Freeway Incident Evaluation and Mitigation Strategies using Intelligent Transport System

A thesis presented by

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Academic Integrity Declaration

I hereby confirm that the work presented here does not incorporate without acknowledgement any material submitted for a degree or a diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except for those where due reference is made in the text.

Signed by:

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Executive Summary

Freeways are the most efficient infrastructures of transportation network used all around the world for improving travel time and road efficiency. However, due to the increasing population and vehicle ownership, the traffic flow through a freeway section has also increased in recent years leading to reduction in efficiency of freeway network. This has resulted in numerous disadvantages such as increased travel times, delays, Carbon Dioxide (CO_2) and Nitrogen Oxide compounds (NO_X) emissions and adverse impacts on road safety. The effects of increased traffic flows are sometimes accompanied with incidents that often result in severe traffic congestion due to freeway capacity being exceeded.

This report describes the evaluation of impacts of incidents on Darlington Freeway section in Adelaide Southern Suburbs. It also covers the research for mitigation measures that could be applied in order to reduce the incident impacts through the use of Intelligent Transport Systems (ITS). Incident and ITS modelling on the freeway section in the research were conducted using microsimulation software AIMSUN. The impact of incident based on location, duration and the time of occurrence in Darlington Freeway section for different lane blockage severity (partial lane blockage and full lane blockage) has been quantified in terms of travel time, congestion, delay and emissions using the microsimulation model. The measures for reducing the incident impacts have been established using Variable Message Signs (VMS) for traffic diversion from incident occurrence area for efficient traffic incident management.

AIMSUN software was used for traffic incident modelling of Darlington Freeway section because it is a package exclusively used by the Department of Infrastructure and Transport (DIT). The base model was provided by the DIT which has been calibrated and validated in terms of section flows, travel times and queue length and found to be fit-for-purpose for the detailed freeway modelling. Several incident scenarios were modelled and the effects and consequences of each incident scenario and characteristics was established and the benefits of introducing Variable Message Signs during incident occurrence was evaluated. While diverting the traffic from adjacent routes from the freeway, the study of whole network performance is necessary to determine the impact of vehicle diversion from freeway to adjacent roads. Thus, in this research, the impact and extent of level of vehicle diversion on adjacent intersection was evaluated using SIDRA Intersection software.

Two different incident locations were studied in the northbound tunnel in Darlington Freeway for three different durations in Morning Peak of incident occurrence for the future model 2031 with different lane blockage severity levels. The results generated from incident modelling determined that full lane blockages in all cases have the highest impact on traffic performance indicators, the worst case of AM peak indicated more delay by 17.85 sec/km, increase in travel time by 15.12 minutes, queue by 212 vehicles and emissions by 6.76%, following a 15-minute incident than in normal flow conditions. Results further revealed that use of Variable Message Sign have subsequently reduced the incident impact on freeway but at the same time, the diversion of more than 30% vehicles during the worst case in AM Peak caused the whole network in the study area to reach their capacity and resulted in a complete network gridlock, vehicle diversion exceeding 60% during non-peak time caused network gridlock. It was also observed that an incident that have short time duration and cause only one lane closure would not require any traffic diversion, even in the busiest peak hour, due to current freeway having enough spare capacity to cope with such occurrences.

The outcome of this research would be beneficial for developers and road designers to establish incident response mechanism using Intelligent Transport System for effective Traffic Incident Management in freeways.

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List of Acronyms:

ATIS: Advanced Traveler Information System

AWS: Advanced Warning Systems

CV Technology: Connected Vehicle Technology

CO_2: Carbon Dioxide

CO_2-e: Carbon Dioxide equivalent. (The amount of CO_2 which would have equivalent impact on global warming.)

COR: Concept of Operations Report

DIT: Department of Infrastructure and Transport.

DPTI: Department of Transport Planning and Infrastructure.

ITS: Intelligent Transport System

LOS: Level of Service

MASTEM: Metropolitan Adelaide Strategic Transport Evaluation Model

NO_x : Nitrogen Oxide Compounds

O-D (matrix): Origin-Destination Matrix

PAR: Project Assessment Report

TIM: Traffic Incident Management

VMS: Variable Message Signs

VSL: Variable Speed Limits

Chapter 1

Introduction

North-South Corridor is a major route for continuous traffic trips to and from Adelaide for employment, commercial and freight purposes. According to Department of Infrastructure and Transport (DIT), the current road network is not capable of handling the future projected travel demand for vehicles as well as freight carriers. Thus, as a response, upgrade of 78 kms road section of North-South Corridor from Gawler to Noarlunga was proposed by South Australian and Australian Federal Governments which will provide a non-stop North-South corridor with strategic non-stop road links, eliminating the worst bottlenecks and connecting the residential, recreational and industrial areas from north to south creating more opportunities for social and economic development of South Australia.

Darlington Freeway section was selected as a case study for the research which is a significant part of North-South corridor. The upgrade of Darlington Freeway consists of upgrading 3.3 kms of existing main South Road from Tonsley Boulevard to provide a non-stop motorway to Southern Expressway. Five different intersections of Flinders Drive, Sturt Road, Sutton Road/Mimosa Terrace, Ayliffes Road and Tonsley Boulevard were upgraded and the project was accomplished in mid-2020.

Although the masterplan of increasing the capacity of Darlington Freeway has been implemented by upgrading the 3.3km section of road spending $603 billion dollars, the main challenge is to maintain the serviceability and efficiency of road, and comfort and safety of the road users which can be done by implementing proper measures for traffic management.

Thus, this research is an attempt to provide an insight to Traffic Incident Management of the Freeway by investigating the implications of incident occurrence in the Darlington Freeway section using microsimulation and analytical approaches by means of AIMSUN and SIDRA INTERSECTION software. The major aim of this research is to identify the impact of incident characteristics such as location, duration, time of the day (AM Peak/ PM Peak) on vehicular travel time, level of congestion of road, vehicular delay along with environmental impacts on Darlington Freeway section and to explore and suggest the mitigation measures by introducing Variable Message Sign (VMS) into the Freeway section during incident occurrence. VMS is a component of Traffic Incident Management that employs Intelligent Transport System technologies.

1.1 Background

Darlington Freeway Section is an integral part of North-South Corridor, and is a major route for traffic trips to and from Adelaide for employment, commercial, freight and recreational purposes. Figure 1 depicts the significance of Darlington Road section being a major road network to link the commercial zones, employment areas, international gateways to the southern residential areas of Adelaide.

Image removed due to copyright restriction.

Figure 1: Industrial / Employment areas, freight and international gateways (DPTI, 2016)

The infrastructure upgrade of the Darlington road section was deemed necessary as the existing South Road was running at capacity and was insufficient to meet the travel demand of future traffic (DPTI, 2015). Any interruption in travel such as incidents, vehicular breakdowns, road crashes could have extensive impacts on the whole road network. Furthermore, the condition of South Road imposed economic issues like poor accessibility, reduced reliability, imposing additional business costs and constraining the future as well as current economic development scenario in the state. Limited social and recreational opportunities, congestion and relative isolation of the Southern- Outer Adelaide led to further social disadvantage. (DPTI, 2016)

As the upgraded road section has now come to successful operation, the necessity of traffic incident management is even more significant and important for maintaining the serviceability and safety of the road section. According to Statistical summary of Road Crashes and Casualties in South Australia (DPTI, 2017), 517 non-recurring road incidents such as vehicular breakdowns and crashes were reported in Department of Transport Planning and Infrastructure (DPTI) roads in City of Marion including Darlington Freeway section some resulting in minor injuries, some serious injuries and some with no casualties. The level of impact is expected to rise as the freeway section come into operation for public use.

The level of impact of incidents and the extent of Intelligent Transport System to be introduced into the freeway for effective traffic incident management during incident occurrence has neither been quantified nor justified by DPTI which is further discussed in the literature review section and is a major justification of the necessity of this research.

1.2 Research aims and objectives

In this research, the impact of incident characteristics such as different incident location, different duration and the time of the day (AM peak or PM peak) of the Darlington Freeway section in the serviceability parameters of road section such as delay, congestion, vehicular travel time and emissions is investigated using analytical and simulation approaches such as AIMSUN and SIDRA software. The consequences of introducing Intelligent Transport System on the freeway section as well as arterial roads during incidents are evaluated and the best possible solutions are suggested to minimize the impact of incidents and for minimizing the traffic congestion and improving safety.

After performing a thorough research and literature review, a research gap was identified which requires further study and research to address the existing gaps. Thus, a set of targeted aim was established for a better research outcome.

The aims and objectives of the research are:

- Performing microsimulation approach to generate the microscopic traffic model of Darlington Freeway section.
- Analyze the performance of existing freeway without incidents and compare the performance of freeway by modelling several traffic scenarios for incidents.
- Investigate the impacts of incident location, duration and the time of the day (AM/ PM peak) in different lane blockage severity levels and evaluate the performance of freeway with performance indicators like travel time, delay, congestion and emissions.
- Identify the worst location of incident occurrence in the freeway and suggest to fix the problem by introducing the Intelligent Transport System components such as Variable Message Signs (VMS).
- Evaluate the performance of adjacent intersections and ramps during vehicle diversion from freeways using VMS.
- Suggest alternative solutions for improving level of service of freeway for future traffic growth along with the implementation of Intelligent Transport Systems.
- Evaluate the effects of implementation of ITS in movement of people and use of freeway.

The base model of Darlington Freeway section provided by Department of Infrastructure and Transport (2016) has been calibrated and validated for the expected traffic volume in the section for the year 2031 by section flows, queue lengths and travel times.

1.3 Report Structure

This research paper consists of six different chapters, divided into further sections and subsections.

Chapter 1 provides the basic overview of the project followed by Chapter 2 which provides the detailed review of literature in relation to the significance and importance of this research.

Subsequently, the next chapter, Chapter 3 includes the adapted methodology and specifications used for the modelling process of the Freeway using AIMSUN microsimulation software. In this chapter, the process of data collection, modelling, calibration and validation of the model, the justifications of using AIMSUN microsimulation package along with SIDRA Intersection software for the modelling and research will be provided. Furthermore, the limitation of the existing model is discussed in this chapter.

Chapter 4 presents the results generated from AIMSUN model for several traffic incidents at various locations, durations and peak hours on Darlington Freeway and performance assessment of freeway from the traffic performance indicators such as travel time, delay time, congestion and emissions. Moreover, results from SIDRA Intersection evaluating the effects on performance of ramps/intersections due to vehicle diversion from freeway to arterial roads during incidents are presented. Furthermore, suggestive measures for the mitigation of consequences generated by sudden incidents on freeway is deliberated and interconnected by using Intelligent Transport System.

Further, Chapter 5 provides a brief description of generated results. Additionally, this chapter provides implications of using Intelligent Transport System into the Freeway section and description of how the introduction of ITS affects the movement of people and use of Freeway. And to conclude, the Chapter 6 provides the conclusion of this research along with the recommendations and future research scope using Intelligent Transport System for evaluation of incidents on Freeway.

Chapter 2

Literature Review

This chapter will briefly describe the existing literature to justify the importance of this thesis, providing an insight of existing research for incident modelling in road networks. Various techniques to quantify the incident impacts are evaluated and several methods established for the Traffic Incident Management to mitigate the incidents' impact with the use of Intelligent Transport components will be examined. Further, the existing research gap and the necessity of ITS approach for incident management in Darlington Freeway and the contribution of this thesis topic in existing research will be discussed by the end of this chapter.

2.1 Impacts of Incidents on Freeways:

Road incidents contribute to about 50 percent of road congestion in major cities of Australia (Taylor, 2008). Increase in purchasing power of people has gradually increased the number of vehicles on the road causing increase of traffic flow volume which has resulted in reduction in capacity of road networks, motorways and freeways.

Generally, it is believed that freeways are the most efficient roads in terms of improving travel times. However, as the traffic flow increases, the number of unpredictable and irrepressible incidents in freeways increases, leading to congestion and further consequences on travel time, delay, environmental impacts, carbon emissions, increase in cost and reduction in safety and efficiency. (Koorey, et al., 2015)

Figure 2 illustrates the impacts of freeway incidents in social, economic, psychological and environmental components.

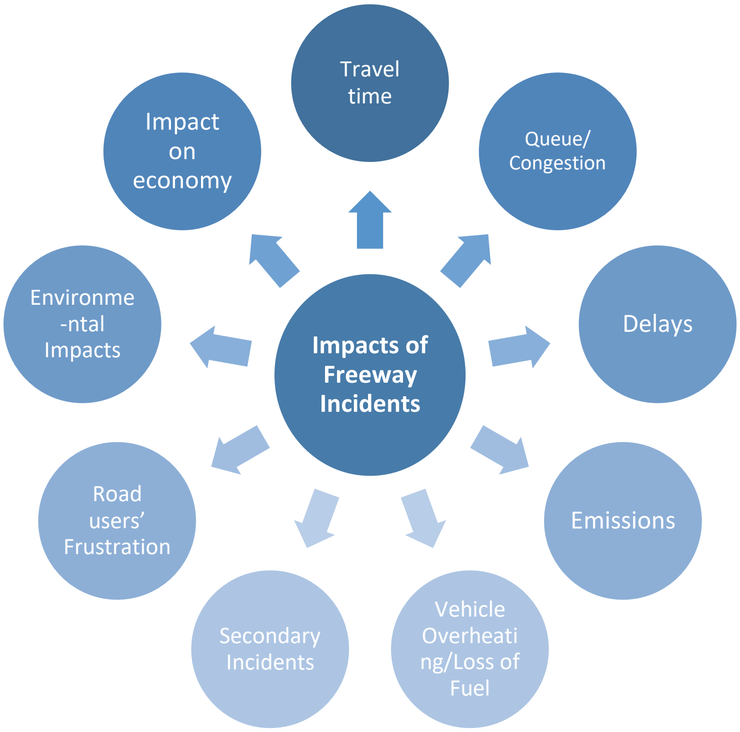

Figure 2: Diagram showing the impacts of freeway incidents (de Barros Baltar, et al., 2021), (Dia, 2011)

2.1.1 Impacts on congestion, travel times and delay:

Freeways are the most important parts of road infrastructure linking small towns to cities and cities to metropolitan areas. Congestion in freeways has significant effect in traffic conditions such as increased travel times, increased consumption and environmental impacts. (Ferrara, et al., 2013). Irregular but frequent interruptions caused due to freeway incidents such as vehicle breakdown, accidents, flat tires intensify the congestion even more (de Barros Baltar, et al., 2021). Further, several lane blocking incidents result in difficulty in operation and traffic management. (Sheu, 2013)

Koorey, et al. (2015) defines traffic congestion as of two different types, non-recurring and recurring congestion; non-recurring congestion occurs during temporary and unexpected capacity reduction of transport network due to incidents (e.g. crashes, vehicle breakdowns, environmental factors) and recurring congestion occurs when the capacity of transport system is not enough to meet the travel demand. Several control approaches have been proposed and implemented for traffic management in the recent years in order to reduce the congestion in freeway systems such as ramp metering, variable speed limits, route diversion and vehicle infrastructure integration systems (Ferrara, et al., 2013).

Similarly, delay is another traffic performance indicator to determine the impact of incident occurrence. The incident-induced delay as defined by Li, et al. (2006) can be quantified as a function of several factors including the rate of flow of traffic, duration of incidents, normal capacity as well as reduced capacity of freeway network. In other words, incident induced delay can be defined as a difference in travel time experienced by a vehicle during normal flow condition and during incidents (Kabit, et al., 2014).

In order to quantify the travel time reliability during incidents, a study conducted by Wright, et al. (2015) for a freeway segment in Seattle metropolitan area, for three different types of lane severity (shoulder, single lane and multiple lane) scenarios indicated that the travel time during multiple lane incidents increased by 205%, compared with the normal travel condition indicating that traffic incidents are the most important factor for capacity reduction of freeway and thus affecting the reliability of travel time. Chen, et al. (2003) describes travel time as the most meaningful measure for the driver which also can be evenly expressed in terms of monetary cost. Thus, the determination of the travel time, delay and congestion for measure of freeway capacity is indeed significant for this research.

2.1.2 Environmental impacts

The economic growth and urbanization of major cities have raised challenges such as traffic congestion along with the high degree urbanization (Bai, et al., 2017). Prolonged travel times, excessive fuel consumption, noise and increased environmental pollution such as greenhouse gases emission occur due to incident induced congestion (de Barros Baltar, et al., 2021).

According to National Greenhouse Gas Inventory (2020), total emissions in Australia in 2020 is 499 Mt of Carbon dioxide equivalent (CO_2 -e). Figure 3 depicts that in the year 2020, 87.8 Mt CO_2-e of the total annual emissions is generated by road transport alone, contributing to 17.6% of nation's gross emissions.

