Evaluation of incident impacts on integrated motorway and arterial networks using traffic simulation

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1 Introduction

The task of quantifying the impacts of incidents is an important and necessary undertaking in order to justify the expenditure of public funds on Intelligent Transport Systems (ITS) and other road projects. Roadway incidents impose a substantial cost to society when delays, congestion, secondary accidents, and environmental emissions are taken into consideration (Gillen and Levinson, 2004; US Department of Transportation, 2008). Incident impacts can be substantially reduced through implementation of incident management programs. In recent times, there has been a growing interest among researchers and practitioners in developing traffic management plans for integrated motorway and arterial road networks. However, comprehensive research tools for evaluating the benefits of these systems have not been fully developed. For example, the impacts of incident management programs will depend on the extent of existing congestion on the road network, and will also vary according to the severity of the incident, its duration, and the time of day during which it occurs. The use of computer modelling, and microscopic traffic simulation in particular, offers a cost-effective approach in which input conditions can be varied (e.g. to reflect incidents during peak and non-peak conditions) and the impacts of incidents on network performance can be evaluated (Dia and Cottman, 2002; Ben-Akiva *et al.*, 2003).

The work reported in this paper aims to quantify the traffic and emissions impacts of motorway incidents and evaluating the benefits of incident management strategies. The test-bed selected for this study comprised a traffic simulation model of the Pacific Motorway (also called the M1 Motorway) between Brisbane and the Gold Coast. The primary objective of this work was to demonstrate the feasibility of using AIMSUN NG microscopic traffic simulation model (TSS, 2008) to evaluate the impacts of incidents using field data and other related information from the Nerang Traffic Management Centre.

2 Methodology and model development

This research study involved the development of a large scale simulation model covering an area approximately 122 kilometres squared, including 43 kilometres of the motorway and about 85 kilometres of arterial roads on the surrounding network (Figure 1). The motorway also includes 15 interchanges which link the motorway to an extensive service road network and to major roads in each locality. The development of the microscopic traffic simulation model was characterised by a high degree of geometric detail and specification of route choice and driver behaviour parameters. The model was extensively calibrated and validated for the a.m. and p.m. peak periods with approximately 90,000 vehicles modelled inside the network during a 2-hour period. The model was calibrated using traffic counts from loop detector sites on the M1 Motorway and mid-block counts on a number of roads on the arterial network. The calibration process involved a detailed examination of the global and local parameters to ensure that the selected parameters produced results for modelled traffic counts and travel times in close agreement with field data. The validation process involved testing the calibrated model using a traffic data set which was not used in model calibration.

The work reported in this paper is part of the second author's Master of Philosophy research thesis which he completed at the University of Queensland

