Evaluation of the Impacts of ITS Using Traffic Simulation

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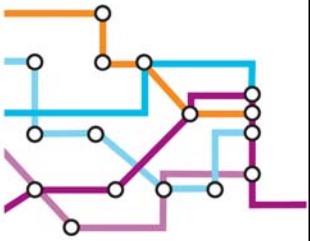

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Presentation Outline

- Background & Objectives
- Methodology
  - Model development
  - Incident modelling
  - Modelling of incident management strategies
  - Results
- Summary and Directions for Future Research

Background

Incidents are any events that reduce the capacity of a road facility

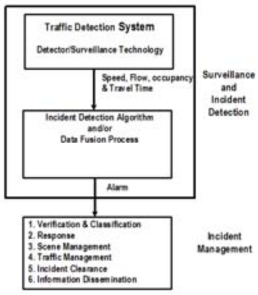
- Roadway incidents impose a substantial cost to society when delays, congestion, secondary accidents and environmental emissions are taken into consideration
- Non-recurrent congestion accounts for 20-40 percent of congestion on motorways
- In Brisbane, the estimated avoidable cost of traffic congestion is $1.472 billion

  Congestion due to traffic incidents could be up to $700 million per year (BTRE)

Background

Incident impacts can be reduced through implementation of incident management (IM)

- Evaluation of incident impacts and benefits of IM strategies is important for justification of expenditure of public funds on ITS
- Ideally, evaluation should be based on field tests but the limited data on dynamic impacts restrict a comprehensive evaluation
- Traffic simulation provides an alternative approach for evaluating the impacts



Objectives

Quantify the impacts of incidents and selected incident management strategies using a traffic simulation approach

- Local and network-wide impacts
- Integrated motorway and arterial environment
- Traffic, fuel consumption, emissions, and operating costs impacts
- Incident management strategies evaluated:
  - Ramp metering
  - VMS information and route diversion
  - Variable speed limits
  - Dynamic traffic signal control

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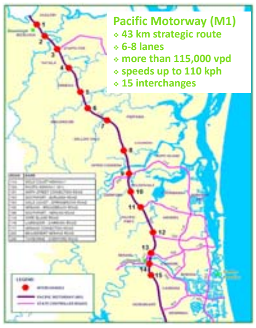
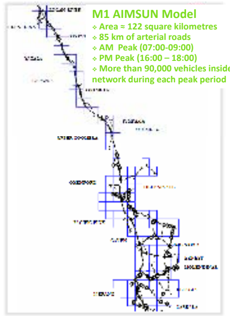
Model Development





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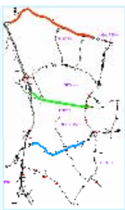
Model Calibration Results

Using traffic counts from loop detector stations on M1 and mid-block counts on arterials



Calibration errors

M1	AM	6 percent
Arterials	AM	10 percent

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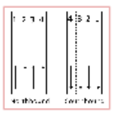
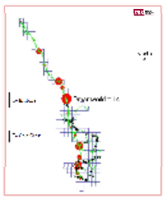
Simulation of Incidents

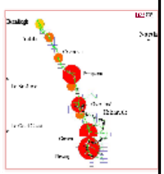
Incident logs were retrieved to determine location of incidents, their duration and severity for incidents dating back to 2004

- Analysis of field data showed a number of locations that were over-represented in terms of their incident frequency
- Incidents were simulated at these locations with varying characteristics reflecting field conditions

54 incidents AM
66 incidents PM
Duration 1 to 1.5 hours
Blocking lane 3 or 4 or both







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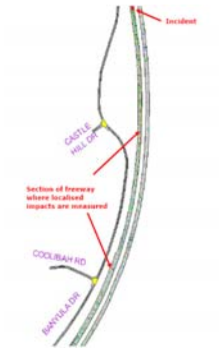
Local Impacts

All incidents were evaluated at the local and network levels

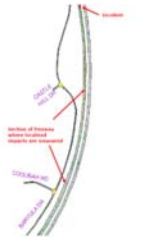
- An example of local impacts is demonstrated by the simulation of a major incident that occurred at 7:15 am, blocked 2 lanes (out of 4) on the northbound direction and lasted for 1.5 hours
- Section of freeway where localised impacts were measured was 600-m long



Local Impacts - *continued*

Section Statistics – Normal 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)
07:00-07:15	3032	98	18	0	0
07:15-07:30	3364	98	19	1	0
07:30-07:45	3276	96	19	1	0
07:45-08:00	3960	95	19	1	0
08:00-08:15	4128	96	19	1	0
08:15-08:30	5020	91	20	2	0
08:30-08:45	4456	94	19	1	0
08:45-09:00	4208	92	20	2	0
Average	**3931**	**95**	**19**	**1**	**0**



Average section flows reduced by 55% (3,931 vs 1,783 vph)

Average section speed reduced by 37% (95 vs 60 kph)