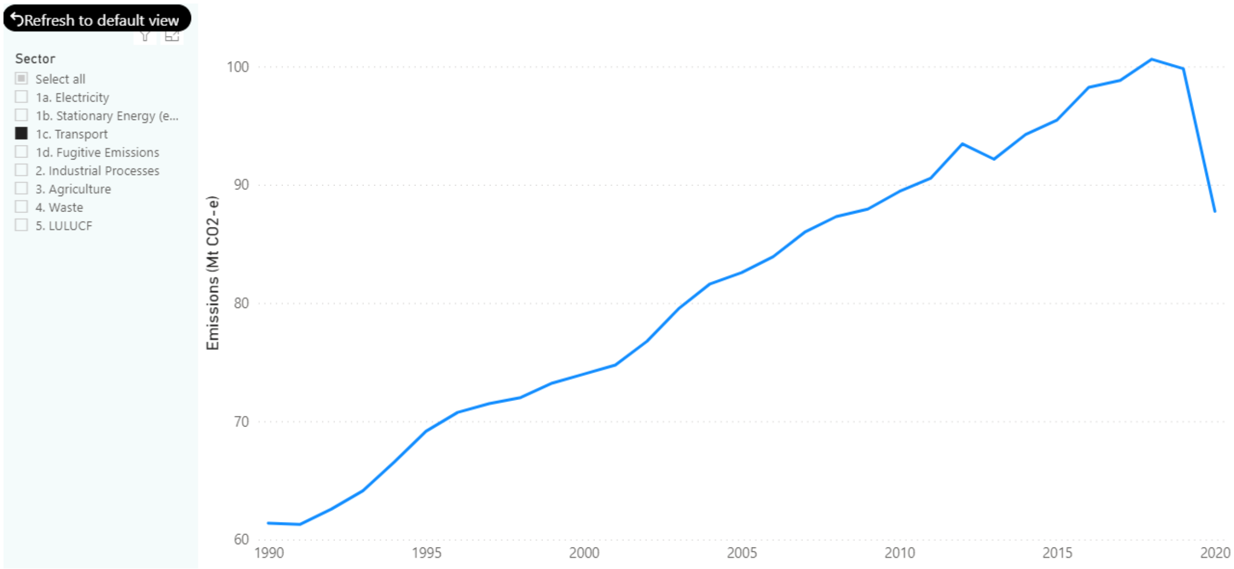

Figure 3: Transport Emissions, actual and trend, December 2010-December 2020. (National Greenhouse Gas Inventory,2020)

Excess emissions caused by an incident as described by Thomas & Jacko (2007), is the difference between the cumulative emissions from the beginning of any incident till the traffic flow resumes to normal after incident clearance. To put the statement in figures, a case study for an accessed data of 2,800 incidents performed by de Barros Baltar, et al. (2021) in Rio de Janeiro freeway demonstrated that incidents increase the CO_2 emissions by 22% than a normal traffic flow. It also determined that broken down vehicles have the greatest impacts on these emissions. The study further signifies that 82.4% of CO_2 increase is linked to morning and afternoon peak hours. Thus, the immense necessity of quantifying the incident impacts and suggesting measures to reduce the negative impacts for the freeway network is observed.

2.1.3 Financial Impacts

Traffic performance as described by Li, et al. (2006) can be measured by several components such as road delay. From measurement of delay, further economic impacts of incident and emissions can be calculated. Kabit et al. (2014) defines the cost of delay as a function of occupant time, expenses of vehicle operation as well as external costs such as air pollution. Traffic incidents such as vehicle breakdowns, queues, environmental emissions and secondary incidents as stated by Dia (2011), imposes substantial cost to the society. This statement is further verified by the statistic that the estimated annual cost of congestion for individual queuing time for all US commuters is $29 billion (Kim, 2019). Further supporting the fact, it was estimated that the potentially avoidable social cost of congestion across the major metropolitan areas of Australia in the year 2020 was $20.36 billion which is an increase by almost 20% over the past 5 years from 2015. (Bureau of Transport and Regional Economics [BTRE], 2020)

From Figure 4, it can be seen that in the year 2003, the road traffic incidents in Adelaide caused a cost of $1.16 billion, equivalent to 2.32% of the Gross Domestic Product (GDP) of the state (Connelly & Supangan, 2006). It is also evident from the figure that total road traffic crashes in Western Australia as well as Northern Territory has high rate of fatalities and hence the cost of road traffic incidents are well above national average. The road quality, road safety furniture, distance to nearest medical facilities as well as emergency response measures contributes to the differences in fatality rates in different state and territories. (Connelly & Supangan, 2006)

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Figure 4: Total cost per capita of road traffic crashes in Australia in AUD, (2003) (Connelly & Supangan, 2006)

2.2 Simulation Models for incidents using analytical computer software.

Computer modelling simulation techniques are powerful tools for studying traffic incidents which enables new trials to be tested for traffic incident detection and management without actually disrupting existing traffic networks (Archer, 2000). Several studies has been conducted by (Ferrara, et al., 2013); (Archer, 2000); (Barceló, et al., 2005); (Hadi, et al., 2007); (Holyoak & Stazic, 2009); (Li, et al., 2006); (Ni, 2003); (Zhicai, et al., 2004); (Xu, et al., 2014); (Sheu, 2013) (Helbing, et al., 2002) (Kabit, et al., 2014); (Koorey, et al., 2015) and (Dia, 2011) using computer-based simulation approaches for investigating the effects of incidents in specific road networks.

Computer simulation is a powerful analytical tool to evaluate the operational performance of existing traffic network and to predict travel future behavior of road network which aids in Traffic Incident Management. Computer modelling offers several benefits in traffic analysis in terms of replication of incidents in peak and non-peak conditions and evaluation of their performance and impacts on road network considering safe, cost effective, laboratory base data without interrupting existing traffic networks (Dia, 2011).

The choice of modelling approach varies depending upon the level of details in modelling, the size of study area and the complexity of outputs. Four different traffic simulation approaches are discussed below macroscopic, mesoscopic, microscopic and nanoscopic in the ascending order of achievable level of details in a model.

2.2.1 Macroscopic simulation models

Macroscopic simulation models estimate the travel patterns for an entire region with a large number of road network (Holyoak & Stazic, 2009). Macroscopic models for incident modelling are used for wide-scale strategic policy testing in travel demand for a range of attributes such as land-use strategies, socio-demographic influences, mode, route and destination choice. Macro model do not represent traveler interactions and provide relatively simpler travel pattern outputs and often level of detail for driver attributes are compromised in this model. Moreover, vehicle emission is underestimated in macroscopic model as the model only applies constant speed for the entire road. (Holyoak & Stazic, 2009).

Linking of macro-simulation and micro-simulation models in cases such as the study by (Helbing, et al., 2002) can be where results are closely related and the simulation model is capable to carry out simultaneous modelling parameter. Further, Bourrel & Lesort (2003) suggested that linking of macroscopic and microscopic models is likely only when characteristics of models coincide and are compatible with one another, at the same time, ensuring the flow conservation and proper-propagation of information at upstream and downstream interfaces.

2.2.2 Mesoscopic simulation models

Usually, mesoscopic simulation involves regional-scale simulation-based traffic planning and management scenario (Song, et al., 2017). Further, Burghout (2005) defines mesoscopic model as ideal for prediction applications, where the detailed modelling of route choice but a limited detail of driver behavior is simulated.

A research conducted by Fontes, et al. (2014) evaluated a mesoscopic traffic model to quantify the traffic incident impact on a regional scale in a 250 km long corridor, and the benefits of using Advanced Traveler Information System (ATIS) for traffic incident management. While, mesoscopic models are more efficient than microscopic models and fill in the gaps of macrosimulation models (Barceló, 2010), the limiting level of detail in driver behavior in mesoscopic models makes it imprecise to a smaller area such as this study. When the driver behavior aspect is not considered in higher detail, the prediction of traffic situations following the incidents such as application of VMS in route diversion, will rapidly deteriorate regardless of quality of simulation model (Burghout, 2005). Hence, the approach of using mesoscopic simulation in this research is not applicable.

2.2.3 Microscopic simulation models

Several studies performed by (Barceló, et al., 2005); (Dia, 2011); (Holyoak & Stazic, 2009); (Archer, 2000); (Hadi, et al., 2007); (Helbing, et al., 2002) explains that the micro simulation approach in traffic incident modelling on freeway involves greater deal of empirical data including relevant driver and vehicular characteristics and behavior. Similarly, Dia (2011) describes microscopic traffic simulation as a cost-effective approach in incident modelling allowing incident modelling in both peak and non-peak conditions. As mentioned earlier that macro-simulation modelling lead to an underestimation of vehicle emissions, the micro simulation model on the contrary considers the influence of vehicle acceleration and deceleration rates leading to improved vehicle emissions leading to precise calculation of emissions (Holyoak & Stazic, 2009). In addition to that, Burghout, et al. (2005) states that micro simulation models are suitable for evaluation of ITS systems because of the level of details in modelling for the vehicle and driver behavior. This statement is further confirmed by Holyoak & Stazic (2009) which describes that micro-simulation model have the ability to include driver interaction attributes such as vehicle awareness and network familiarity into the model allowing for a detailed assessment for ITS technologies.

2.2.4 Nanoscopic simulation models

Nanoscopic simulation is the most refined traffic simulation model, where individual parameters for individual vehicles such as cognition, perception, errors and decision making are considered. (Ni, 2003), (Ratrout & Rahman, 2009).

According to Ni (2006), nano simulation is particularly concerned with replicating the individual behavior, modelling waiting times and individual interaction. The network description of nano-simulation is similar to micro-simulation. However, the key difference between the two modelling systems are the person-based travel in contrary to vehicle-based travel respectively. As stated in a report by NSW Government (2013), considering the similarities of two different modelling approaches, several microsimulation software such as AIMSUN now employs a nanoscopic agent-based simulation in the model.

2.3 Traffic Incident Management

The impact of incident significantly reduces when incident management programs are implemented. Depending upon the existing road complexity and incident severity such as level of congestion, travel times of the road, the extent of application of incident management programs can be determined (Dia, 2011). According to Kopelias, et al. (2013), traffic incident management is a significant action to relieve congestion other than adopting other measures like pricing and high occupancy lanes. Thus, traffic incident management is substantial for generating appropriate information and preplanning any incident response.

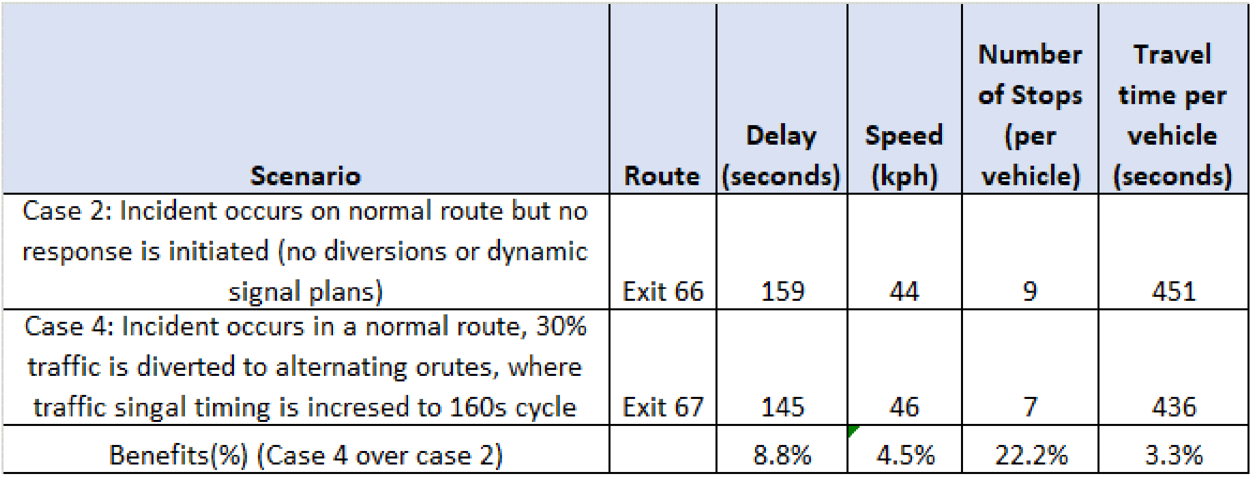
2.3.1 Incident Management using ITS Technology

Intelligent transport system integrates several information and communication technologies in the traffic flow for effective traffic management to ensure safe and effortless travel. Ozbay & Bartin, (2004) describes intelligent transport systems as easily implemented and cost-effective solution for traffic congestion on motorways and road networks. Most common tools that employ ITS for traffic incident management are Variable Message Signs (VMS) and Variable Speed Limits (VSL). A study conducted by Grant-Muller & Usher (2014) determined that implementation of Variable Speed limits (VSL) in UK M42 motorways have reduced the vehicle emissions by 10%. In addition, the fuel consumption was reduced by 4%. Ozbay & Bartin, (2004) suggests that traveler information using VMS is effective ITS technology for reducing travel times as well as reducing traveler cost.

VMS and VSL not only improve the road efficiency but also serve several benefits by reducing the impact during incidents by route diversion and reducing the incident duration by clearing the lanes. Dia (2011), successfully established the benefits in terms of travel times and delay using VMS as an efficient incident impact reduction on freeway. Moreover, the study also assessed the viability of VSL to reduce delay and travel times during incidents.

Table 1 summaries the benefits with and without introducing VMS in a freeway section during incidents where case 2 refers to the incident occurrence and no response initiated whereas case 4 refers to the introduction of VMS in the freeway system as a response to traffic incident management. (Dia, 2011)

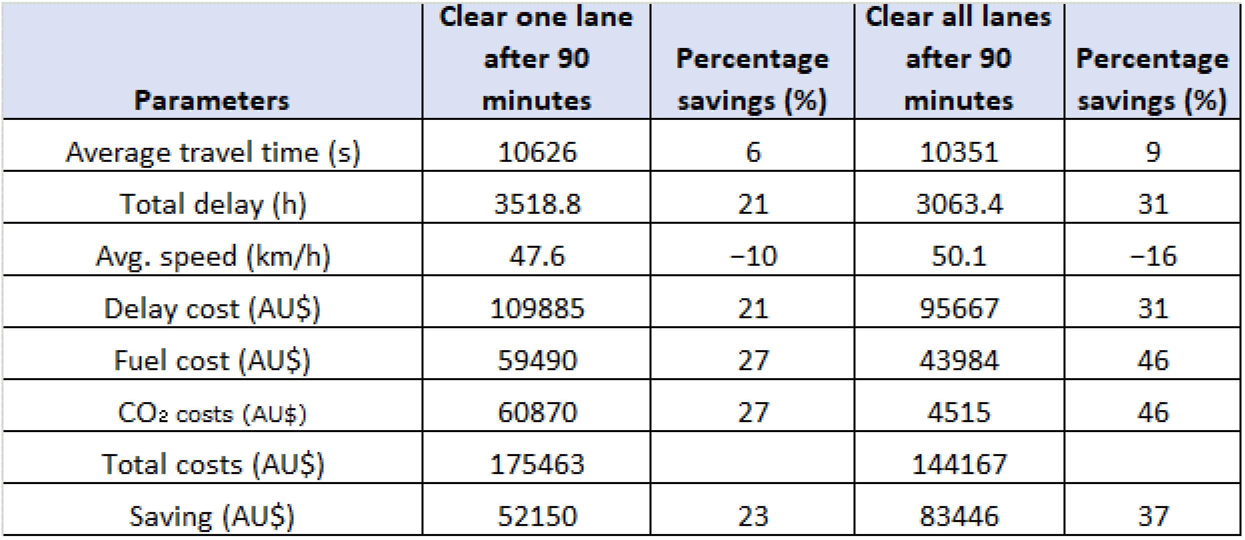
Table 1: Comparison with and without VMS route Diversion on Delay, speed and Travel time (Dia, 2011)



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 in a normal route, 30% traffic is diverted to alternating orutes, where traffic singal timing is incresed to 160s cycle	Exit 67	145	46	7	436
Benefits(%) (Case 4 over case 2)		8.8%	4.5%	22.2%	3.3%

Examination of impacts of incidents and estimation of resultant cost on traffic flow provides reliable data for evaluating several traffic incident management programs (Kabit, et al., 2014), (Hojati, et al., 2011). Kabit et al. (2014) has explored the VMS route diversion to reduce the impact of incidents in a greater detail in terms of estimation of associated costs caused by incident-induced delay, fuel consumption as well as CO_2 emissions. A summary of incident impact reduction in terms of financial savings is presented in Table 2, as suggested by the literature, assigning Variable message sign to reduce a two-hour incident to 90 minutes incident clearance duration, saves the financial cost by 23% during one lane clearance, similarly, 37% of the cost savings when all lane cleared in the same duration was achieved.

Table 2: Incident impact reduction in terms of financial savings using ITS (Kabit, et al., 2014)



Parameters	Clear one lane after 90 minutes	Percentage savings (%)	Clear all lanes after 90 minutes	Percentage savings (%)
Average travel time (s)	10626	6	10351	9
Total delay (h)	3518.8	21	3063.4	31
Avg. speed (km/h)	47.6	−10	50.1	−16
Delay cost (AU$)	109885	21	95667	31
Fuel cost (AU$)	59490	27	43984	46
CO_2 costs (AU$)	60870	27	4515	46
Total costs (AU$)	175463		144167	
Saving (AU$)	52150	23	83446	37

2.3.2 Incident Response using ITS

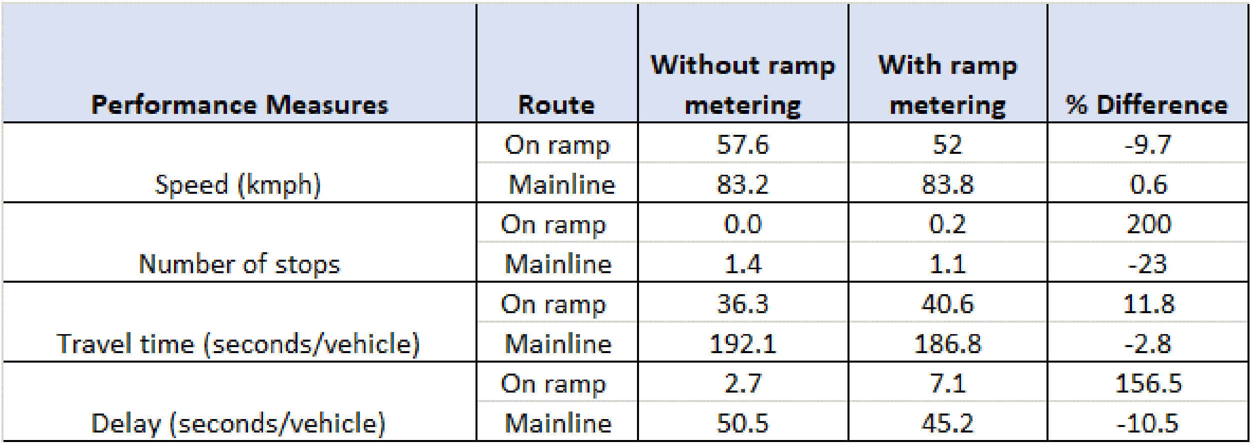
In order to reinstate the traffic flow in a quick and safe manner, traffic incident management program comprises of a multidisciplinary process for detection, response and clearance of traffic during incidents (Houston, et al., 2008).