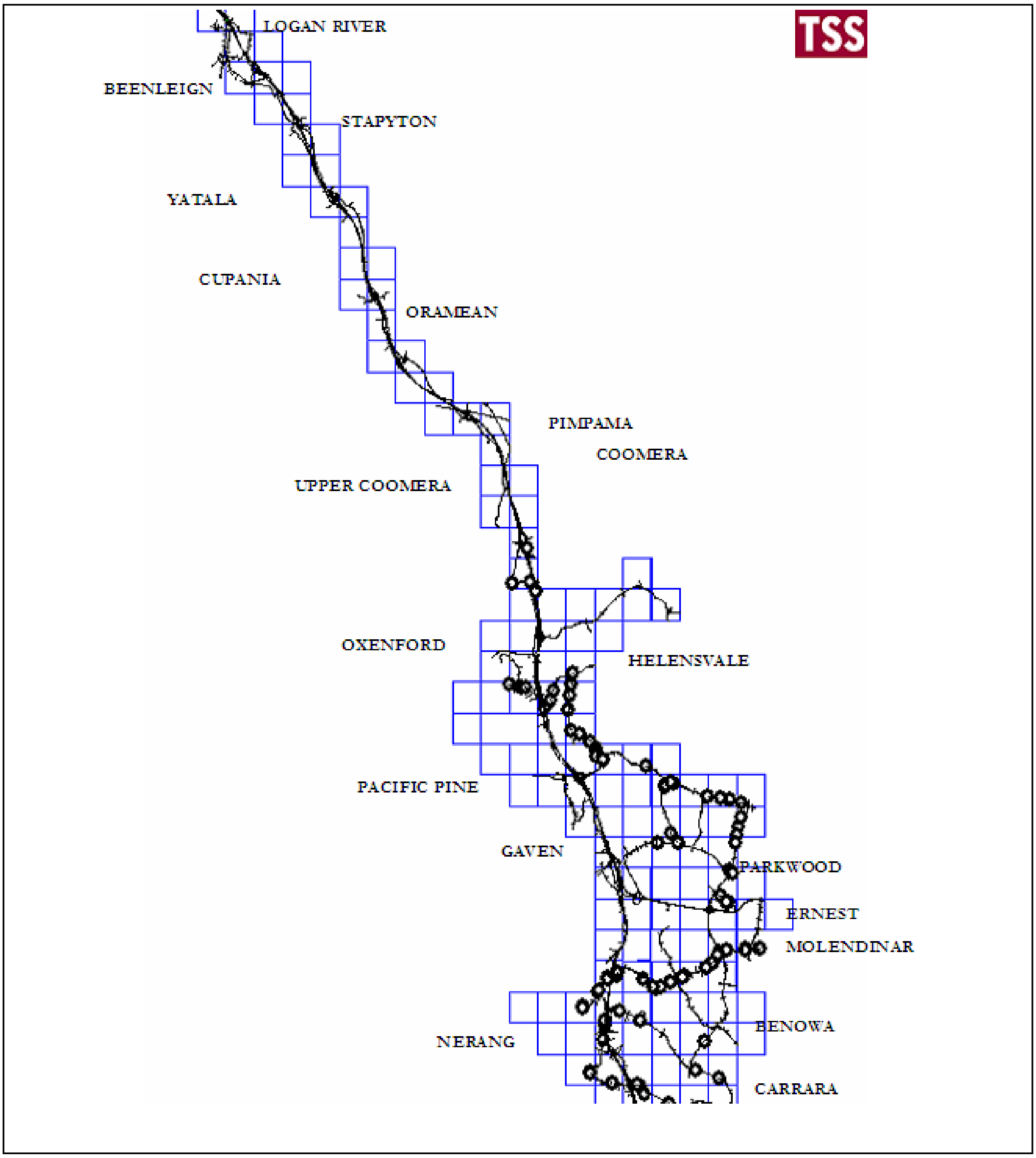

Figure 1 – Schematic of the AIMSUN Model

A detailed discussion of the model development tasks is beyond the scope of this paper and has been reported in previous publications (Stirzaker and Dia, 2007; Dia and Panwai, 2007). A brief description of some of the details relevant to this paper is provided next.

2.1 Determination of traffic demand data

This task involved the extraction of traffic demand data from an existing EMME/2 model for the Gold Coast area for both the a.m. and p.m. peak periods and adjusting the matrix using traffic counts and matrix estimation techniques. The original O-D matrix which comprised 188 EMME/2 zones was grouped into 43 zones based on the proximity of the zones. Both 2-hour and 15-minute O-D matrices for private vehicles and trucks were provided in the model for the a.m. peak (07:00-09:00) and p.m. peak (16:00-18:00) periods.

2.2 Traffic modelling, calibration and verification

A number of signalised and unsignalised intersections were modelled on the arterial network. Signalised intersections in the model operated under fixed-time and vehicle actuation (isolated) modes. The signal timing control plans were extracted from the STREAMS traffic control system for the a.m. peak (07:00-09:00) and p.m. peak (16:00-18:00). The maximum and minimum green times for the vehicle actuated (isolated) intersections were also obtained. For the un-signalised intersections, the control was modelled using stop and yield signs. Pedestrian crossings were also included in the model. The pedestrian crossings phases were part of the vehicle phases for the fixed-time control while the minimum green time was used in the case of vehicle actuation.

This task also involved examination of the AIMSUN global and local parameters to produce results for modelled traffic counts and travel times 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 census data. A number of replications and statistical tests were applied to ensure statistical reliability of results. This task also included verification of the model's operation including checks on link connectivity, infeasible paths and undefined turns.

2.3 Calibration and validation results

The calibration process involved a detailed examination of the AIMSUN global and local parameters to ensure that the selected parameters produced results for modelled traffic counts and travel times which were in close agreement with field data. The M1 and arterials model was calibrated using traffic counts from loop detector sites on the M1 and mid-block counts on a number of roads on the arterial network. The calibration results for the M1 showed traffic count errors of around 14 and 6 per cent during the a.m. and p.m. peak periods, respectively. For the arterials, the calibration errors were around 10 and 13 per cent for the a.m. and p.m. peak periods, respectively. The calibrated M1 model was validated using average speeds collected from loop detector sites on the motorway. The validation results showed overall validation errors of around 8.5 per cent, which is an excellent result given the large scale of the model. For the arterial roads, three performance measures were used for validation. These included mid-block traffic counts, speeds and travel times. The results showed overall travel time errors between 0.6 and 18 per cent; speed errors between 8 and 20 per cent; and mid-block traffic count errors between 12 and 24 per cent. All of these errors are acceptable given the large scale of the model coverage and also given the random nature of traffic (Caltrans, 1992; Elmar *et al.* 2004). The results of the calibration and validation showed that the model provided an accurate representation of field conditions and that its precision is consistent with findings reported for similar large scale models. These results provided a good degree of confidence in the model's ability to replicate field conditions and its suitability for use as a valid tool for modelling traffic management and ITS applications on the M1 and surrounding arterial network on the Gold Coast.