Average section travel time increased from 19 sec to 145 sec

Average section delays increased from 1 sec to 127 sec

Average stopped time increased from 0 to 111 sec

Section Statistics – 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)
07:00-07:15	3032	98	18	0	0
07:15-07:30	2336	40	93	75	51
07:30-07:45	2180	10	307	288	250
07:45-08:00	2288	13	267	249	209
08:00-08:15	2168	16	424	406	374
08:15-08:30	792	100	18	0	0
08:30-08:45	756	100	18	0	0
08:45-09:00	728	101	18	0	0
Average	**1783**	**60**	**145**	**127**	**111**

Network Impacts

AM

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%**

AM Peak comprised 86,142 cars and 5,498 HV

PM Peak comprised 81,467 cars and 23,745 HV

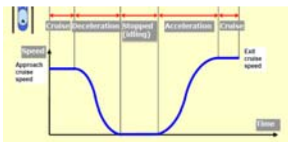
PM

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%**

Fuel Consumption/Emissions Impacts

Evaluation conducted using four-mode elemental model (Akcelik & Besley, 2003)

This model is based on drive cycles to estimate fuel consumption and emissions



Model was integrated with the traffic simulator using AIMSUN's Application Programming Interface (API)

AIMSUN tracks the movement of individual vehicles and generates speed, acceleration & deceleration estimates for use by the emissions model

Fuel Consumption & Emissions Impacts

AM

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	99,776	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%**

AM Peak comprised 86,142 cars and 5,498 HV
Average increase of $21,000 in operating costs

PM Peak comprised 81,467 cars and 23,745 HV
Average increase of $13,000 in operating costs

PM

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	106,763	530	328
Case 12	107,904	500	313
Case 18	106,906	488	316
Case 24	107,809	471	304
Case 30	106,674	504	323
Case 36	107,458	487	310
Case 42	107,719	478	313
Case 48	107,751	476	306
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%**

Total Cost (based on average increase in operating costs) for peak hour incidents = $2,041,000

Evaluation of IM Strategies – *Ramp Metering*

Flow metering algorithm (based on minimum and maximum number of vehicles to be released per unit time)

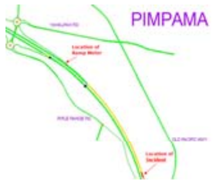
Incident which caused major disruptions (closure of 2 lanes) was simulated

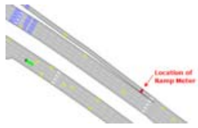
Performance Measure	Existing Ramp Demand	Without Ramp Metering (current conditions)	With Ramp Metering	% Difference
Speed (kph)				
	On-ramp	57.8	52.8	-8.1
	Mainline	68.2	67.7	-0.8
Number of stops per vehicle				
	On-ramp	0.0	0.2	200.0
	Mainline	0.3	0.3	0.0
Travel Time (second/vehicle)				
	On-ramp	36.2	40.3	11.2
	Mainline	171.5	173.0	0.9
Delay (seconds/vehicle)				
	On-ramp	2.9	6.8	131.2
	Mainline	29.7	31.2	4.9

No mainline benefits at this location

Performance Measure	25% Increase in Ramp Demand	Without Ramp Metering (current conditions)	With Ramp Metering	% Difference
Speed (kph)				
	On-ramp	57.8	52.0	-9.7
	Mainline	63.2	63.8	0.6
Number of Stops				
	On-ramp	0.0	0.2	200.0
	Mainline	1.4	1.1	-23.0
Travel Time (seconds/vehicle)				
	On-ramp	36.3	40.6	11.8
	Mainline	192.1	186.6	-2.8
Delay (seconds/vehicle)				
	On-ramp	2.7	7.1	158.5
	Mainline	50.5	45.2	-10.5

Some benefits with increased ramp demand





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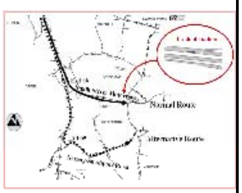
IM Strategies – *VMS & Route Diversions*

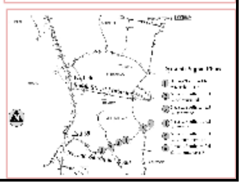
Incident simulated on arterial and VMS information provided on Motorway

Motorway traffic diverted at different proportions (30 to 80 percent)

Case Number	Description	Traffic Signal Timing	Driver Compliance Rate With VMS Information or Diversion Rate (Percent)
Case 1	Normal conditions	Normal plan 140 seconds	Not applicable
Case 2	Incident conditions	Normal plan 140 seconds	Not considered
Case 3	Incident conditions	Incident plan 160 seconds	Not considered
Case 4	Incident conditions	Incident plan 160 seconds	30
Case 5	Incident conditions	Incident plan 160 seconds	40
Case 6	Incident conditions	Incident plan 160 seconds	50
Case 7	Incident conditions	Incident plan 160 seconds	80

Dynamic signal plans implemented on normal and diversion routes following the occurrence of incident