Most of the literature revolves around the simulation approaches to quantify the incident impacts. However, a study conducted by Kabit, et al. (2011) used the traffic incident data to establish a rapid incident response and management plan. This study does not incorporate any previously discussed traffic incident management techniques like VMS, VSL or ramp metering but rather uses logistic duration model. The literature discusses the rapid deployment of incident response agencies prioritizing the incidents based on their characteristics and severity. Inability to properly assess and prioritize the incident leads to inaccurate and mixed response which significantly increases the incident impact as well as incident duration. Hypothetically, the incident response plan would reduce the incident duration and this study can be compared to Kabit, et al. (2014), where simulation of reduction of incident duration has resulted in significant improvement in incident impacts.

2.3.3 Ramp metering

Ferrara, et al. (2013) defines ramp metering as a control action that has been studied for decades and are adopted in freeways where the traffic flow on-ramp are properly regulated by adopting traffic lights. However, ramp metering is a less prevalent traffic incident management on Freeways and a very few literatures exists which access its characteristics (Dia, 2011), (Ozbay & Bartin, 2004). Ramp metering is a form of ITS control system which specifies the number of vehicles to be released on the freeway at a given time (Dia, 2011). Ramp metering according to Ozbay & Bartin (2004) can be really beneficial to relieve congestion on freeway if coordinated with arterial signals. The same piece of literature further suggests that ramp metering can create unanticipated queue on local roads by causing congestion on freeway exit-ramp. Dia, (2011) suggested in a study that ramp metering can be beneficial during traffic incidents only when traffic demand start to increase. The same study further suggested that as summarized on Table 3 that when traffic demand during any incident intensifies by 25%, travel times are reduced by 2.8%, the delays by 10.5%, and the number of stops declines by 23% as a result of implementation of ramp metering.

Table 3: Performance of Ramp metering during increased travel demand and incident occurrence (Dia, 2011)



Performance Measures	**Route**	**Without ramp metering**	**With ramp metering**	**% Difference**
Speed (kmph)	On ramp	57.6	52	-9.7
	Mainline	83.2	83.8	0.6
Number of stops	On ramp	0.0	0.2	200
	Mainline	1.4	1.1	-23
Travel time (seconds/vehicle)	On ramp	36.3	40.6	11.8
	Mainline	192.1	186.8	-2.8
Delay (seconds/vehicle)	On ramp	2.7	7.1	156.5
	Mainline	50.5	45.2	-10.5

2.4 Case Study Selection

Federal and State Government strategies in several government reports such as (DPTI, 2015) (DPTI, 2016) clearly outlines the importance of Darlington freeway as a significant road linking the rapidly escalating residential areas in south with the central employment and industrial zones. Darlington Road is a 3.3 km section of road providing non-stop access between the Southern Expressway and the north of Tonsley Boulevard supporting over 73,000 vehicles flow per day (DPTI, 2016). The new motorway connects the existing southern end of Southern Expressway through a free flow interchange underneath Main South Road and it connects the Main South Road between Tonsley Boulevard and York Avenue, Clovelly Park at the northern end. (DPTI, 2016). Designed to contend extremely complex traffic movements, Darlington Upgrade is an important part of long-term vision of North South Corridor for Adelaide. (Parrott, 2018)

Aspiration for improving connectivity and productivity of people, (Infrastructure Australia, 2016) highlights the significance of Darlington Upgrade project for improving road connection for industrial and business purposes and international gateways. The efficient and improved road connection within Darlington Precinct will provide people with an improved access and employment opportunities contributing economic growth of South Australia. In addition to that, the freeway section of Darlington avoiding five different traffic lights southbound and four different traffic lights northbound reduces congestion and delay thereby reducing the greenhouse gas emissions (Infrastructure Australia, 2016) leading to a more environment friendly and sustainable infrastructure. Furthermore, the 30-year plan of Greater Adelaide foresees a steady population growth of 560,000 people and construction of 258,000 more homes in Adelaide in coming years (DPTI, 2016). Thus, an integral part of North South Corridor, the Darlington Road Upgrade is a major landmark for connecting new residential zones to and for the major employment areas and freight in future.

A representative layout of the design of the Darlington Road Section with road and ramp details along with the location of the road section in Adelaide is shown below in Figure 5.

Image removed due to copyright restriction.

(a) (b)

Figure 5: Darlington Upgrade Project-roads and ramps (a), Map of Adelaide showing the location of Darlington Road (b), (DPTI, 2016)

The infrastructure upgrade and changes have definitely reduced the delays for traffic and improved overall condition of road section. Still, some sections of the freeway seem to be operating at a bad level of service even without any incidents as seen in the south bound motorway Level of Service Figure 6 and north bound motorway Level of Service Figure 7 without incidents in sections of freeway (DPTI, 2015). Thus, it is necessary to study and analyze the capacity of road network with and without incidents in the road section.

Image removed due to copyright restriction.

Figure 6:South Bound motorway level of Service without Incidents pg. 78. (DPTI, 2015)

Image removed due to copyright restriction.

Figure 7:North Bound motorway level of Service without Incidents Pg. 79 (DPTI, 2015)

As mentioned earlier, the Darlington Road section is indeed an important piece of infrastructure of South Australia. After a thorough study from Department of Transport (DIT), 10-year strategy of North-South Corridor pg.33 (DPTI, 2015), it was revealed that current traffic management system is running at capacity. The Concepts of Operations Report (DPTI, 2015) states that “the capacity of existing traffic management needs to be optimized for the future traffic condition where incident management shall be done by establishing the Intelligent transport system components.” The report further articulates that “several locations in North South Corridor including the existing South Road is a suburban arterial road of modest standard without ITS in sections which has not been upgraded. For the upgrade of which corresponding gaps on ITS infrastructure like the extent of application, must be filled” (DPTI, 2015). The report has revealed that co-operative ITS systems for traffic incident management will be progressively deployed both in the expressway and the arterial roads. Having stated that, the report however failed to list the background, consequences and the extent of application of ITS in the road section for effective traffic incident management.

Roadway incidents inflict a significant economic impact taking the increase in delays, travel time and congestion. As previosuly mentioned in the introduction, DPTI (2017) states that total 517 incidents (recurring and non-recurring) were recorded in the year 2017 in the City of Marion including the Darlington Road section. It is more evident that as the recently upgraded road section came into public operation, the level of impact on road will rise. Thus, traffic incident management in the road section seems even more significant.

Thus, comprehending the present condition of the Darlington Freeway section and realizing that the Freeway section is of utmost importance for social, cultural as well as economic growth of South Australia, the detailed traffic analysis of Darlington Freeway for providing better serviceability is deemed necessary.

Chapter 3

Methodology

In this chapter, the reason of selection of the AIMSUN and SIDRA software for the study is described along with the detailed process of traffic incident modelling, traffic management strategies such as vehicle diversion in AIMSUN and the modelling process and inputs for SIDRA INTERSECTION.

The methodology for this research involves the process of incident modelling following the validation of the base model provided by Department of Infrastructure and Transport. The AIMSUN model provided by DIT was calibrated and validated by using section flows, queue lengths and travel times.

3.1 Choice of Software

Microscopic traffic simulators are the most versatile, popular and powerful traffic analysis tools which has the ability to generate significantly accurate results for the ever-increasing complexity of traffic engineering phenomenon. (Barceló, et al., 2005). Comparing several modelling approaches in Literature review section, microsimulation approach is considered most efficient for incident modeling for studying the impacts of incidents on Darlington Freeway and for evaluating the model in terms of travel times, delay, speed, emissions and use of ITS for-warning drivers and for traffic diversion.

AIMSUN (Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks) is one of the World's leading and the most versatile microsimulation software which generates the vehicle movement data and driver data from the model. For the scope of our research, the vehicle movement parameter is involved. AIMSUN microsimulation software is used in the study for detailed modelling and simulation of traffic incidents on freeway for the traffic flow in morning peak hour using MASTEM (Metropolitan Adelaide Strategic Transport Evaluation Model).

Additionally, SIDRA intersection is a powerful tool to determine the intersection's performance in terms of intersection delay, queue length and level of service. In this research, the performance comparison of intersections before and after incidents is executed to determine the impact and influence of vehicle diversion from freeway to the arterial roads during incident occurrence.

AIMSUN microsimulation is preferred in the research to generate a microsimulation model for incident scenarios modelling, due to being widely accepted software by DIT for strategic transport modelling. The software is capable to quantify the impact of incidents in terms of travel times, emissions, delay times and congestion. Moreover, AIMSUN microsimulation is also able to incorporate Variable Message Signs as traffic demand and incident management strategies. Detailed capabilities of the software are discussed in section 3.2.

On the other hand, SIDRA INTERSECTION is a powerful software to analyze the intersection along with the ability to optimize the intersection signal timing for a future model. As opposed to AIMSUN, SIDRA is only capable of analyzing intersections and roundabouts whereas AIMSUN is capable of simulating a whole traffic network in detailed level of individual vehicle.

As this research is conducted for a future traffic model of year 2031, the limitation of AIMSUN to optimize the intersections for future model was addressed by using SIDRA software. In addition to intersection optimization, the performance of intersection was determined in terms of Level of Service (LOS) from SIDRA software and hence, both the software together addresses each research objectives.

3.2 AIMSUN

AIMSUN is a continuously improving and evolving microsimulation tool in terms of functionalities and features and used for traffic analysis which has the ability to incorporate the ITS application in analysis which is the essential trend for traffic incident management in the modern world. (Barceló, et al., 2005)

According to the AIMSUN User's Guide, (2021), AIMSUN is capable of evaluation of travel demand management strategies, evaluation of highway capacity, calculation of level of emissions and environmental impact of a traffic model, assessment and optimization of Transit Signal Priority and bus rapid transit schemes and so on.

AIMSUN realistically follows the flow of individual vehicles through a road network providing feasibility in transportation studies such as high occupancy vehicles, high occupancy toll lanes etc. AIMSUN microsimulation requires model parameters in terms of vehicular as well as driver parameters and calculation is performed in every simulation step, realizing the circumstances and condition of each network. (Barceló, et al., 2005)

AIMSUN microsimulation tool is widely accepted and practiced tool for traffic analysis all over the world along with Department of Infrastructure and Transport, South Australia. The capabilities of AIMSUN (AIMSUN user's guide ,2021) applicable to this research are listed below:

- Ability of incident impact analysis of highway infrastructure (freeway).
- Ability of environmental impact analysis in terms of fuel consumptions and emissions.
- Ability to evaluate the travel demand management strategies.
- Ability to integrate Intelligent Transport Systems.
- Ability of freeway capacity analysis and safety analysis.

3.3 Limitation of AIMSUN

AIMSUN is a World's leading and the most versatile microsimulation software, however, it has some limitations as listed below:

- Inability to optimize the intersection signal timing for a future model.

In order to determine the level of impact of vehicle diversion using VMS on the performance of whole network, the study of adjacent ramps and intersections needs to be conducted. However, as this study is conducted for future model of year 2031, the limitation of AIMSUN to optimize the intersection may lead to inaccurate interpretation of results. Thus, to overcome the drawbacks of the software, SIDRA INTERSECTION was used in the study to optimize the intersection more effectively and efficiently and to evaluate the performance of intersection during vehicle diversion from freeway.

3.4 SIDRA INTERSECTION

SIDRA INTERSECTION is an advanced micro-simulation tool used for design and evaluation of individual signalized or un-signalized intersections and intersection network based on Origin-Destination movements. (SIDRA user’s guide,2020). The capacity and performance of intersection is determined in terms of level of service, queue length and delay.

SIDRA is a powerful software which simulate the signalized intersections using several traffic control strategies as well as provides an insight to congestion relieving techniques. In this study, SIDRA Intersection is used to study several scenarios of vehicle diversion to determine the level of impact each diverted percentage of vehicle from the incident location has on the existing network performance.

3.5 Intelligent Transport Systems

Intelligent Transport System comprises of a set of applications for information and communication technologies in field of transportation with an objective of delivering large community, energy and economic benefits (Stough, 2001).

A fully managed freeway consists of several systems and traffic management components. Effective implementation of Intelligent Transport Systems aids to improvement of freeway traffic performance and effective management of the traffic flow on freeway. (Austroads, 2009)

ITS incorporates the road infrastructure, vehicle and the user for collecting, processing and integrating information in real time for dynamic management of a road network. In the recent years, ITS is continuously evolving and devoting more efforts and resources to their development and implementation and is a dynamic technology for traffic incident management.

Similarly, Variable Message Sign is an electronic message displaying mechanism that employs Intelligent Transport System technologies for displaying real-time traveler information such as incidents, delay, speed limits, road work alerts, diversion alerts and so on.

3.6 Modelling in AIMSUN

This section will outline the implemented methodology for the traffic incident modelling of Darlington-Freeway section in AIMSUN. The detailed process of incident generation and traffic management strategies using AIMSUN model is discussed along with the model calibration and validation, confirming the real-life resemblance of model.

3.6.1 Network Development in AIMSUN

The Darlington Expressway (Freeway) network consisting of Tonsley, Ayliffes, Sturt and Flinders Drive as major intersections up to Southern Expressway were modelled which consisted of all the major and strategic roads, signalized and un-signalized intersections, pedestrian crossings and other significant traffic controls within Bedford park, Marion road and Sturt. Though, a particular section of freeway extending from Tonsley Boulevard to the Sturt road south is considered as a scope of research. The model was extended beyond the scope of research so as to initiate a more realistic pattern of traffic arrival as per Department of Transport's AIMSUN model development manual. The network consisted of 48 centroids which establishes the proportion of vehicles released to each road section and are the source of traffic generation in the model. A total of 22,904 vehicles flowing through the morning peak duration throughout the entire network was assigned through the Origin-Destination (O-D) matrix for different vehicle classes like cars and heavy vehicles. All traffic entering to the model were allowed to enter without any significant virtual queues at the boundaries.

Network modelling is the most time consuming and complicated part in this research because of the micro- level of detail required for the modelling in terms of individual lanes as well as individual vehicular characteristics. Thus, considering the complexity as well as time required for the modelling, the base model provided by DIT was calibrated and validated and was used for detailed freeway modelling using geometric configuration features.

Figure 8 shows the aerial image of study area in Darlington Freeway section extending from north of Tonsley Boulevard to south of Sturt Road.

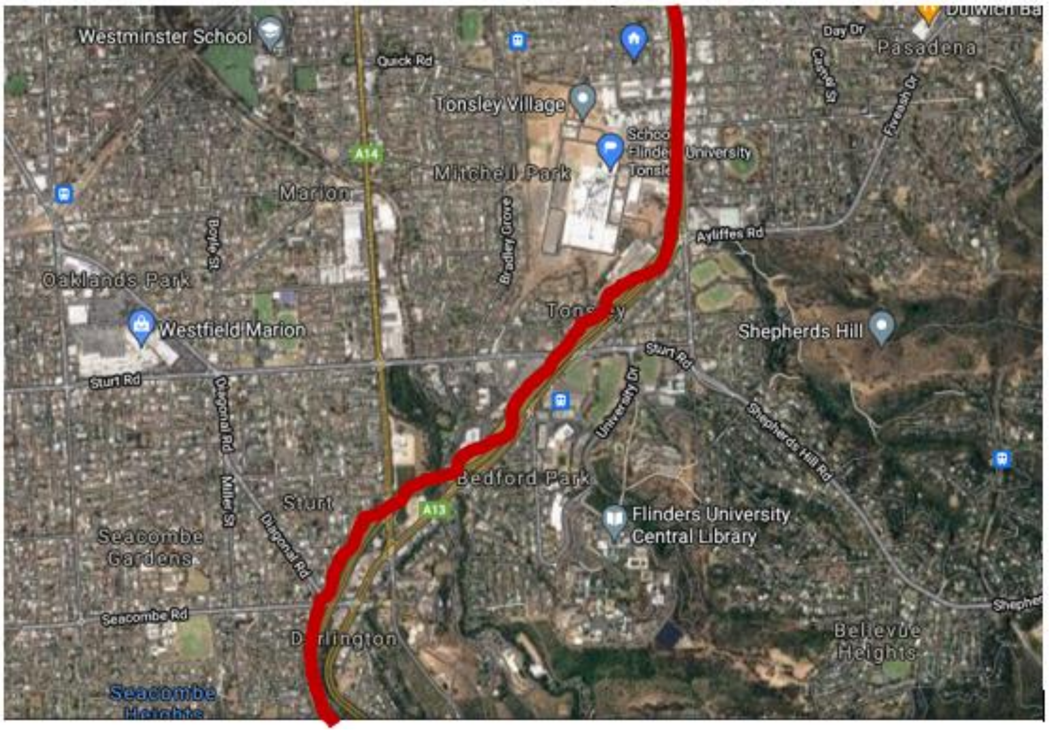


Figure 8:Aerial image of study area (from Google Maps)

Figure 9 portrays the microsimulation model of whole network showing road links and centroids (left) and the extent of detail in the model (right). Every individual vehicular characteristics and behavior is modelled in this research.