2.4 Simulation of incidents

The incident databases at the Nerang Traffic Management Centre were examined to retrieve information about the location of incidents, their duration and severity (in terms of the number of blocked lanes) for incidents dating back to 2004. The information included the time the incident occurred, the time when it was cleared, classification of each incident and the time-stamped loop detector data from both the immediate upstream and downstream stations where the incident occurred. Analysis of this data showed a number of locations that were over-represented in terms of their incident frequency. A large number of incidents were simulated at these locations with durations of 1.0 to 1.5 hours with incidents modelled to block either one or two lanes. A total of 54 incidents were simulated for the morning a.m. peak and 66 incidents for the p.m. peak (total of 120 incident cases). A number of localised and network-wide key performance indicators including average speeds, travel times, delays, number of stops, fuel consumption, operating costs and emissions were collected.

3 Evaluation of incident impacts

The traffic impacts were measured at both the local and network levels. For the local impacts analysis, a major incident that occurred at 7:15am and blocked two lanes on the northbound direction was simulated for 1.5 hours. Figure 2 shows the incident and the resulting queues around 45 minutes after its occurrence.

3.1 Local impacts

For local impacts, traffic statistics were collected for the section of motorway immediately before the incident location (this section of road is around 600 metres in length as shown in Figure 2). Table 1 lists the traffic statistics that were collected for the base case scenario (without incident) and Table 2 lists the corresponding statistics for the incident case scenario.

These results show that traffic flows in the section immediately before the incident reduced from 3,931 to 1,783 vehicles per hour due to the incident. This meant that the incident resulted in a reduction of around 55 per cent in the volume of traffic that passed through the section. The results also showed that average section speed dropped from 95 to 60 km/h (a reduction of around 37 per cent in average speeds) and that the average section travel time increased from 19 to 145 seconds. The average delay per vehicle increased from 1 to 127 seconds and the average stopped time increased from zero to 111 seconds per vehicle.

