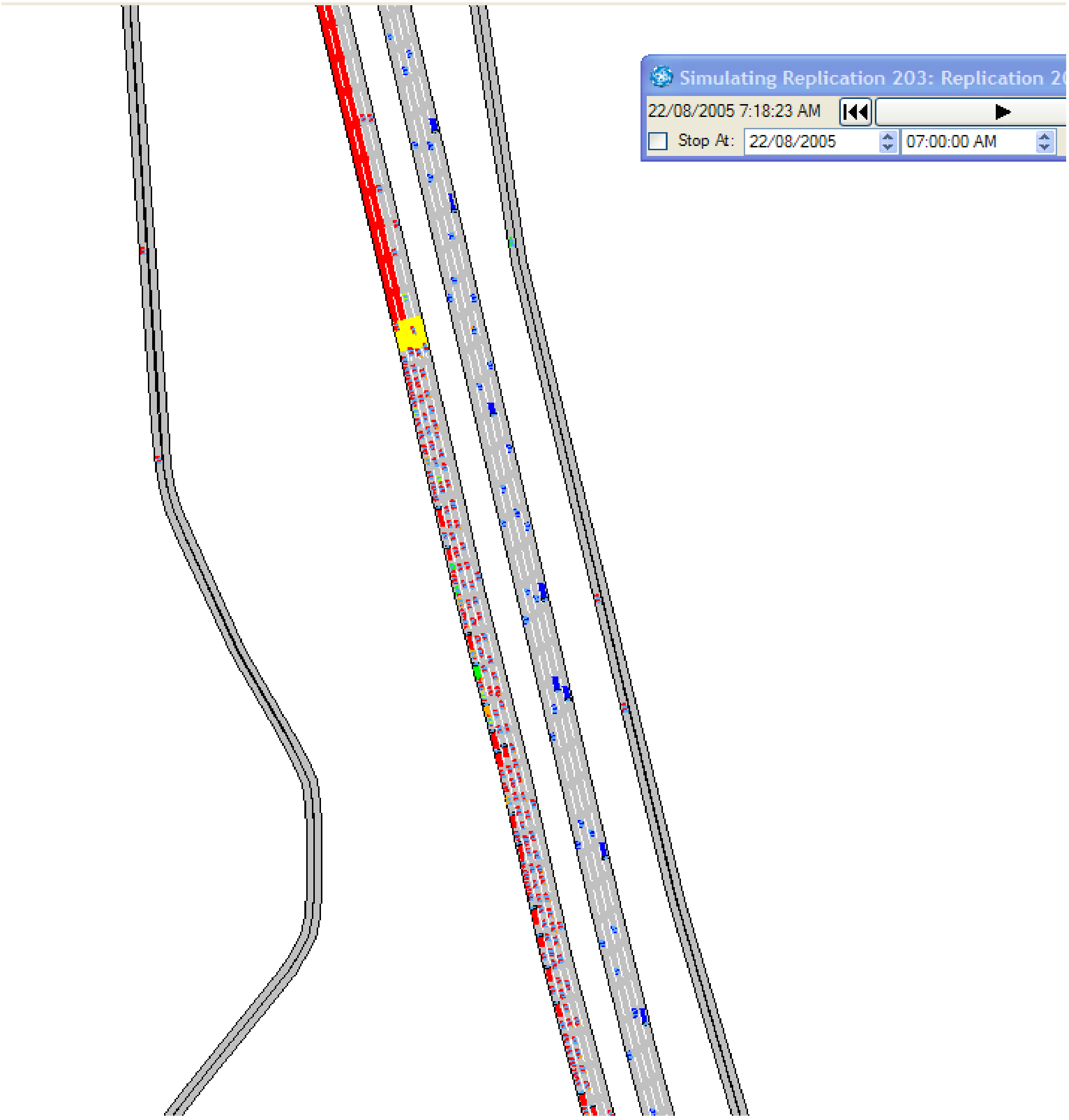

Figure A3 Simulated traffic queues at incident site

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