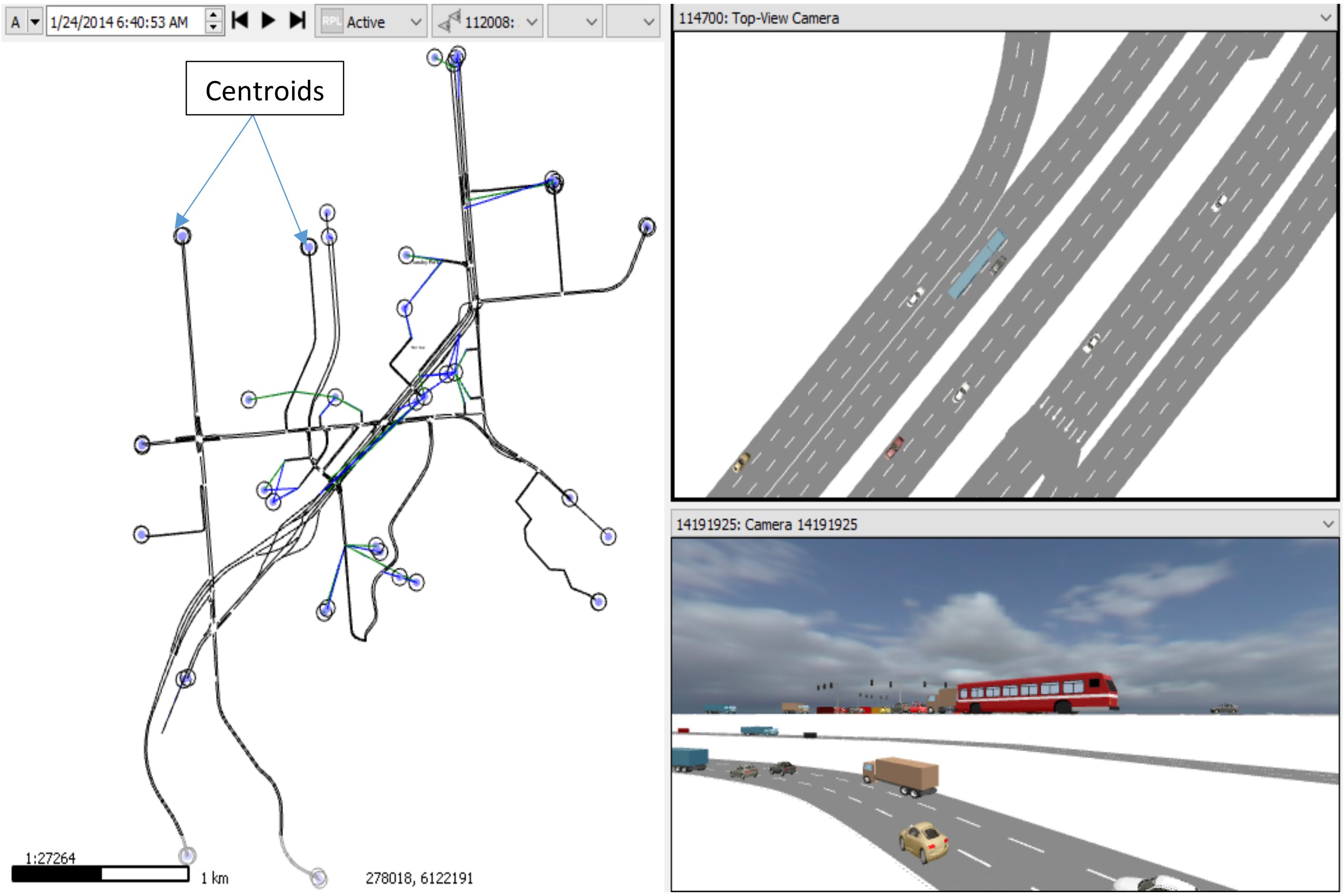


Figure 9: Modelled network of study area (left), level of detail for individual vehicles on AIMSUN microsimulation model (right)

3.6.2 Travel Demand

Traffic flow model often requires three different set of data: model input, model parameter and the model output (Barceló, et al., 2005). In the model, an Origin-Destination (O-D) matrix involving the demand data for the traffic simulation split into light vehicles such as cars and heavy vehicles such as buses and trucks for the future model was derived from Metropolitan Adelaide Strategic Transport Evaluation Model (MASTEM) and developed in the excel sheet. O-D demand represents the travel demand between centroids. Since the traffic data was provided by Department of Transport, thus more accurate origin-destination count was developed. Moreover, the output data was validated with the observed in real life to evaluate the accuracy of the outputs.

The construction of O-D matrix followed the steps listed below.

Step 1: The turning counts for the freeway were calculated for both directions of travel.

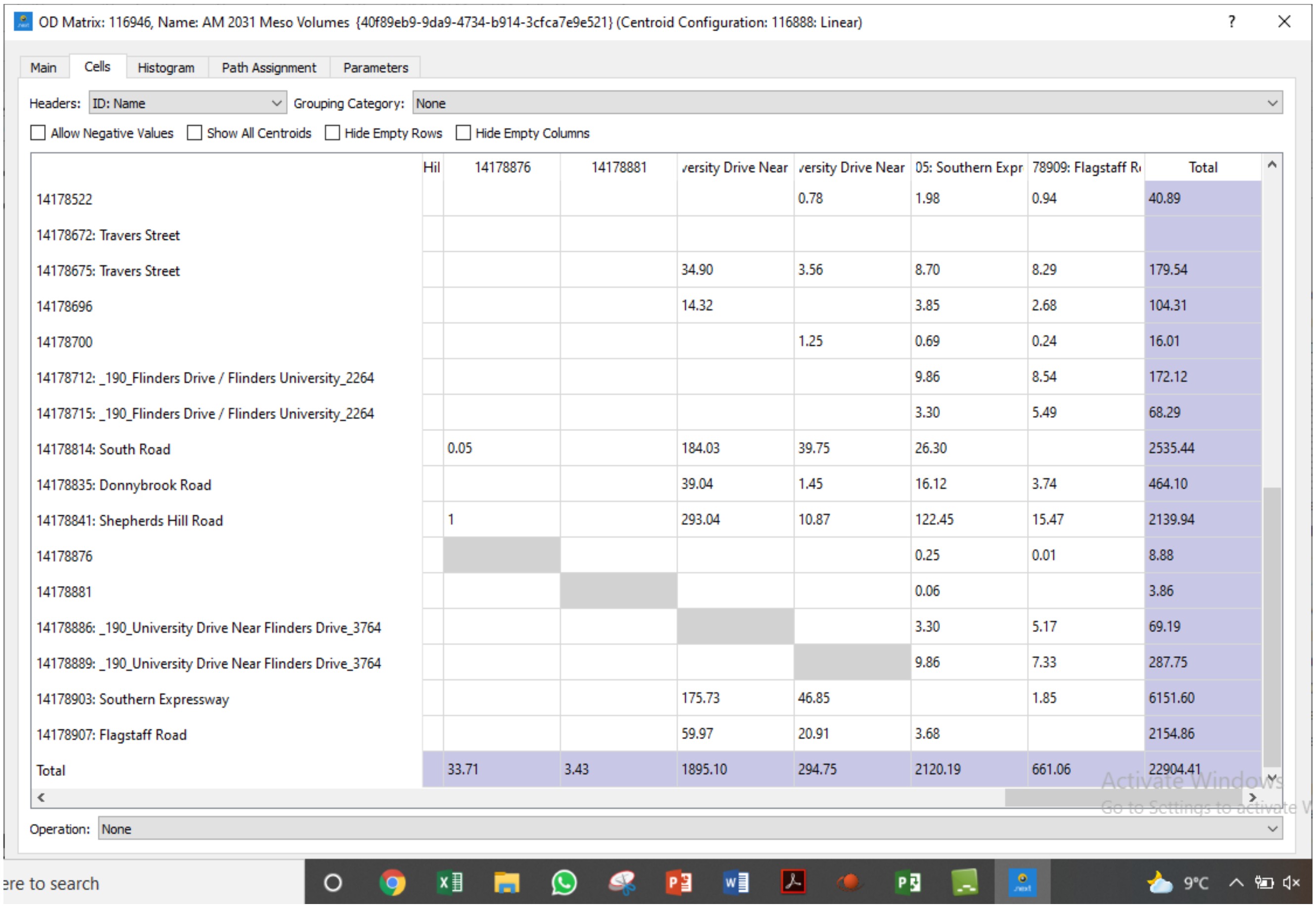
The traffic counts were calculated for number of links selected study network for the time intervals in AM peak.

Step 2: The through movement of Northbound and Southbound traffic was determined.

The through movement of Northbound and Southbound traffic was determined with an assumption that no vehicle will have both exit and entry from the same zone.

Step 3: The traffic routes were input in O-D matrix.

The O-D matrix generated from the observed flows for morning peak was adjusted and the matrix was input for dynamic simulation in the AIMSUN microsimulation model.



OD Matrix: 116946, Name: AM 2031 Meso Volumes {40f89eb9-9da9-4734-b914-3cfca7e9e521} (Centroid Configuration: 116888: Linear)

Headers: ID: Name
Grouping Category: None

☐ Allow Negative Values ☐ Show All Centroids ☐ Hide Empty Rows ☐ Hide Empty Columns

	Hil	14178876	14178881	ersity Drive Near	ersity Drive Near	05: Southern Expr	78909: Flagstaff R	Total
14178522					0.78	1.98	0.94	40.89
14178672: Travers Street								
14178675: Travers Street				34.90	3.56	8.70	8.29	179.54
14178696				14.32		3.85	2.68	104.31
14178700					1.25	0.69	0.24	16.01
14178712: _190_Flinders Drive / Flinders University_2264						9.86	8.54	172.12
14178715: _190_Flinders Drive / Flinders University_2264						3.30	5.49	68.29
14178814: South Road		0.05		184.03	39.75	26.30		2535.44
14178835: Donnybrook Road				39.04	1.45	16.12	3.74	464.10
14178841: Shepherds Hill Road		1		293.04	10.87	122.45	15.47	2139.94
14178876						0.25	0.01	8.88
14178881						0.06		3.86
14178886: _190_University Drive Near Flinders Drive_3764						3.30	5.17	69.19
14178889: _190_University Drive Near Flinders Drive_3764						9.86	7.33	287.75
14178903: Southern Expressway				175.73	46.85		1.85	6151.60
14178907: Flagstaff Road				59.97	20.91	3.68		2154.86
Total		33.71	3.43	1895.10	294.75	2120.19	661.06	22904.41

Operation: None

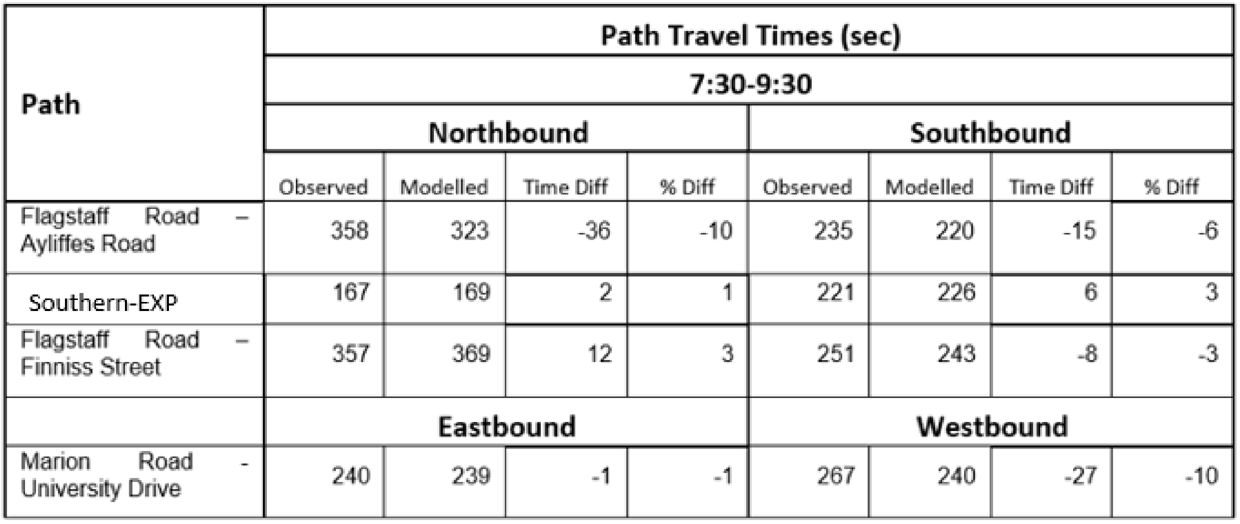
Figure 10: Origin-Destination Matrix input in microsimulation software

Figure 10 shows the Origin-Destination matrix input from the AIMSUN model.

3.6.3 Model calibration and Validation

Model calibration is an iterative process to change the model parameter comparing the outputs to reach a predefined level of agreement with the real-life data (Casas, et al., 2010). In other words, the objective of model calibration is to test the accuracy of the model and to refine it so that more accurate and assertive results can be generated. The microsimulation base model represents the existing traffic conditions of year 2016 and has been calibrated in terms of queue length, section flows and traffic volume to improve the match between the observed and the modelled traffic movement pattern using path travel time information. Travel time measure provides more accurate trips measurement. Thus, this model enables to access and compare several traffic incident scenarios for the year 2031 to generate more reliable results.

Table 4: AM peak Travel Time Comparison



Path	Path Travel Times (sec)							
	7:30-9:30							
	Northbound				**Southbound**			
	Observed	Modelled	Time Diff	% Diff	Observed	Modelled	Time Diff	% Diff
Flagstaff Road – Ayliffes Road	358	323	-36	-10	235	220	-15	-6
Southern-EXP	167	169	2	1	221	226	6	3
Flagstaff Road – Finniss Street	357	369	12	3	251	243	-8	-3
	Eastbound				**Westbound**			
Marion Road - University Drive	240	239	-1	-1	267	240	-27	-10

For a traffic incident simulation to behave like real-life data, the model outputs must be validated for real experimentation. The validation of the microsimulation model was performed by comparing the observed travel times data and the outputs from the simulation model. Table 4 shows the travel time comparison of the base model 2016 and the real-life observed data. The modelled and observed traffic movements shows an acceptable level of confidence. Thus, the model was found to be well calibrated and appropriate for construction for testing the construction staging scenarios.

3.6.4 Incident modelling in AIMSUN

This section will outline the details of incident modelling and the significance of location and time choice along with the detailed lane blockage scenarios.

3.6.4.1 Selection of Incident Location, Time and Duration:

After calibrating and validating the AIMSUN model for AM peak, from the total traffic count for AM peak, the maximum traffic flow volume was identified during 06:30AM-09:30AM. The data was then analyzed and the total travel time for the network was determined for 3 hours of maximum flow volume to calculate the busiest time and duration of traffic flow in the freeway in AM peak during normal operation. A representative graph for average travel time was generated from the acquired results as shown in Figure 11.

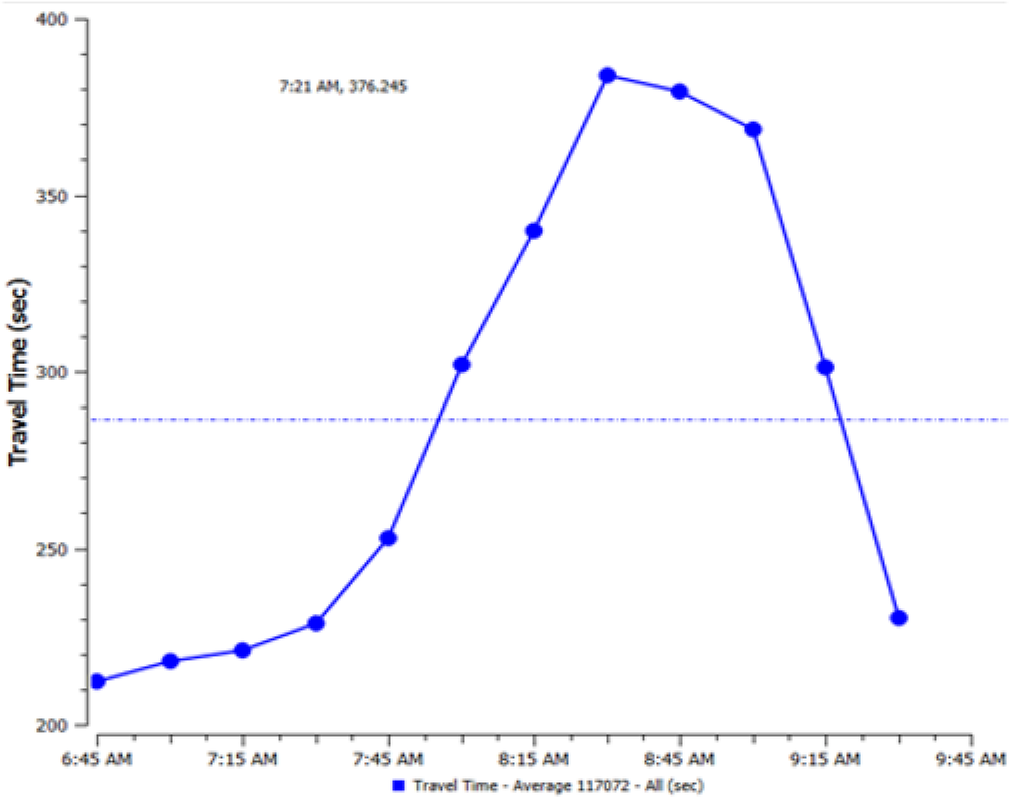
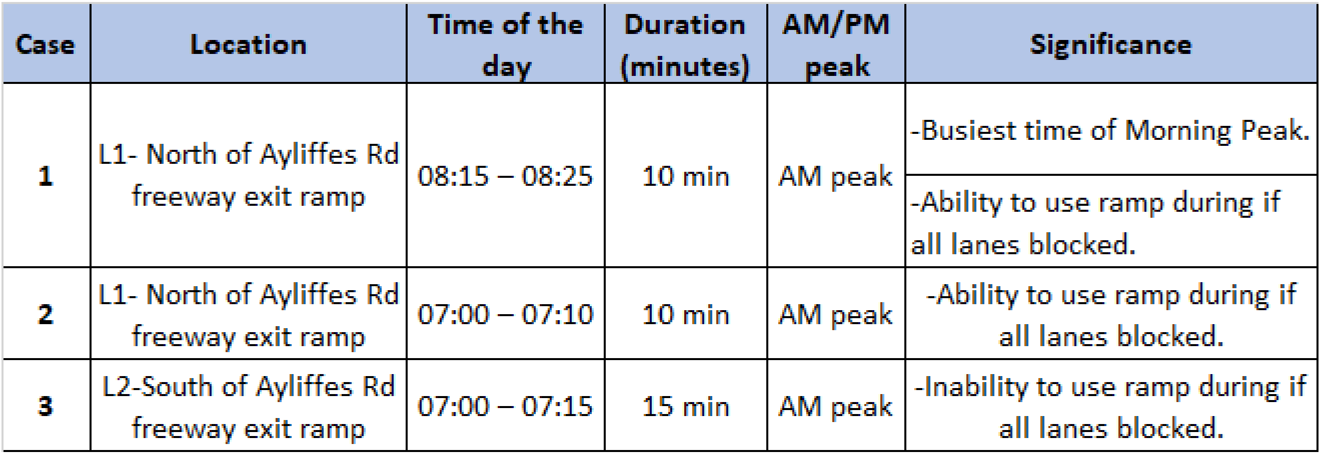


Figure 11: Total travel time of the entire network showing the busiest time during morning peak

The time around 08:15 AM seemed to be the busiest time based on travel times. Hence, the incident time of 08:15 AM- 08:25 AM for 10 minutes' duration was modelled for the study to study the impact of incident during AM peak. The northern location on Northbound Tunnel on freeway was selected to study the impact and level of vehicle diversion while allowing traffic access to the Ayliffes Road ramp from the freeway in case of any interruption due to incident in the freeway. Similarly, an incident duration of 10 minutes at the same location and 07:00AM-07:10AM was modelled. Additionally, along with the critical time and duration, a second location was selected south of the Northbound Tunnel, without giving vehicle access towards the freeway-exit ramp in case of incident occurrence was modelled. Thus, at this location a 15 minutes' duration incident was modelled for 07:00AM- 07:15AM.