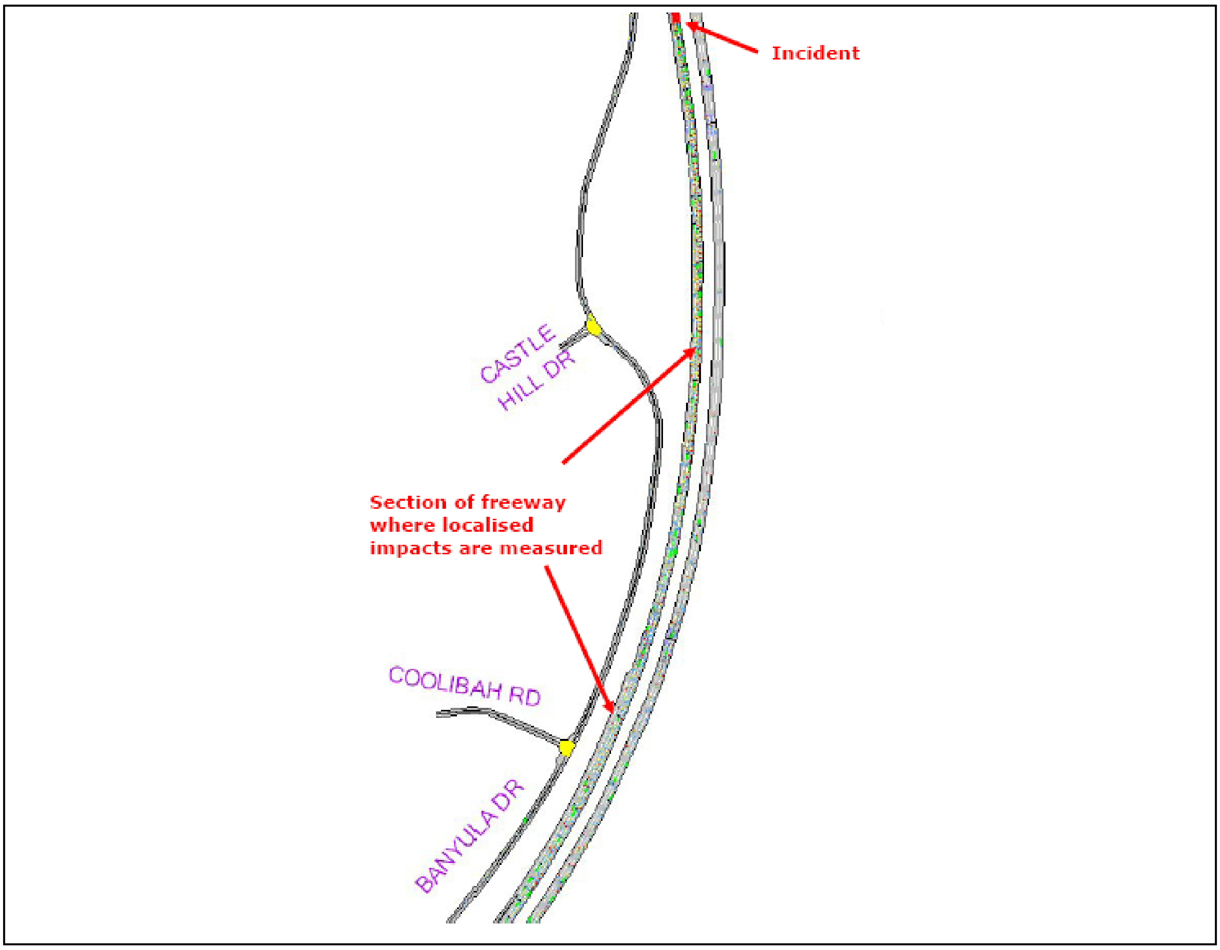

Figure 2 – Schematic of M1 Showing Incident Impacts after 45 Minutes

Table 1 – Traffic statistics for section of freeway immediately before incident (Normal conditions without incidents)

Time Interval	*Average section flow (veh/h)*	*Average section speed (km/h)*	*Average section travel time (second)*	*Average delay per vehicle in section (second)*	*Average stopped time per vehicle in section (s)*	*Average number of stops per vehicle in section*
07:00-07:15	3032	98	18	0	0	0
07:15-07:30	3364	98	19	1	0	0
07:30-07:45	3276	96	19	1	0	0
07:45-08:00	3960	95	19	1	0	0
08:00-08:15	4128	96	19	1	0	0
08:15-08:30	5020	91	20	2	0	0
08:30-08:45	4456	94	19	1	0	0
08:45-09:00	4208	92	20	2	0	0
Average	**3931**	**95**	**19**	**1**	**0**	**0**

Table 2 – Traffic statistics for section of freeway immediately before incident (Incident conditions)

Time Interval	*Average section flow (veh/h)*	*Average section speed (km/h)*	*Average section travel time (second)*	*Average delay per vehicle in section (second)*	*Average stopped time per vehicle in section (s)*	*Average number of stops per vehicle in section*
07:00-07:15	3032	98	18	0	0	0
07:15-07:30	2336	40	93	75	51	2
07:30-07:45	2180	10	307	288	250	6
07:45-08:00	2268	13	267	249	209	5
08:00-08:15	2168	16	424	406	374	4
08:15-08:30	792	100	18	0	0	0
08:30-08:45	756	100	18	0	0	0
08:45-09:00	728	101	18	0	0	0
Average	**1783**	**60**	**145**	**127**	**111**	**2**

3.2 Network impacts

The traffic impacts were also measured at the network level for each of the simulated incidents. This analysis provided a more global picture of the impacts outside the immediate area in the vicinity of the incident. It also allowed for measuring the environmental impacts on the whole road network. Table 3 and Table 4 provide the traffic impact results for the a.m. and p.m. models, respectively. Only the individual results for a selected number of incidents are provided in these tables along with an average that was calculated for all the incidents.

The results for the a.m. model showed that, on average, the 54 incident cases resulted in around 2.2% increase in travel time; 5.7% increase in delays; 10.0% increase in densities; 11.5% increase in stop times and 11.1% increase in number of stops. The results for the p.m. model showed a similar trend where the 66 incident cases resulted in around 2.5% increase in travel time; 4.5% increase in delays; 8.3% increase in densities; 3.4% increase in stop times; and 25.0% increase in number of stops.

It should be mentioned here that although some of these impacts appear small (e.g. 2.5% increase in travel times), the corresponding financial costs are substantial. Dia (2003) evaluated the benefits of reductions in travel times on fourteen routes comprising 41 kilometres and 66 signalised intersections in the city of Mooloolaba in Queensland. The results showed savings of around A$ 37 per signalised intersection per day for every one per cent improvement in travel time. It was estimated that for a city like Brisbane, a one per cent saving in travel times is valued at A$ 222K per day or A$ 81M per year.

Table 3 – Traffic network-wide performance using the a.m. model

Case	*Travel time (sec/km)*	*Delay (sec/km)*	*Density (veh/km)*	*Stop time (sec/km)*	*Number of stops*
Base case scenario without incidents					
	90	35	10	26	0.9
Selected incident cases					
Case 6	93	38	11	29	1.0
Case 12	92	38	11	28	1.0
Case 18	94	39	11	30	0.9
Case 24	92	37	11	28	1.0
Case 30	91	37	11	27	1.0
Case 36	92	37	11	28	1.1
Case 42	90	36	10	27	0.9
Case 48	93	38	12	29	0.8
Case 54	93	38	12	29	0.8
Average of all 54 incident cases for the duration of the 2-hour a.m. peak period	**92**	**37**	**11**	**29**	**1.0**
Difference between base case and incident scenarios	**2.2%**	**5.7%**	**10.0%**	**11.5%**	**11.1%**