IM Strategies – *VMS & Route Diversions*

Traffic flow variations suggest diversion rate of 30% produces best distribution of flows between the normal and alternative routes

Time Interval	Case 1 Normal Conditions		Case 4 Incident 30% Diversion		Case 5 Incident 40% Diversion		Case 6 Incident 50% Diversion		Case 7 Incident 80% Diversion	
	Exit 66	**Exit 69**	**Exit 66**	**Exit 69**	**Exit 66**	**Exit 69**	**Exit 66**	**Exit 69**	**Exit 66**	**Exit 69**
07:00-07:15	1,712	668	1,712	668	1,712	668	1,712	668	1,712	668
07:15-07:30	1,884	1012	1,884	1012	1,884	1012	1,884	1012	1,884	1012
07:30-07:45	2,120	872	2,120	872	2,120	872	2,120	872	2,120	872
07:45-08:00	1,984	904	1,984	904	1,984	904	1,984	904	1,984	904
08:00-08:15	2,056	840	2,056	840	2,056	840	2,056	840	2,056	840
08:15-08:30	2,012	852	2,012	852	2,012	852	2,012	852	2,012	852
08:30-08:45	2,064	716	1,508	1052	1,304	1156	1,120	1224	576	1224
08:45-09:00	1,920	816	1,208	1248	1,124	1240	880	1200	400	1272

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IM Strategies – *VMS & Route Diversions*

Traffic impacts show that Case 3 (only incident signal timing plans without diversions), does not produce much benefits on normal route (Exit 66) compared to Case 4 (incident signal timing plans with diversions)

Scenario	Route	Delay (seconds per vehicle)	Speed (kph)	Number of Stops (per vehicle)	Travel Time per Vehicle (seconds)
Case 1 (Normal Conditions-140s cycle)	Exit 66	145	46	7	437
	Exit 69	157	21	4	410
Case 2 (Incident -0% Diversion-140s cycle)	Exit 66	159	44	9	451
	Exit 69	157	21	4	410
Case 3 (Incident -0% Diversion-160s cycle)	Exit 66	160	44	9	451
	Exit 69	157	21	4	410
Case 4 (Incident- 30% Diversion-160s cycle)	Exit 66	145	46	7	436
	Exit 69	292	30	9	656
Case 5 (Incident- 40% Diversion-160s cycle)	Exit 66	145	46	7	436
	Exit 69	287	30	9	658
Case 6 (Incident- 50% Diversion-160s cycle)	Exit 66	145	46	7	435
	Exit 69	304	29	10	668
Case 7 (Incident- 80% Diversion-160s cycle)	Exit 66	146	46	7	436
	Exit 69	322	29	11	689

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IM Strategies – *VMS & Route Diversions*

Comparison of scenario where the incident occurs and no action is taken (Case 2) with scenario where the two IM responses are implemented (Case 4) is shown below

Scenario	Route	Delay (seconds)	Speed (kph)	Number of Stops (per vehicle)	Travel Time per Vehicle (seconds)
Case 2 Incident occurs on normal route but no response is initiated (no diversions or dynamic signal plans)	Exit 66	159	44	9	451
Case 4 Incident occurs on normal route, 30% of traffic is diverted to alternative route, where traffic signal timing is increased to 160s cycle	Exit 66	145	46	7	436
Benefits (%) (Case 4 over Case 2)		8.8%	4.5%	22.2%	3.3%

Best benefits realised when the two IM responses are implemented simultaneously (30% diversion combined with incident timing plans)

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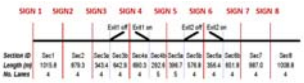
IM Strategies – *Variable Speed Limit (VSL)*

Preliminary investigation of VSL as a means to reduce incident impacts

- 8-km section of M1 was tested
- Some of the factors that affect performance of VSL include distances between signs, triggers for changing speed limits, speed limit increments, levels of congestion etc
- Flow homogenisation (reduction in the variation of the speeds between vehicles, both within a lane and adjacent lanes) and reduction in decelerations at the back of queued vehicles were found



Preliminary Findings

- VSL has potential 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 percent following the speed limit reduction from 110 kph to 70 kph as a result of the incident
- VSL was found to provide an 11 percent improvement in delays upstream of the incident

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Summary

- Study demonstrated feasibility of using traffic simulation to evaluate the impacts of incidents and IM strategies
- Simulated incidents, based on characteristics of real-life incidents, were found to have substantial impacts on network performance, operating costs and emissions
  - e.g. AM Peak incidents resulted in
    - 2.2% increase in travel time
    - 5.7% increase in delays
    - 1.5% increase in CO emissions
    - 5.0% increase in operating costs
- Selected IM strategies were explored
  - Ramp metering
  - VMS information, route diversions and dynamic signal timing plans
    - best results obtained when diversions were combined with incident signal timing plans
- Results are network-dependent; will vary across networks; and are a function of existing levels of congestion, availability of alternative routes and congestion on these route; driver route choice behaviour and compliance with traffic advise etc

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