Table 5 summarizes the incident location, duration and the time of the day used for the study.

Table 5: Summary of modelled incident location, duration, time of the day for the study



Case	Location	Time of the day	Duration (minutes)	AM/PM peak	Significance
1	L1- North of Ayliffes Rd freeway exit ramp	08:15 – 08:25	10 min	AM peak	-Busiest time of Morning Peak. -Ability to use ramp during if all lanes blocked.
2	L1- North of Ayliffes Rd freeway exit ramp	07:00 – 07:10	10 min	AM peak	-Ability to use ramp during if all lanes blocked.
3	L2-South of Ayliffes Rd freeway exit ramp	07:00 – 07:15	15 min	AM peak	-Inability to use ramp during if all lanes blocked.

Figure 12 and Figure 13 demonstrates the location of incidents and the location of VMS.

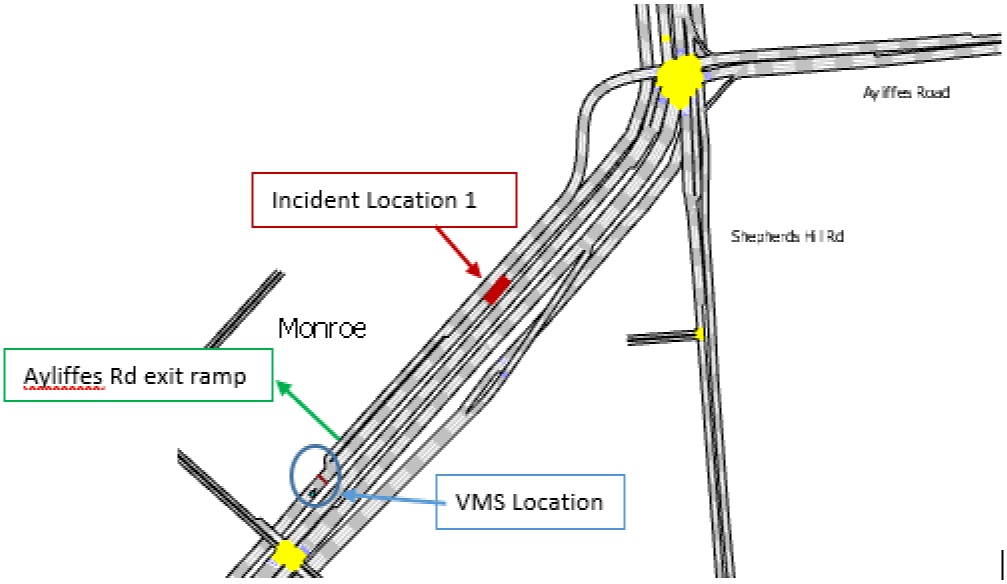


Figure 12:Incident Location L1 -North bound Tunnel - North of Ayliffes Road freeway exit ramp

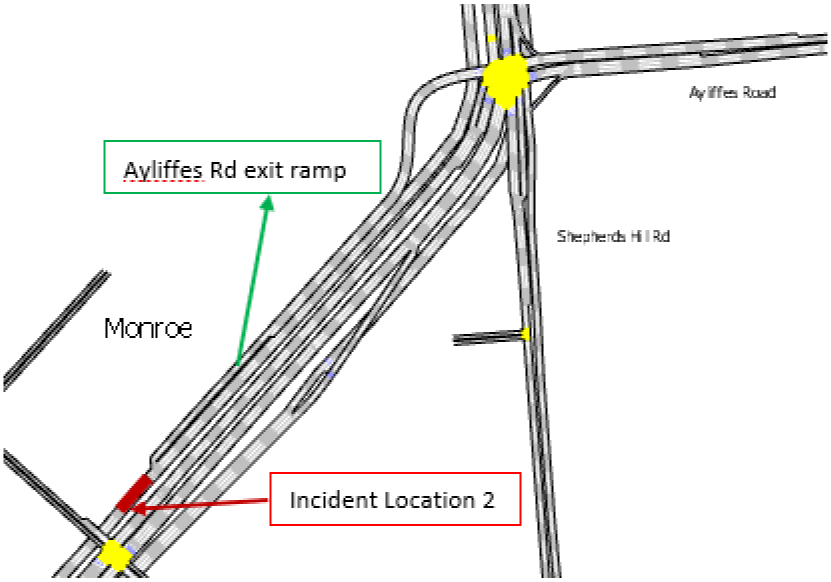


Figure 13: Incident Location L2- North bound Tunnel - South of Ayliffes Road freeway exit ramp

3.7 AIMSUN Specifications

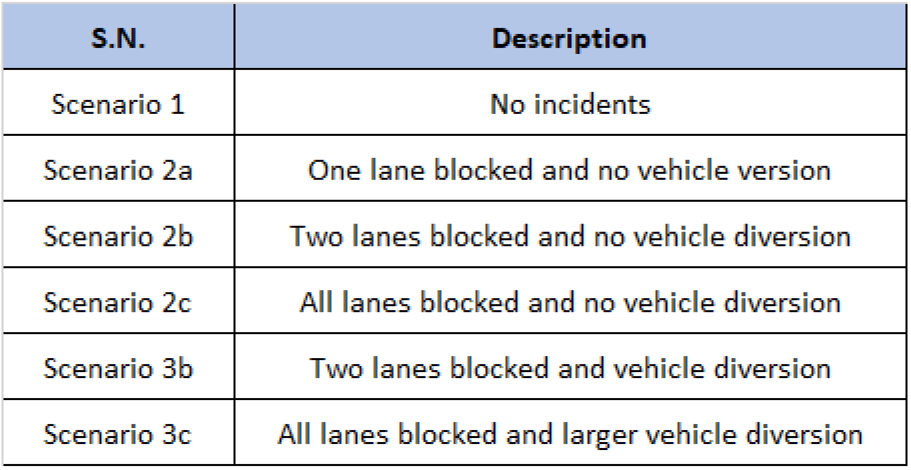
This section will demonstrate the process of incident scenario specifications, incident specification, incident duration specification as well as vehicle diversion assign using Variable Message Sign (VMS) in AIMSUN.

3.7.1 Incident Scenario Specifications

The incident modelling for the freeway network has been divided into three incident severity types of lane blockages for each incident location, duration and time of the day and the speed reduction to 50km/h. Each type is further subdivided into different scenarios for varied lane blocking circumstances and vehicle diversion.

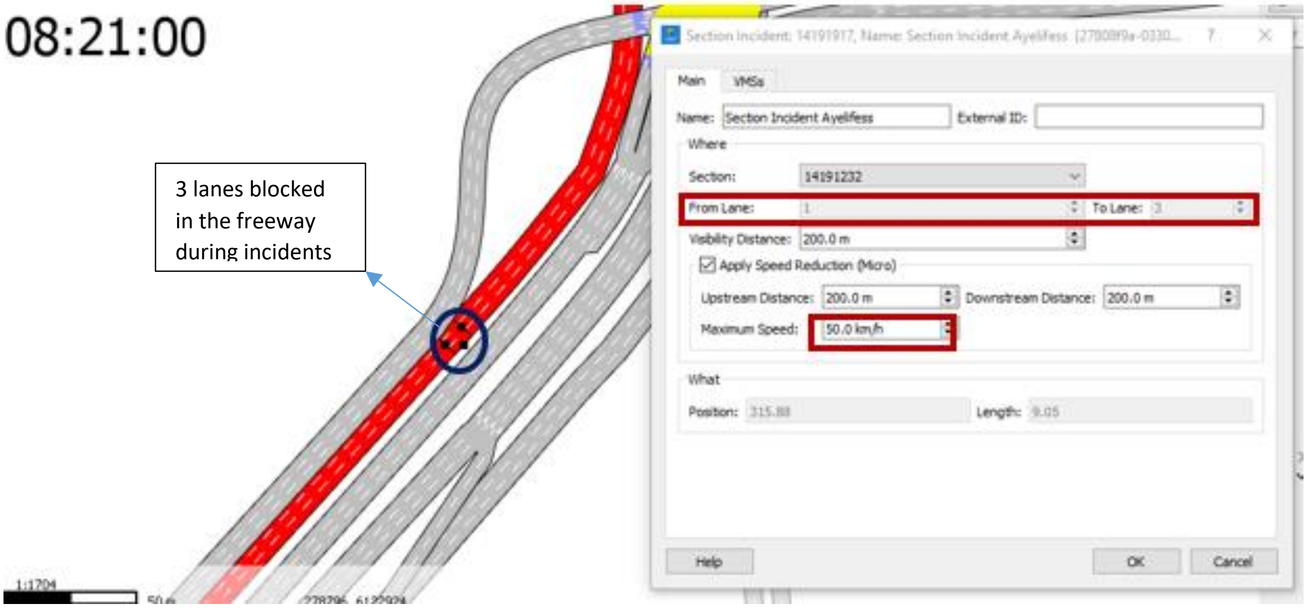
All the scenarios in Table 6 included the use of 2031 model and the assumed speed reduction of 50km/h due to incidents.

Table 6: Description of incident scenarios modelled in AIMSUN



S.N.	Description
Scenario 1	No incidents
Scenario 2a	One lane blocked and no vehicle version
Scenario 2b	Two lanes blocked and no vehicle diversion
Scenario 2c	All lanes blocked and no vehicle diversion
Scenario 3b	Two lanes blocked and vehicle diversion
Scenario 3c	All lanes blocked and larger vehicle diversion

Additionally, Figure 14 shows the specification in AIMSUN model for lane blockage severity for three lanes. Similar representation diagram for one-lane and two-lane blocking scenarios are presented in Appendix A.



3 lanes blocked in the freeway during incidents

Section Incident: 14191917, Name: Section Incident Ayelifess {27008f9a-0330...

Name: Section Incident Ayelifess
External ID:

Where
Section: 14191232
From Lane: 1
To Lane: 3
Visibility Distance: 200.0 m
☑ Apply Speed Reduction (Micro)
Upstream Distance: 200.0 m
Downstream Distance: 200.0 m
Maximum Speed: 50.0 km/h

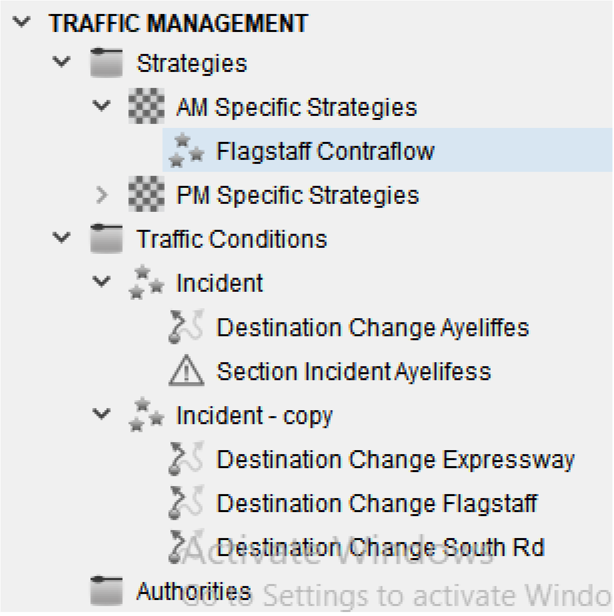
What
Position: 315.88
Length: 9.05

Figure 14: Modelling of 3 lane blocking scenario; blocked lanes (1-3), speed= 50.0 kmph

3.7.4.1 Incident Specification

In AIMSUN the probable traffic incidents were modelled using traffic management tab in selected locations of freeway for different lane severity types (one lane blockage, two lane blockage).Figure 15 shows the screenshot from AIMSUN software for the traffic management parameter specified in the model where traffic conditions refers to the trigger and obstracles such as incidents during a certain specified duration. The software allows to model the start time and the duration of incidents as in Figure 16 and the nature of incidents such as speed and the lane blockage severity as presented in Figure 17.

As incident occurs on the freeway, traffic demand increases. To overtake traffic congestion problems in future due to incidents, more traffic management strategies are required to cope with the extra demand. Thus, the management strategies to divert the flow from one origin centroid to destination centroid through a different route is assigned in the model replicating the driver behaviour of route diversion in real life as a response to information from VMS as shown in Figure 18 and Figure 19. The management strategies were assigned such that the traffic entering to the Darlington Freeway section heading towards Adelaide city during incidents were diverted through the Marion Road-Sturt Road intersection as well as Main South Road from the freeway-exit ramp.

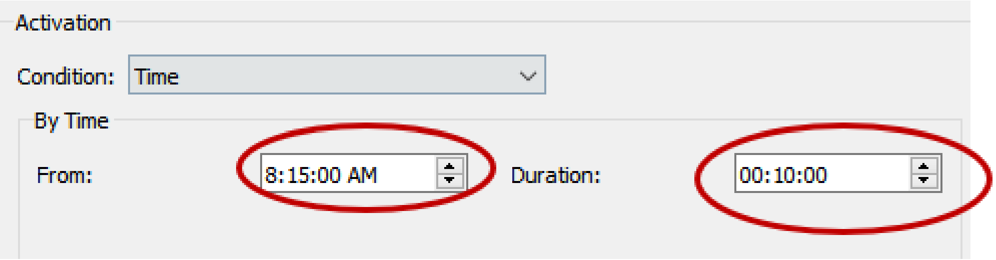


- TRAFFIC MANAGEMENT
  - Strategies
    - AM Specific Strategies
      - Flagstaff Contraflow
    - PM Specific Strategies
  - Traffic Conditions
    - Incident
      - Destination Change Ayeliffes
      - Section Incident Ayelifess
    - Incident - copy
      - Destination Change Expressway
      - Destination Change Flagstaff
      - Destination Change South Rd
  - Authorities

Figure 15: Traffic management strategies and traffic incident assign in AIMSUN

3.7.4.2 Incident Duration:

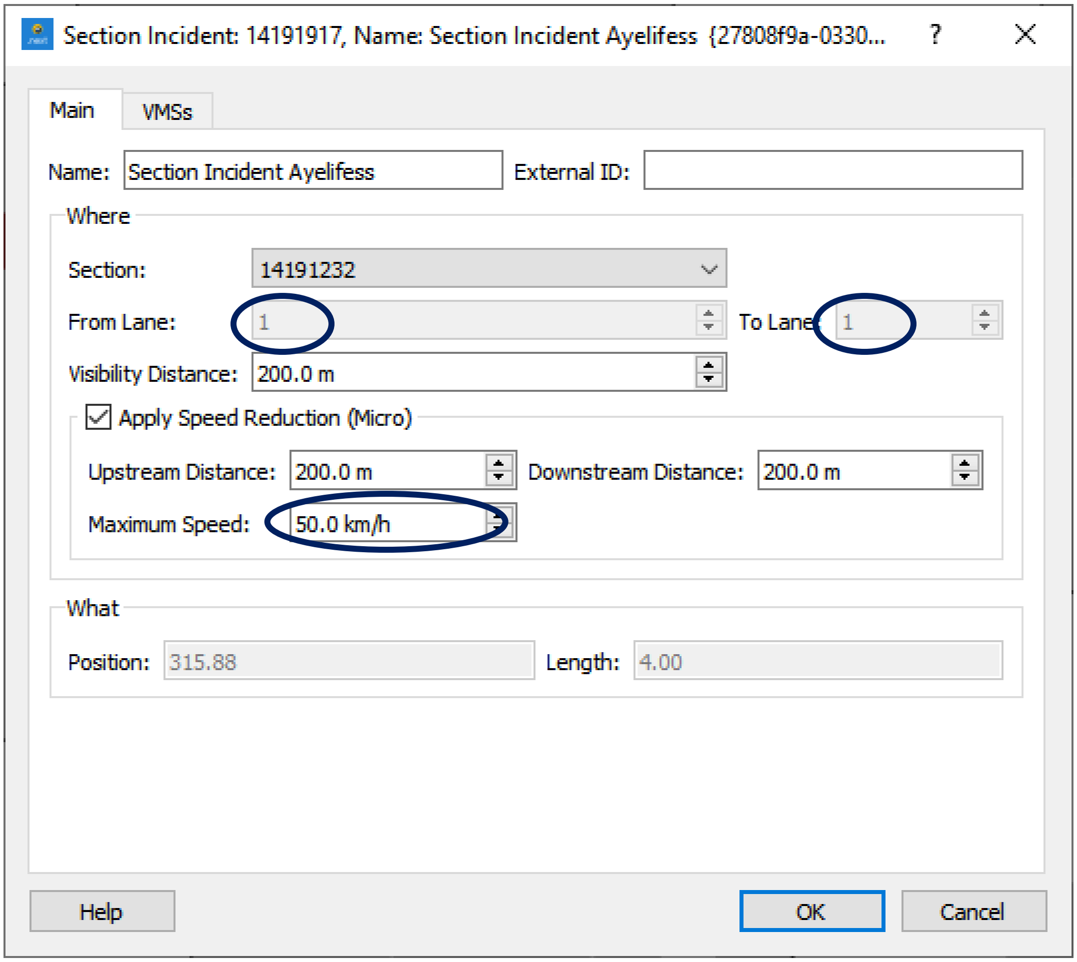
Figure 16 depicts the incident duration starting from 08:15 AM for a duration of 10 minutes. Similarly, other two different time durations were assigned at different locations and different time of the day for the study.