Table 4 – Traffic network-wide performance using the p.m. model

Case	*Travel time (sec/km)*	*Delay (sec/km)*	*Density (veh/km)*	*Stop time (sec/km)*	*Number of stops*
Base case scenario without incidents					
	120	67	12	58	1.6
Selected incident cases					
Case 6	123	69	13	60	1.6
Case 12	126	72	13	62	1.8
Case 18	123	69	13	59	1.7
Case 24	121	68	13	58	1.7
Case 30	124	70	13	60	1.7
Case 36	120	67	13	58	1.6
Case 42	122	68	13	59	1.7
Case 48	121	68	13	59	1.6
Case 54	120	66	13	59	1.6
Average of all 66 incident cases for the duration of the 2-hour p.m. peak period	**123**	**70**	**13**	**60**	**2.0**
Difference between base case and incident scenarios	**2.5%**	**4.5%**	**8.3%**	**3.4%**	**25.0%**

3.3 Fuel consumption, operating costs and emissions impacts

Vehicle emissions and fuel consumption rates are functions of the instantaneous speed and acceleration of individual vehicles. Micro-simulation models can produce accurate emissions and fuel consumptions estimates, although this depends on the accuracy of speeds and accelerations produced by the car following model. Traditionally emissions estimates have been calculated using functions based on average speeds. In general, the average speed method is inadequate because different driving patterns can produce the same average speed, while exhibiting totally different driving dynamics, and consequently different emissions and fuel consumption rates (Sturm *et al.*, 2000).

The four-model elemental model (Akcelik and Besley, 2003) was used in this study. This model is based on drive cycles to estimate fuel consumption and pollutant emissions. The drive cycles come from the standard drive cycle or drive-cycle data representing a series of traffic events which are specified in term of cruise, idle and speed change. The algorithm is based on the power-based model developed by Post *et al.* (1985), which relates instantaneous fuel consumption to the instantaneous power demand of the vehicle.

The key advantage of the power-based model is that it relates fuel consumption to the fundamentals of vehicle motion which is relatively easy to calibrate using an instrumented vehicle. In the model implementation in SIDRA INTERSECTION, emissions are calculated for Light (1,400 kg) and Heavy Vehicles (11,000 kg). Buses, trucks, semi-trailers (articulated vehicles), cars towing trailers or caravans, tractors and other slow-moving vehicles are classified as Heavy. All other vehicles are defined as Light Vehicles. These models have been calibrated and validated for Australian vehicles (Biggs and Akcelik, 1986) and used in SIDRA INTERSECTION and SIDRA TRIP models estimate fuel consumption, CO_2, CO, HC, and NO_x. The main inputs to these models include driver behaviour attributes (vehicle speed and acceleration), vehicle characteristics (weight or mass) and road geometry (grade).

Once the emissions models had been tested and verified, they were applied within AIMSUN using AIMSUN's Application Programming Interface (API). The model tracks the movement of individual vehicles and generates the statistics per vehicle (e.g. fuel consumption, emission, operating cost etc) and then averages it for all vehicles in the simulation. The results for the a.m. and p.m. periods are provided in Table 5 and Table 6. It should be noted that the a.m. peak O-D matrix comprised 86,142 cars and 5,498 heavy vehicles while the p.m. peak O-D matrix comprised 81,467 cars and 23,745 heavy vehicles.

These results in Table 5 show that on average, the 54 incident cases which were modelled for the duration of the 2-hour a.m. peak period resulted in 1.5 per cent increase in CO emissions and fuel consumption and 5.0 per cent increase in operating costs. Table 6 shows similar results for the p.m. peak period where the CO emissions and fuel consumption increased by around 1.9 per cent and the operating costs increased by 2.7 per cent.

It should also be highlighted here that the a.m. incidents resulted in an average increase in operating costs of around \$21,000 (from \$425,000 to \$446,000); and that the p.m. incidents resulted in an average increase of around \$13,000 (from \$487,000 to \$500,000). The lower increase in vehicle operating costs for the p.m. period is probably due to the smaller delays, stop times and number of stops for the p.m. period.

Table 5 – Average operating costs and emission results for all vehicles – a.m. model

Case	*Fuel consumed (litres)*	*Operating cost ($ 1,000)*	*CO emissions (kg)*
Base case scenario without incidents			
	99,622	425	296
Selected incident cases			
Case 6	100,590	430	300
Case 12	103,569	459	306
Case 18	99,775	469	297
Case 24	102,436	437	301
Case 30	103,005	426	299
Case 36	104,367	436	309
Case 42	104,433	426	302
Case 48	100,878	428	299
Case 54	106,250	515	328
Average of all 54 incident cases for the duration of the 2-hour a.m. peak period	**101,116**	**446**	**304**
Difference between base case and incident scenarios	**1.5%**	**5.0%**	**1.5%**

Table 6 – Average operating costs and emission results for all vehicles – p.m. model

Case	*Fuel consumed (litres)*	*Operating cost ($ 1,000)*	*CO emissions (kg)*
Base case scenario without incidents			
	106,458	487	310
Selected incident cases			
Case 6	108,763	530	328
Case 12	107,904	500	313
Case 18	108,906	488	316
Case 24	107,809	471	304
Case 30	108,674	504	323
Case 36	107,458	487	310
Case 42	107,719	478	313
Case 48	107,751	476	305
Case 54	107,847	476	301
Average of all 66 incident cases for the duration of the 2-hour p.m. peak period	**108,480**	**500**	**316**
Difference between base case and incident scenarios	**1.9%**	**2.7%**	**1.9%**

The average incident costs for the a.m. and p.m. peak periods can be extrapolated to the incident data set that was obtained from the Nerang Traffic Management Centre. That data covered the period from 01-Jan-2004 to 10-Sep-2006 with a total of 421 incidents recorded. Out of those, only 65 incidents occurred during the a.m. peak (their average duration was 0.97 hours; minimum duration was 0.33 hour; and maximum duration was 5 hours); and only 52 incidents occurred during the p.m. period (their average duration was 1.12 hours; minimum duration 0.33 hours and maximum duration 4.17 hours). Therefore, the results in Table 5 and Table 6 can be extrapolated as follows:

- a.m. peak: Average cost of incident ($21,000) x 65 incidents = $ 1,365,000
- p.m. peak: Average cost of incident ($13,000) x 52 incidents = $ 676,000
- Total cost for peak hour incidents = $ 2,041,000

This cost is only for the 117 incidents that occurred during the a.m. and p.m. peak periods. The remaining incidents (304 incidents) occurred during off-peak and their impacts cannot be evaluated using the existing simulation model which covers only the peak periods. However, it is reasonable to assume that these 304 incidents would have had considerable impact (and hence cost) even though they occurred outside the peak periods.

The findings of this study based on a large number of simulated incidents show that incidents can have a substantial impact on network performance, operating costs, fuel consumption and emissions. The reduction of these impacts using incident management and congestion mitigation measures is reported next.

4 Evaluation of the effectiveness and efficiency of selected incident management strategies

This study also examined the effectiveness and efficiency of selected traffic management strategies in reducing the negative impacts of incident-induced congestion. The study considered the following incident management strategies: ramp metering; VMS information dissemination and route diversions; and variable speed limit systems. The task of evaluating the impacts of these strategies required coding each of these traffic management strategies in the M1 simulation model. This task also verified the operation of the strategy and identified issues that may limit its application. Once the traffic management strategies were coded and verified, they were then applied to the M1 model and the incident scenarios identified previously. The effectiveness of each of the strategies was identified and documented.

4.1 Ramp metering

In this study, ramp meters were simulated for a particular field incident which severely disrupted traffic conditions (Figure 3).

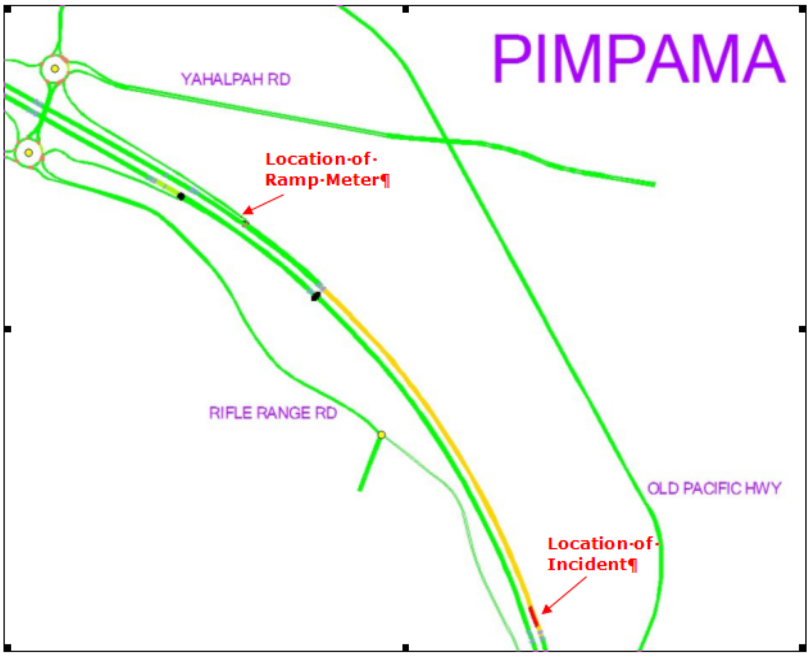

Figure 3 – Schematic of location of the incident and ramp meter experiment

This field incident occurred on 9 November 2005 starting from 8:40 a.m. to 9:46 a.m. at Pimpama (between Exit 49 and Exit 54 Southbound) resulting in the closure of two lanes (out of 4 lanes). The aim of this part of the study was to test the effectiveness of ramp metering under incident conditions. The ramp meter was modelled on ramp Exit 49 Southbound (Yahalpah Road as shown in Figure 3) to allow a ramp flow of 500 vehicles per hour (with 450 vehicles per hour and 750 vehicles per hour for minimum and maximum values). The ramp meter controller was simulated from 7.00 to 9.00 a.m.. The incident was simulated from 8.40 a.m. to 9.00 a.m. reflecting the field conditions of the real incident. During the simulation, statistics covering the impact area were gathered. The statistics included delay, flow, speed, number of stops, and travel time which were averaged at 15-minute interval.