Activation
Condition: Time
By Time
From: 8:15:00 AM
Duration: 00:10:00

Figure 16: Assign of incident duration

During the incident, the vehicle speed was reduced to 50.0 km/h and the number of lane closure were specified in each scenario for every lane blockage severity as specified in Figure 17.


Section Incident: 14191917, Name: Section Incident Ayelifess {27808f9a-0330...

Name: Section Incident Ayelifess
External ID:

Where

Section: 14191232

From Lane: 1

To Lane: 1

Visibility Distance: 200.0 m

☑ Apply Speed Reduction (Micro)

Upstream Distance: 200.0 m

Downstream Distance: 200.0 m

Maximum Speed: 50.0 km/h

What

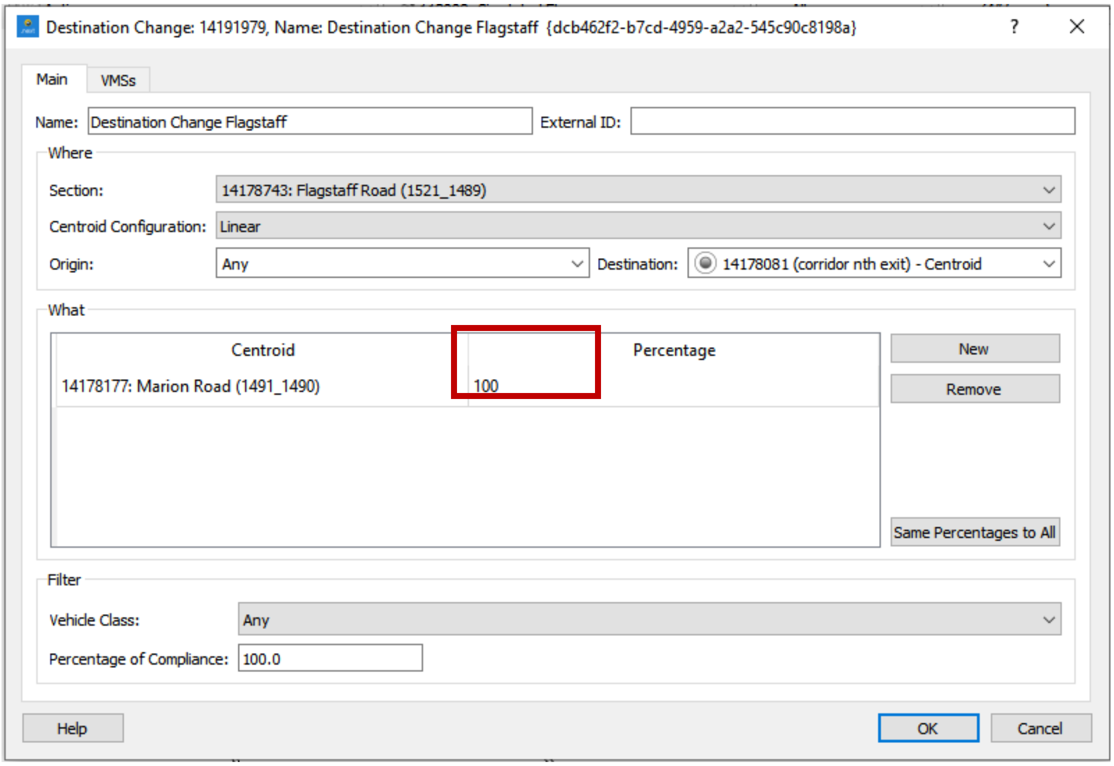
Position: 315.88

Length: 4.00

Figure 17: Specification of one lane blockage severity and the modelled speed in AIMSUN model

3.7.4.3 Vehicle Diversion Assign:

In AIMSUN, the destination change tab was assessed to specify the vehicle diversion, the destination centroids for vehicles entering northbound towards the Darlington Freeway were diverted towards an alternative route and the diversion percentage of vehicle for each road section was specified. As shown in Figure 18 and Figure 19, vehicles from Flagstaff road section as well as Southern Expressway heading towards Northbound freeway tunnel were diverted towards Marion Road as well as Main South Road respectively via the freeway exit ramp for varied diversion percentage.



Destination Change: 14191979, Name: Destination Change Flagstaff {dcb462f2-b7cd-4959-a2a2-545c90c8198a}

Name: Destination Change Flagstaff
External ID:

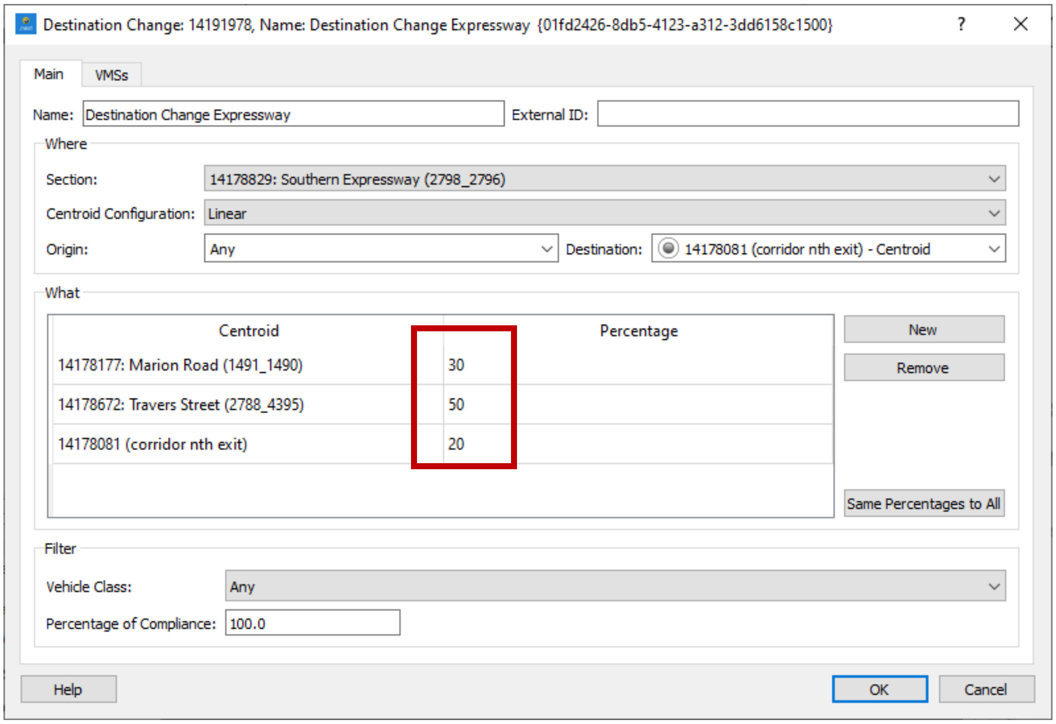
Where
Section: 14178743: Flagstaff Road (1521_1489)
Centroid Configuration: Linear
Origin: Any
Destination: 14178081 (corridor nth exit) - Centroid

What

Centroid	Percentage
14178177: Marion Road (1491_1490)	100

Filter
Vehicle Class: Any
Percentage of Compliance: 100.0

Figure 18: Destination Change of vehicles from Flagstaff road section heading towards Northbound freeway to Marion road (Specified diversion percentage=100%)



Destination Change: 14191978, Name: Destination Change Expressway {01fd2426-8db5-4123-a312-3dd6158c1500}

Name: Destination Change Expressway
External ID:

Where
Section: 14178829: Southern Expressway (2798_2796)
Centroid Configuration: Linear
Origin: Any
Destination: 14178081 (corridor nth exit) - Centroid

What

Centroid	Percentage
14178177: Marion Road (1491_1490)	30
14178672: Travers Street (2788_4395)	50
14178081 (corridor nth exit)	20

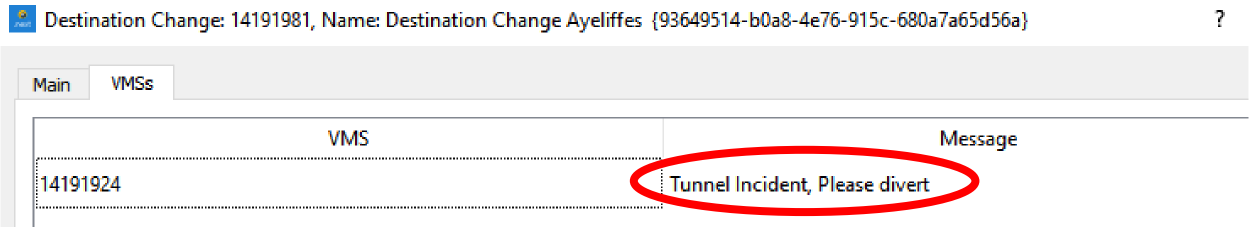
Filter
Vehicle Class: Any
Percentage of Compliance: 100.0

Figure 19: Destination Change of vehicles from Southern Expressway section heading towards Northbound freeway to Main South road via freeway exit-ramp and Marion Road.

3.7.4.4 Variable Message Signs:

Variable Message Sign (VMS) is the electronic information display system which employs Intelligent Transport System technologies. VMS affects the reflexes of road users to use their judgement to divert to an alternative route, reduce the speed and apply brakes during any incident occurrence on freeway. VMS assign can be performed using AIMSUN. VMS contains a set of probable display messages which during simulation process can be activated anytime.

In the model, an electronic information display system was activated with the message “Tunnel Incident, Please Divert” and the effect of vehicle diversion using VMS was evaluated.



Destination Change: 14191981, Name: Destination Change Ayeliffes {93649514-b0a8-4e76-915c-680a7a65d56a}

VMS	Message
14191924	Tunnel Incident, Please divert

Figure 20: Information on VMS display

Figure 21 shows the message on VMS display from the AIMSUN model.

Figure 21: Display message in VMS traffic sign in AIMSUN

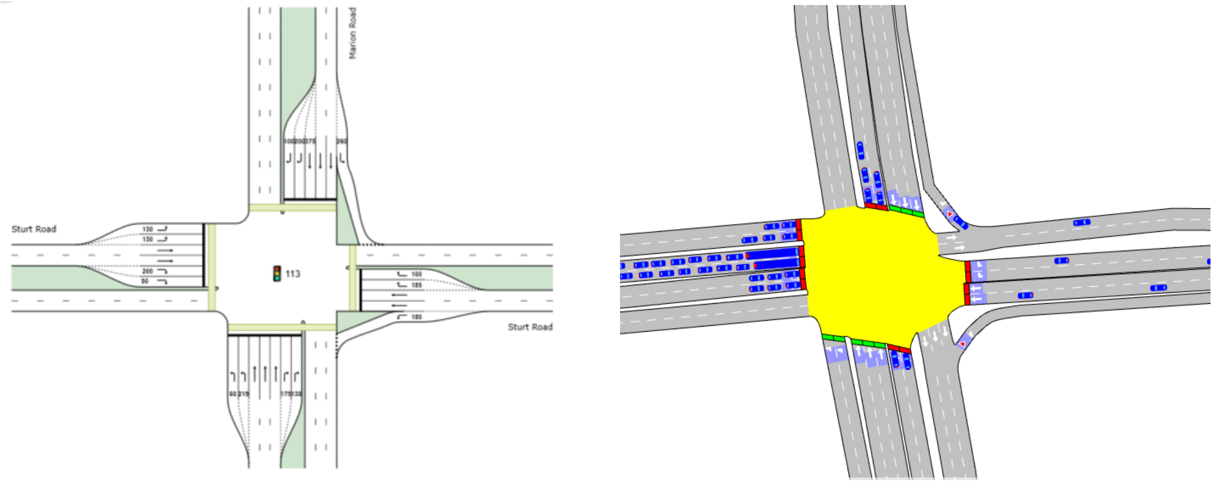
3.8 Intersection Modelling in SIDRA

This section will outline the approach implemented for Marion Road-Sturt Road intersection modelling in SIDRA for the performance evaluation of the intersections during vehicle diversion as a result of traffic management during any incident occurrence on Darlington Freeway section.

The performance of intersection of Marion Road- Sturt Road during normal traffic flow and for different level (0-100%) of vehicle diversion from the Northbound Tunnel during incident occurrence in morning peak is evaluated in terms of Level of Service (LOS) and the consequences and implications are discussed.

3.8.1 Intersection Geometry Development

The Marion Road-Sturt Road intersection was modelled in SIDRA for 2031 specifying the number of lanes, slip lanes, vehicle movement and vehicle volume inputs and it was matching DIT's AIMSUN model specifications for the same intersection phasing. The process of model development was implemented as recommended in DIT's SIDRA Modelling Guide. Figure 22 represents the geometry of the intersection from SIDRA model (left) as well as corresponding AIMSUN model (right).



a.

b.

Figure 22: Intersection geometry in the SIDRA model (a) and from corresponding AIMSUN model (b)

In order to make the SIDRA model produce more realistic results, it was assumed that, the parking (short lane) on the North-exit of the intersection would be removed as shown in Figure 23 during incident occurrence and the model results were analyzed.

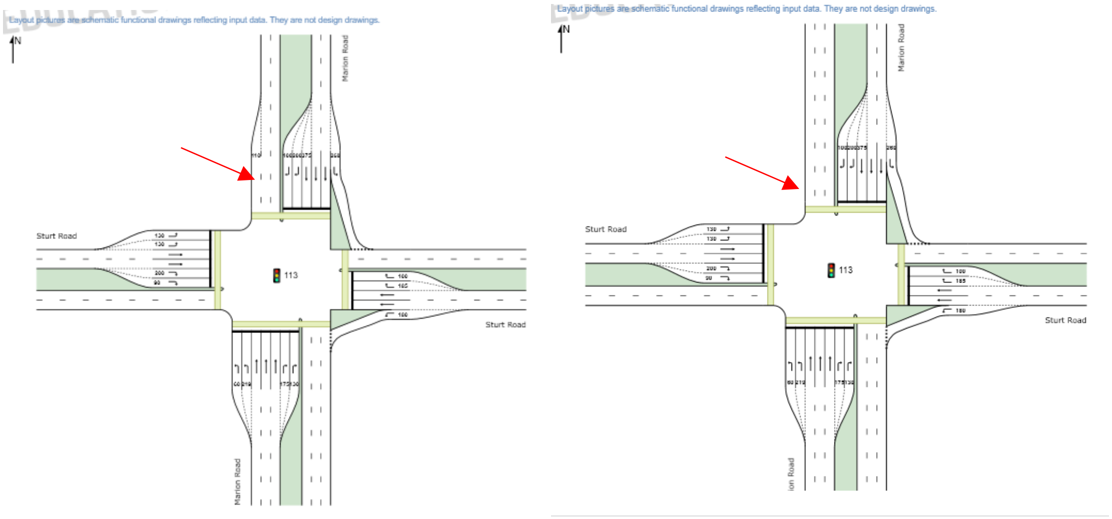


Figure 23: SIDRA geometry with the parking lane (a) SIDRA geometry with the parking lane removed (b)

3.8.2 Volume count

For the vehicle diversion on to Marion Road, the original traffic volume was taken from AIMSUN scenario 1 with no vehicle diversion. The volume for 15 minutes during AM peak for the cars and trucks were modelled for the period 8:15 to 8:30. Table 7 shows the total traffic volume count in Marion Road-Sturt road intersection during normal flow conditions.

Table 7: Traffic Volume Count of the intersection

	South			East			North			West		
8:15-8:30	Left	Through	Right	Left	Through	Right	Left	Through	Right	Left	Through	Right
Cars	152	438	35	10	136	36	115	129	44	106	209	28
Trucks	5	26	0	0	9	0	1	13	5	4	4	3
Total	157	464	35	10	145	36	116	142	49	110	213	31

3.8.3 Diverted Traffic Volume

Total diverted volume count to the intersection during vehicle diversion from Northbound freeway to the Marion Road-Sturt Road intersection is specified below in Table 8. A total of 960.25 cars and 60.25 trucks were diverted towards the intersection as a result of incident during morning peak in location L1 whereas 729.79 cars and 49.79 trucks were diverted towards the intersection during incident occurrence at location L2.

Table 8: Total diverted vehicle counts towards Marion Road-Sturt Road intersection

From Centroid	Original Centroid		Count 1 hour	Count 15 minutes	Diversion to Marion Rd
14178903 - Southern Exwy	14178081 - Corridor North Exit	Cars	3411	852.75	100%
14178903 - Southern Exwy	14178081 - Corridor North Exit	Trucks	221	55.25	100%
14178907 - Flagstaff Hill	14178081 - Corridor North Exit	Cars	430	107.5	100%
14178907 - Flagstaff Hill	14178081 - Corridor North Exit	Trucks	20	5	100%
			Total cars	**960.25**	**100%**
			Total truck	**60.25**	**100%**

Figure 24 shows a representative model of vehicle diversion from the Darlington Expressway through the freeway exit ramp towards the Sturt Road- Marion Road intersection as a response to incident in the Northbound Tunnel in freeway.