The ramp metering results showed that metering under current conditions does not produce any substantial benefits on the mainline. This was probably due to the fact that existing ramp volumes were not too heavy. However, it was shown that ramp metering starts to provide substantial benefits when traffic demands increased. For example, when the demand was increased by 25 per cent, the delays on the mainline were reduced by 10.5 per cent; number of stops decrease by 23 per cent and travel times are reduced by 3 per cent as a result of implementing ramp metering.

4.2 VMS information and route diversion

This study also evaluated the benefits of incident response in terms of provision of VMS information on the M1 and implementation of dynamic signal plans on diversion routes. An incident was simulated on an arterial road (Smith Street) and VMS information was provided on the Motorway advising motorists of incident conditions (see Figure 4). The results revealed that traffic adjustments due to the diversions and dynamic signal plans resulted in equilibrium conditions on both the normal route (Smith Street) and alternative diversion route (Nerang-Southport Road) when the diversion rate did not exceed 30 per cent. When the per centage of drivers diverting to Nerang-Southport Road increased above 30 per cent, the traffic volumes on the diversion route increased and started to exceed the traffic volume on Smith Street. The results also showed that the benefits were only realised when the two incident management responses (VMS route diversion and implementation of incident cycle plan 160 seconds) are implemented at the same time. The best benefits were realised for diversion rates of 30% and resulted in the reduction of delays by 8.8 per cent (from 159 to 145 seconds per vehicle); increase in speeds by 4.5 per cent (from 44 to 46 km/h); decrease in number of stops by 22 per cent (from 9 to 7); and decrease in travel time by 3.3 per cent (from 451 to 436 seconds). Furthermore, the maximum queue length reduced to around 70 metres which is a substantial reduction that can be solely attributed to the VMS diversions and incident signal plans.

4.3 Variable speed limit systems

This study also conducted a preliminary investigation of variable speed limits (VSL) as a means to reduce the negative impacts of incidents. The M1 microscopic traffic simulation model was used to test an 8 kilometre section of the Motorway to ascertain whether VSL had a positive impact on the safety and efficiency of the motorway (Lee *et al.*, 2006). This was explored through examination of flow homogenisation (reducing the variation of the speeds between vehicles, both within a lane and adjacent lanes) and reducing decelerations at the back of queued vehicles. The results showed that VSL has the potential to provide an 11 per cent improvement in efficiency and indicated that VSL can be used as a measure to increase the efficiency of congested sections on motorways. VSL was also found to provide safety and efficiency benefits by homogenising the flow in higher speed regimes. The number of stops per vehicle on the motorway reduced by 64 per cent following the speed limit being reduced from 110 km/h to 70 km/h as a result of the incident.

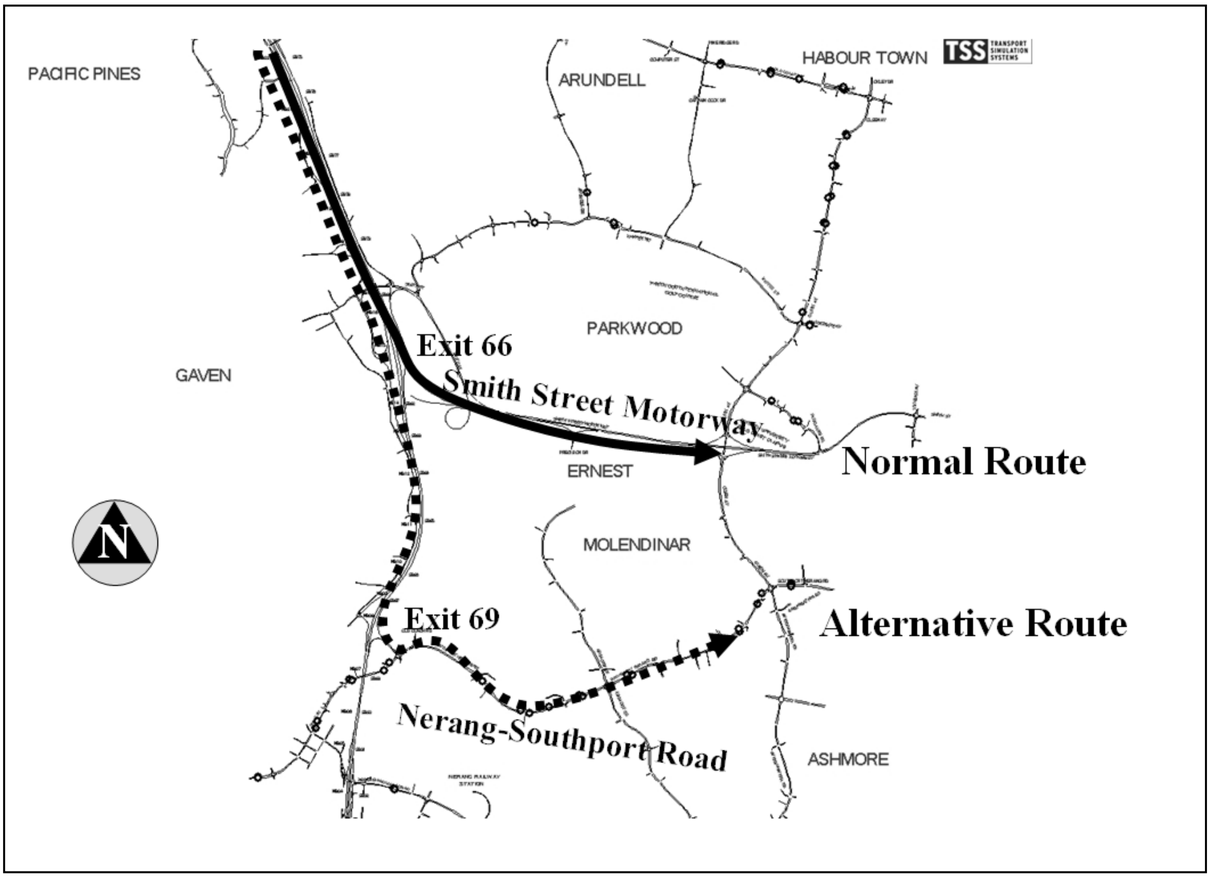

Figure 4 – Schematic showing Smith Street and Nerang-Southport Roads

5 Summary and conclusions

This study demonstrated the feasibility of using a microscopic traffic simulation approach to quantify the traffic and emissions impacts of incidents which occur on a real-life network comprising motorway and arterial roads. The findings of this study, based on a large number of simulated incidents, show that incidents have a substantial impact on network performance, operating costs and emissions. At the local level, the results for a major incident that blocked two lanes for a duration of 1.5 hours showed that the incident resulted in a reduction of around 55 per cent in the volume of traffic that passed through the section. The results also showed that average section speed dropped from 95 to 60 kilometres per hour (a reduction of around 37 per cent in average speeds) and that the average section travel time increased from 19 to 145 seconds (an increase of around 660 per cent due to the incident). At the network level, the results showed that the a.m. peak period incidents resulted in average increases of 2.2 per cent in travel time; 5.7 per cent in delays; 10 per cent in densities; 11.5 per cent in stop times; and 11.1 per cent in number of stops. The results for the p.m. model also showed a similar trend. Network-wide fuel consumption, operating costs and emissions were collected using the power-engine four-mode elemental model. The results showed that on average, the a.m. incident cases resulted in 1.5 per cent increase in CO emissions and fuel consumption and 5.0 per cent increase in operating costs. Similar trends were obtained for the p.m. peak period. Although some of these impacts appear small, their corresponding financial impacts are substantial. On average, an a.m. incident resulted in a $21,000 increase in operating costs while a p.m. incident resulted in an average increase of $13,000 in vehicle operating costs. These results, when extrapolated to the real incidents which occurred in the field, translate into a cost of around $2M for the 117 real incidents which took place during the peak hours between January 2004 and September 2006.

This study also evaluated the effectiveness of selected traffic management strategies. The ramp metering results showed that metering under current conditions did not produce any substantial benefits on the mainline. However, it was shown that ramp metering starts to provide substantial benefits when traffic demands increased. When the demand was increased by 25 per cent, the delays on the mainline were reduced by 10.5 per cent; number of stops decrease by 23 per cent and travel times are reduced by 3 per cent as a result of implementing ramp metering. The study also evaluated the benefits of incident response in terms of provision of VMS information on the M1 and implementation of dynamic signal plans on diversion routes. The results revealed that traffic adjustments due to the diversions and dynamic signal plans resulted in equilibrium conditions on both the normal route (Smith Street) and alternative diversion route (Nerang-Southport Road) when the diversion rate did not exceed 30 per cent. Finally, the study also conducted a preliminary investigation of variable speed limits as a means to reduce the negative impacts of incidents. The results showed that VSL has the potential to provide an 11% improvement in efficiency and showed that VSL can be used as a measure to increase the efficiency of congested sections on motorways. VSL was also found to provide safety and efficiency benefits by homogenising the flow in higher speed regimes. The number of stops per vehicle on the motorway reduced by 64% following the speed limit being reduced from 110 km/h to 70 km/h as a result of the incident.

Finally, it should be mentioned here that these results are network-dependent. The incident impacts and the benefits of incident management strategies will differ across networks and will be a function of existing congestion; availability of alternative routes and congestion levels on these routes; in addition to other issues related to driver route choice behaviour and compliance with traffic information.

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