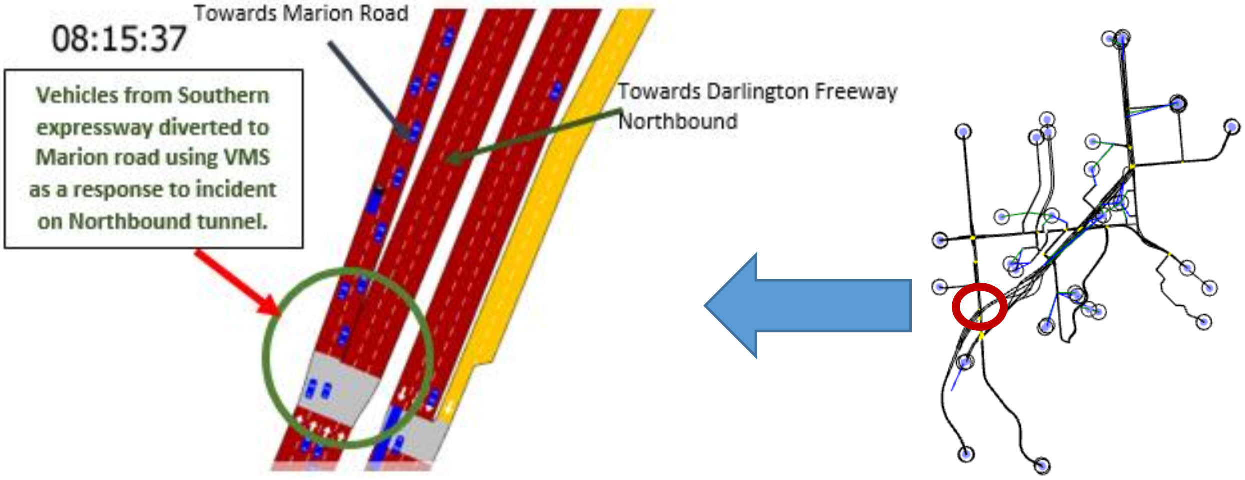
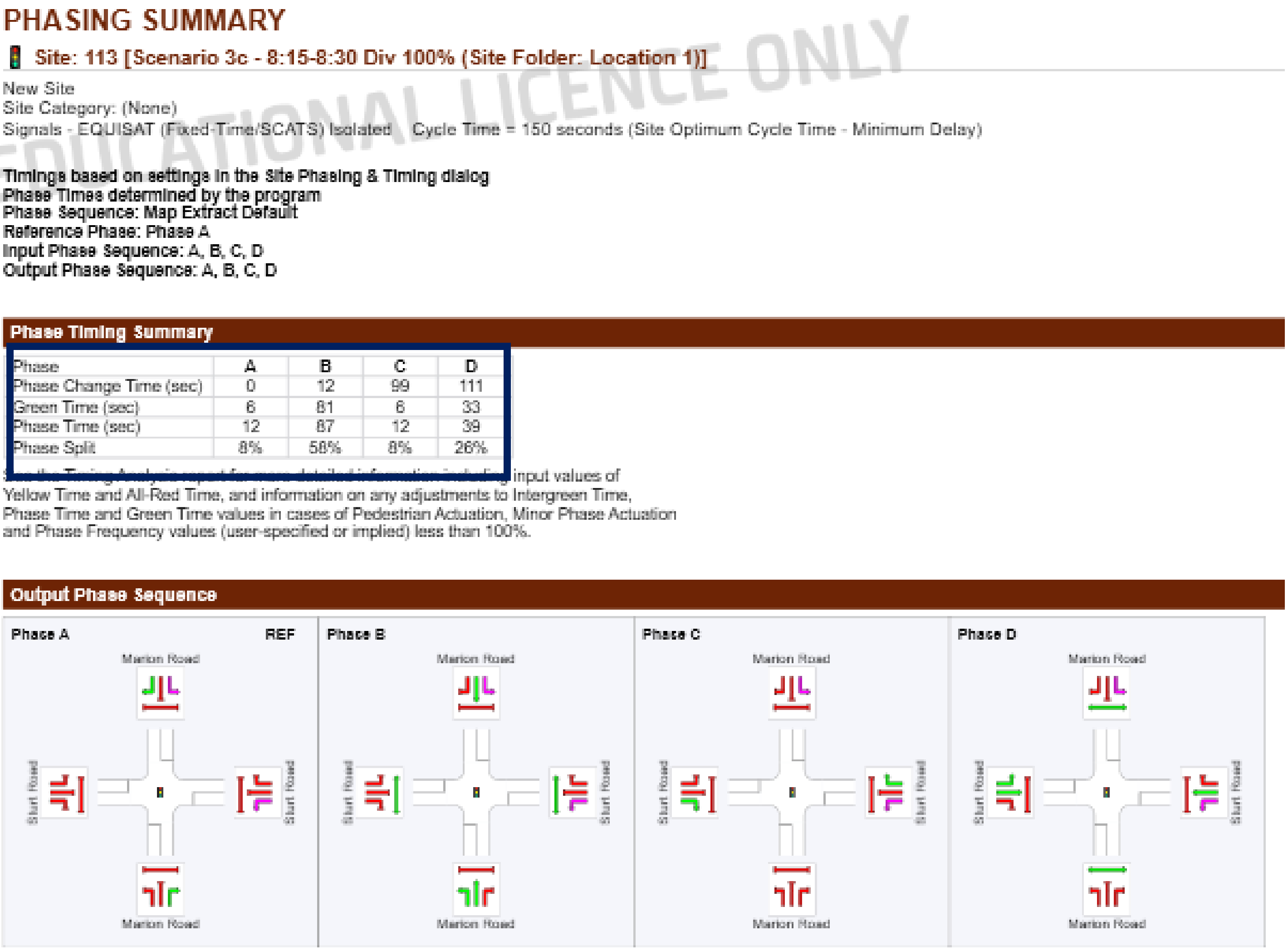


Figure 24: Representative image showing the vehicle diversion from Darlington Expressway to Marion Road- Sturt Road intersection

3.8.4 Phasing and Timing

Phasing is the process of specifying which Origin-Destination (O-D) matrix is assigned for the vehicle movement class as well as pedestrians and which is allowed to run in each signal phase.

Signal phasing and timing was optimized by SIDRA for all scenarios following the vehicle volume changes for the model 2031. Figure 25 shows the phasing summary from the SIDRA model showing running and stop movement for each phase. Similarly, the individual movement timing results are displayed (green, yellow and red) times.



PHASING SUMMARY

Site: 113 [Scenario 3c - 8:15-8:30 Div 100% (Site Folder: Location 1)]

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 150 seconds (Site Optimum Cycle Time - Minimum Delay)

Timings based on settings in the Site Phasing & Timing dialog
Phase Times determined by the program
Phase Sequence: Map Extract Default
Reference Phase: Phase A
Input Phase Sequence: A, B, C, D
Output Phase Sequence: A, B, C, D

Phase Timing Summary

Phase	A	B	C	D
Phase Change Time (sec)	0	12	99	111
Green Time (sec)	6	81	6	33
Phase Time (sec)	12	87	12	39
Phase Split	8%	58%	8%	26%

See the Timing Analysis report for more detailed information including input values of Yellow Time and All-Red Time, and information on any adjustments to Intergreen Time, Phase Time and Green Time values in cases of Pedestrian Actuation, Minor Phase Actuation and Phase Frequency values (user-specified or implied) less than 100%.

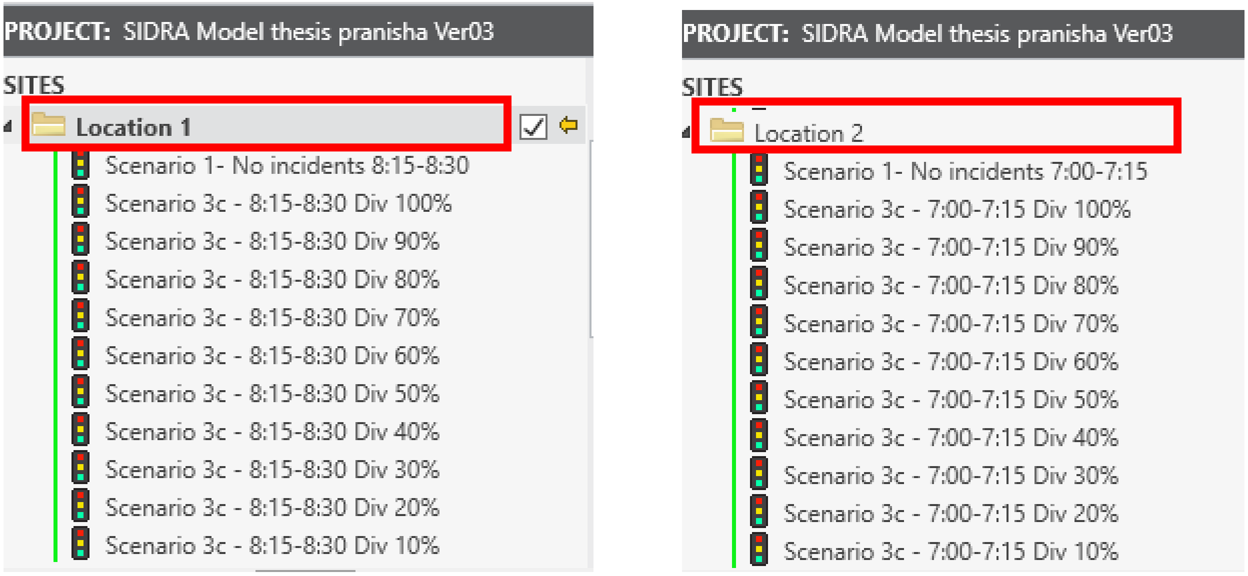
Output Phase Sequence

Figure 25: Phasing Summary from SIDRA model

3.8.5 SIDRA Scenario Description

For each incident location, the diversion of vehicles onto Marion Road was tested for diversion percentage of (0% to 100%) to see how the intersection of Marion Road-Sturt Road would operate at different level of vehicle diversion.

Figure 26 represents the list of scenarios created in SIDRA to test the performance of intersection at different percentages of vehicle diversions.



PROJECT: SIDRA Model thesis pranisha Ver03

SITES

Location 1

- Scenario 1- No incidents 8:15-8:30
- Scenario 3c - 8:15-8:30 Div 100%
- Scenario 3c - 8:15-8:30 Div 90%
- Scenario 3c - 8:15-8:30 Div 80%
- Scenario 3c - 8:15-8:30 Div 70%
- Scenario 3c - 8:15-8:30 Div 60%
- Scenario 3c - 8:15-8:30 Div 50%
- Scenario 3c - 8:15-8:30 Div 40%
- Scenario 3c - 8:15-8:30 Div 30%
- Scenario 3c - 8:15-8:30 Div 20%
- Scenario 3c - 8:15-8:30 Div 10%

PROJECT: SIDRA Model thesis pranisha Ver03

SITES

Location 2

- Scenario 1- No incidents 7:00-7:15
- Scenario 3c - 7:00-7:15 Div 100%
- Scenario 3c - 7:00-7:15 Div 90%
- Scenario 3c - 7:00-7:15 Div 80%
- Scenario 3c - 7:00-7:15 Div 70%
- Scenario 3c - 7:00-7:15 Div 60%
- Scenario 3c - 7:00-7:15 Div 50%
- Scenario 3c - 7:00-7:15 Div 40%
- Scenario 3c - 7:00-7:15 Div 30%
- Scenario 3c - 7:00-7:15 Div 20%
- Scenario 3c - 7:00-7:15 Div 10%

Figure 26: List of scenarios created in SIDRA intersection based on percentage diversion of vehicles

Chapter 4

Results

This chapter will describe the results generated by microsimulation model and the results from assessment of intersection using SIDRA Intersection. The evaluation of impact of incidents on freeway has been quantified in terms of travel times, queue length, emissions and delay depending upon the incident location, duration and time of the day and lane blockage severity levels and the impact of traffic diversion on the whole network will be presented and discussed.

4.1 Incident Evaluation from AIMSUN

This section demonstrates the effects on travel time, congestion, emissions and delay time in the freeway during incident occurrence at all incident locations and for all lane blockage severity types in AM peak and the performance of whole network during incident occurrence is evaluated.

4.1.1 Travel time

4.1.1.1 Travel time comparison of one lane blockage at all locations

When one lane is blocked as a result of incidents in the freeway in both locations and all three durations, it is observed that there is enough capacity on the freeway with two remaining lanes. The travel times are however slightly increased by around 2.5 minutes at the worst location L2 due to the speed reduction due to applying of brakes to divert from one lane to the other. Thus, the results indicate that if one lane is blocked in Northbound tunnel in the freeway (with or without having access to freeway-exit ramp), the network will still have adequate capacity and the network will operate well and it will not require any vehicle diversion.

Figure 27 represents the travel time for all of the modelled location, duration and time compared with scenario one with no prevailing incidents. The graph shows that both durations at incident location L1 will be resumed to normal traffic flow within 10 minutes and incident of 15 minutes at location L2 will resume its normal flow in 20 minutes after the incident is cleared.

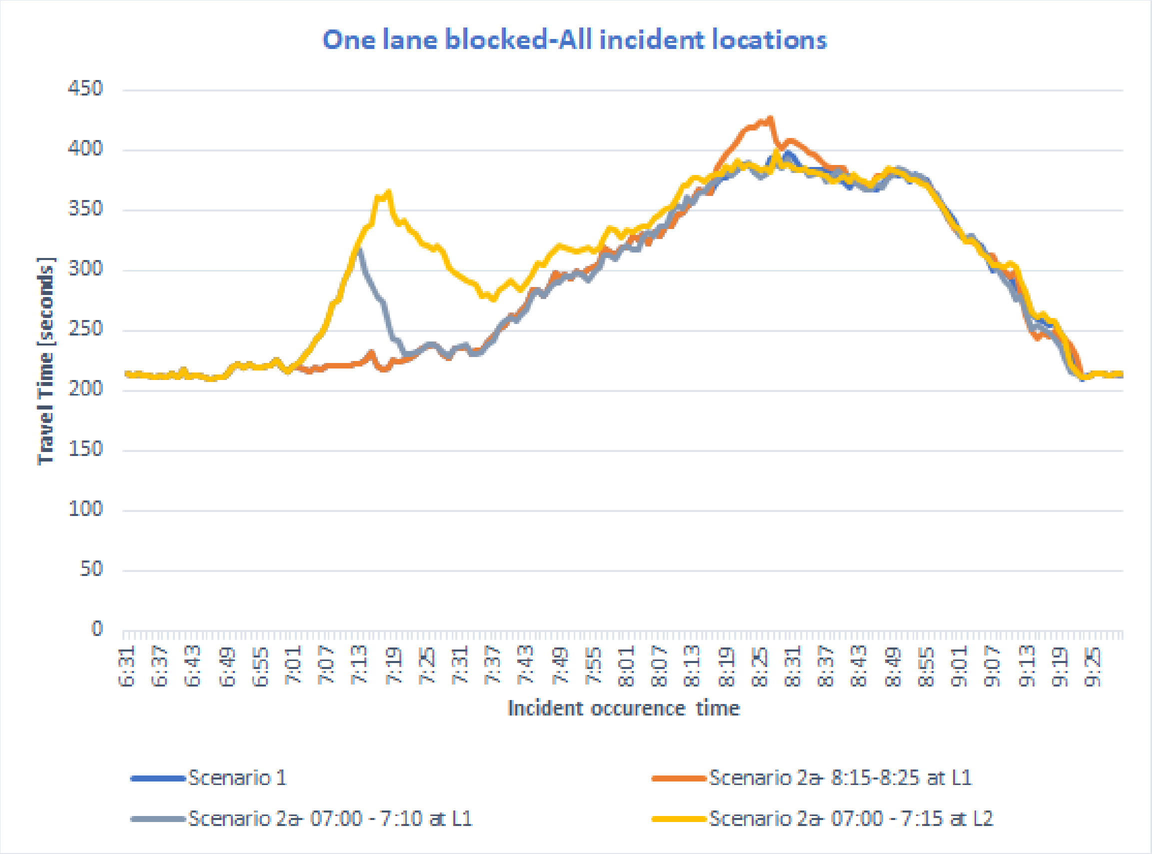


Figure 27: Plot of travel time against one lane blocked scenarios along with Scenario 1 for all incident locations.

4.1.1.2 Effect on travel time during two and three lanes blockage

During two lanes blocked situation in the Northbound Tunnel at Location L1 at 08:15AM-08:25AM, the vehicular speed is reduced to 50 kmph. When comparing with the travel time during normal operation, significant increase in travel times for vehicles (almost double) during the incident is observed. Additionally, the graph in Figure 28 shows that it would take around 25 minutes to clear the queues following a 10-minute incident. It also exhibits that the effect of incident starting from 8:15 AM remains till 9:25 AM implying that effect of congestion during two lane blockage remains up to an hour following the incident clearance after which the traffic flow resumes to normal.

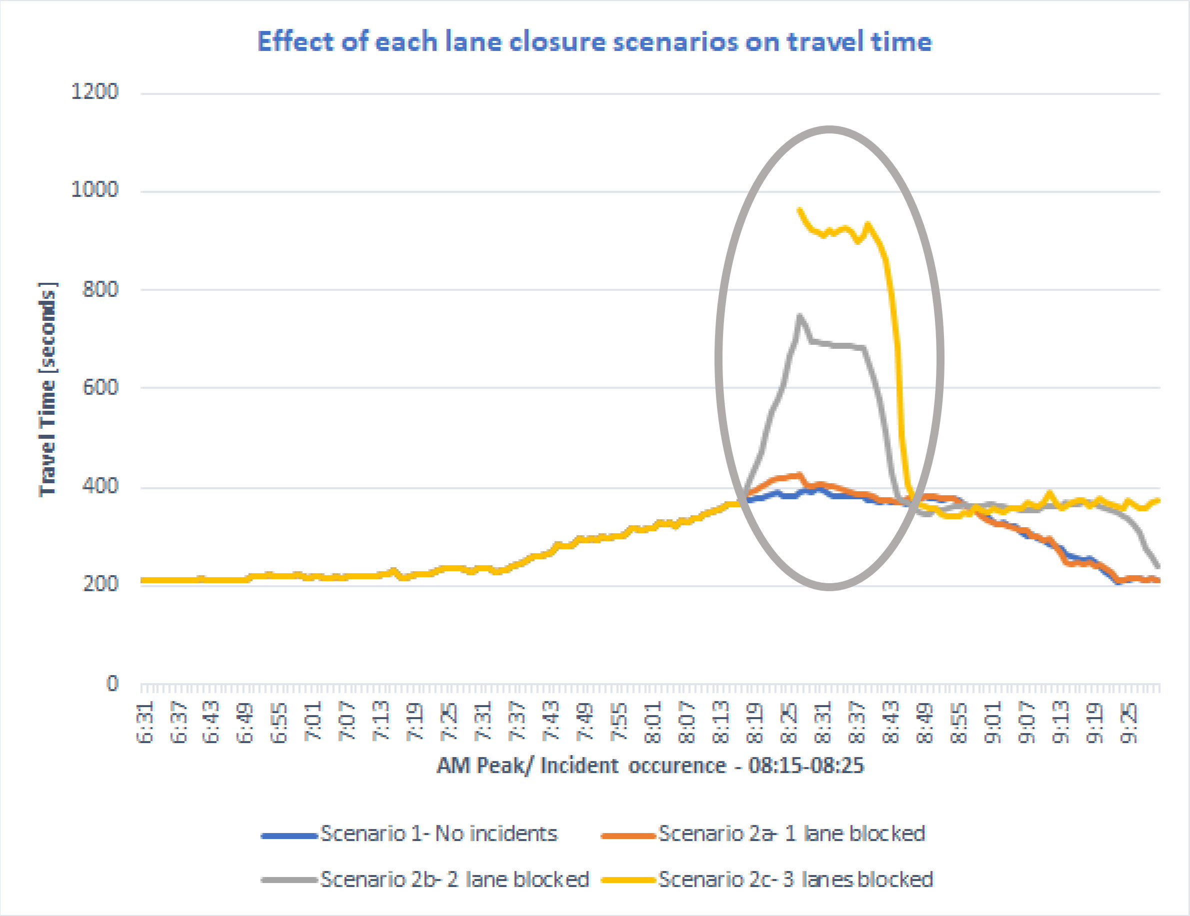


Figure 28: Characteristic graph showing comparsion of total travel time during no incident and when one, two and three lanes are blocked at L1 (08:15am-08:25am).

Similarly, when all three lanes are blocked on the freeway, the travel time upsurges by almost 2.5 times. The broken line in the graph reflects that no vehicle flows through the freeway as a result of blockage. After the incident is cleared, it would take more than 30 minutes to clear up the queues following a 10-minute incident. Effect of congestion during three lane blockage remains more than an hour and continues beyond the research scope of morning peak period of 9:30AM following the incident clearance before resuming to normal traffic flow. This indicates substantial need of traffic management strategies such as vehicle diversion in order to reduce the impact of the incident.

Likewise, at incident location L2, during 7:00AM-7:15AM, considerable increase in travel time is observed during two lanes blockages causing capacity reduction of freeway. Moreover, when three lanes are blocked, extensive (almost 4 times) increase in travel time is established as indicated in Figure 29. After incident clearance, it takes 25 minutes to clear up the queue. In addition to that, the effect of incident starting from 7:00AM lasts beyond 9:30AM in form of traffic congestion during both two and three lanes blockages which signifies that a large portion of vehicle (almost 80-100%) needs to be diverted from the incident location during incident occurrence to eliminate the negative impact of the incident such as congestion, delay, cost and emissions.

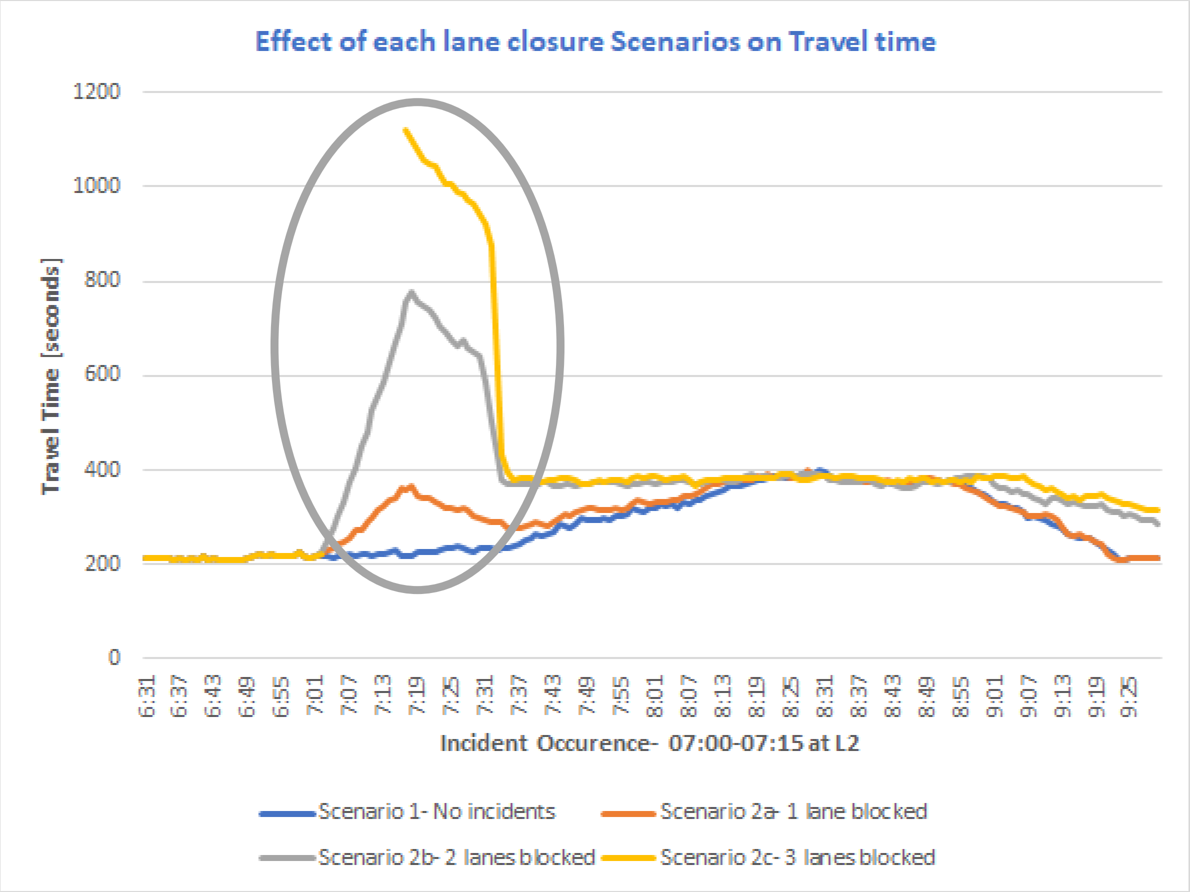


Figure 29: Characteristic graph on comparsion of total travel time when one, two and three lanes blocked respectively due to incidents with travel time during no incident occurrence at L2.

Incident severity at the location L1 during 7:00AM-7:10AM depicts the similar patterns on increment of travel time and the representative graph is shown in Appendix A.

4.1.1.3 Effect of vehicle diversion (using VMS) on two lanes blockage

The graph in Figure 30 portrays that when two lanes are blocked, almost 3.5 times of increase in travel time is observed during the incident. It also indicates that the clearance of queue takes around 25 minutes following a 15-minute incident. The impact of incident prevails in form of traffic congestion for more than 2 hours if no any traffic management strategies are implemented. Thus, traffic detour is required to maintain the capacity and to reduce the negative impacts of incidents such as increase in travel time, increase in emissions, congestion and delay.

Again, the graph in Figure 30 suggests that diverting vehicles onto other roads such as Marion Road and South Road in the study area will operate the network without any obstructions and the travel time during vehicle diversion is fairly reduced during normal flow which implies that the arterial roads outside the freeway are congested due to vehicle diversion. Therefore, the precise impact of the diversion to adjacent roads needs to be determined for the entire network so as to calculate the maximum capacity of the vehicle volumes, the alternative routes can hold with exceeding their own capacity.

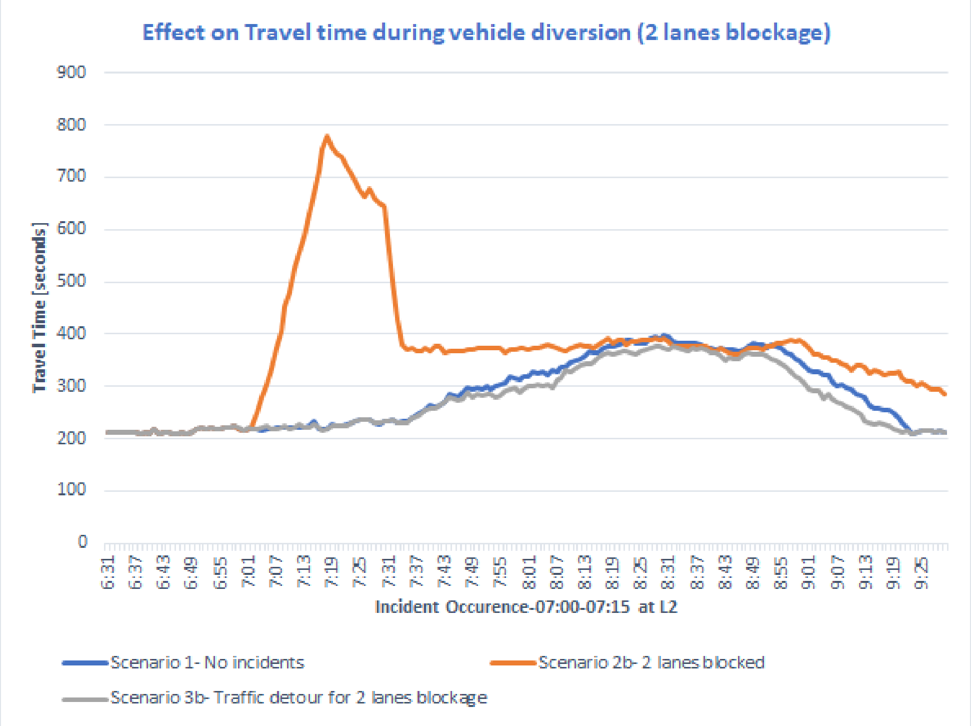


Figure 30: Comparison of travel time while two lanes blocked and traffic diversion assigned within two lanes blocked scenario with the no incidents in location L2 during 07:00AM-07:15AM.

Similar queue patterns are observed during two lanes blockage in remaining locations and the characteristics graphs are presented in the Appendix A.

4.1.1.4 Effect of vehicle diversion (using VMS) during all three lanes blockage

AIMSUN result shows that once all lanes are blocked on the freeway during the busiest morning peak period in location L1, the freeway exit-ramp would be blocked just after 2-3 minutes if no strategies are implemented such as, VMS is not activated.

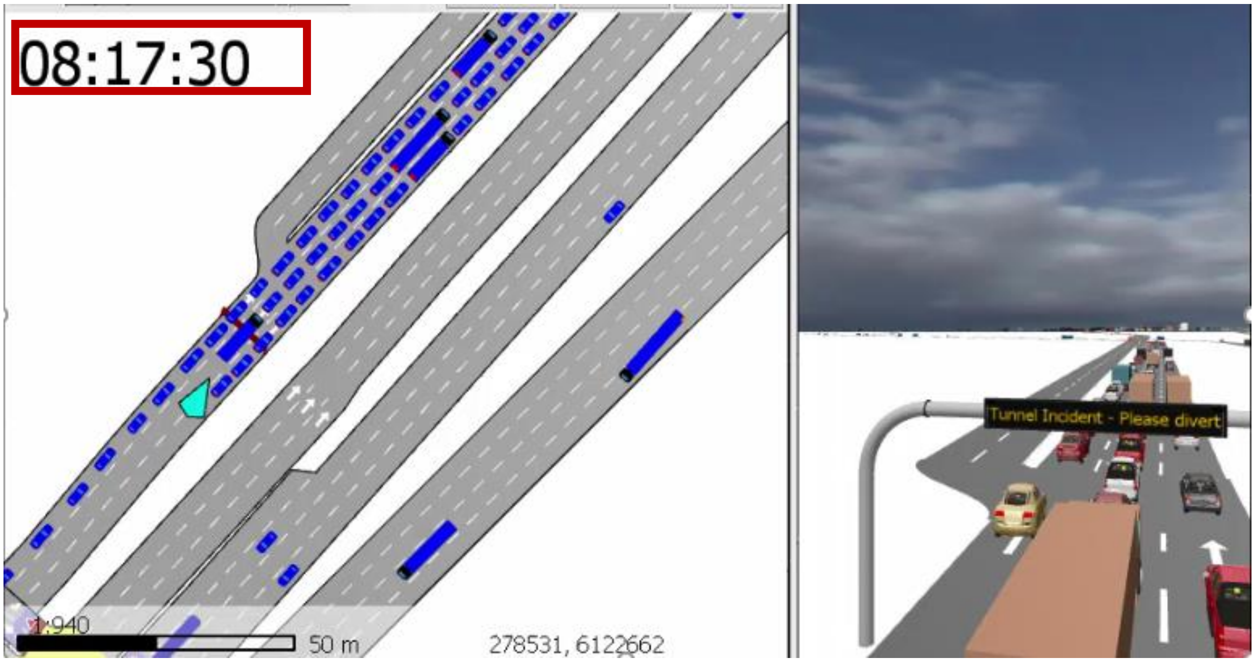


Figure 31: AIMSUN model showing that the freeway-exit ramp is blocked due to congestion in L1 during incidents in just 2 minutes and 30 seconds (i.e. 08:15:00-08:17:30)

Likewise, during all three lane blockages at the worst location of incident occurrence, the graph on Figure 32 reveals that it takes 25 minutes to clear up the queue following a 15-minute incident. The effect of three lanes blockages remained beyond 9:30AM even after the incident clearance. On the contrary, the introduction of VMS to divert the vehicle has reduced the travel time significantly and in addition the effect of congestion is almost diminished after 20 minutes of incident clearance, which shows the importance and significance of traffic diversion as a powerful traffic management strategy to reduce the incident impact.

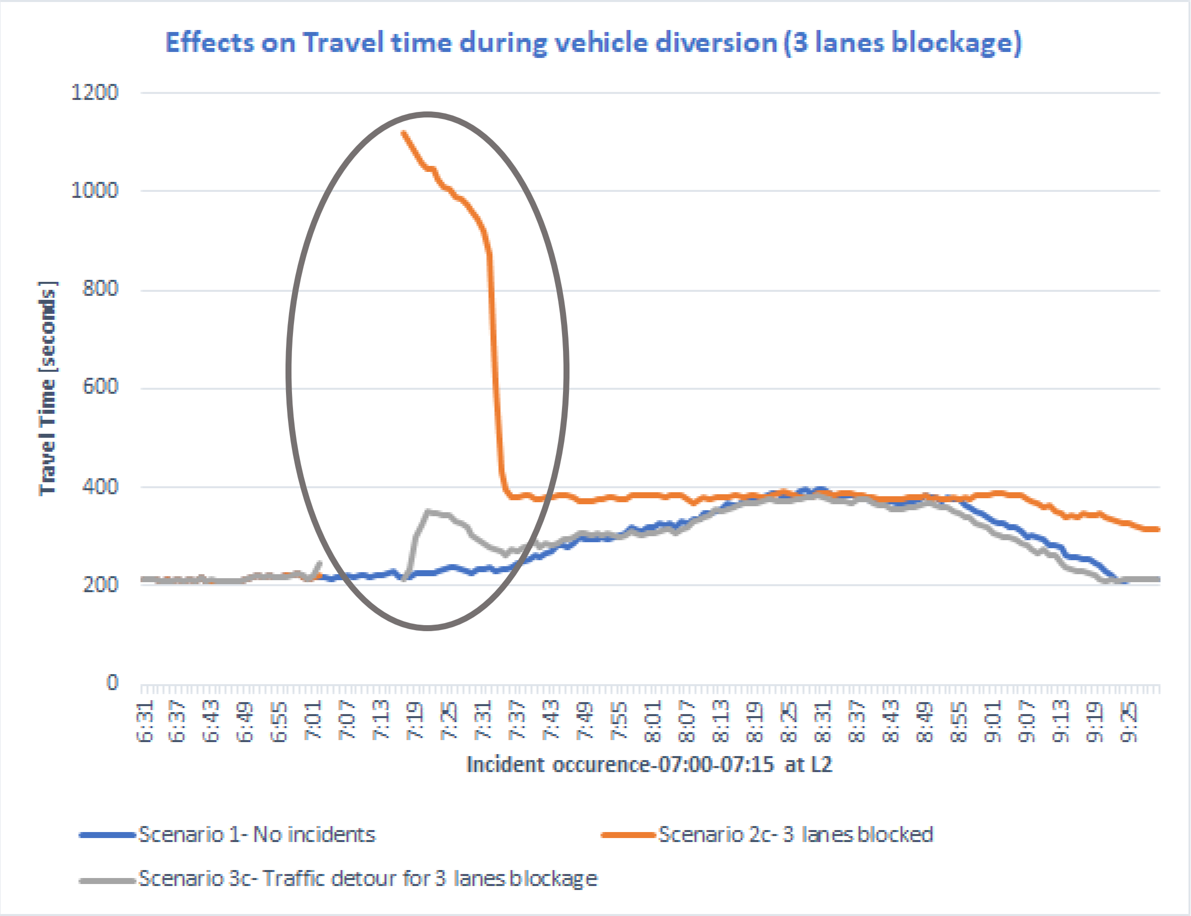


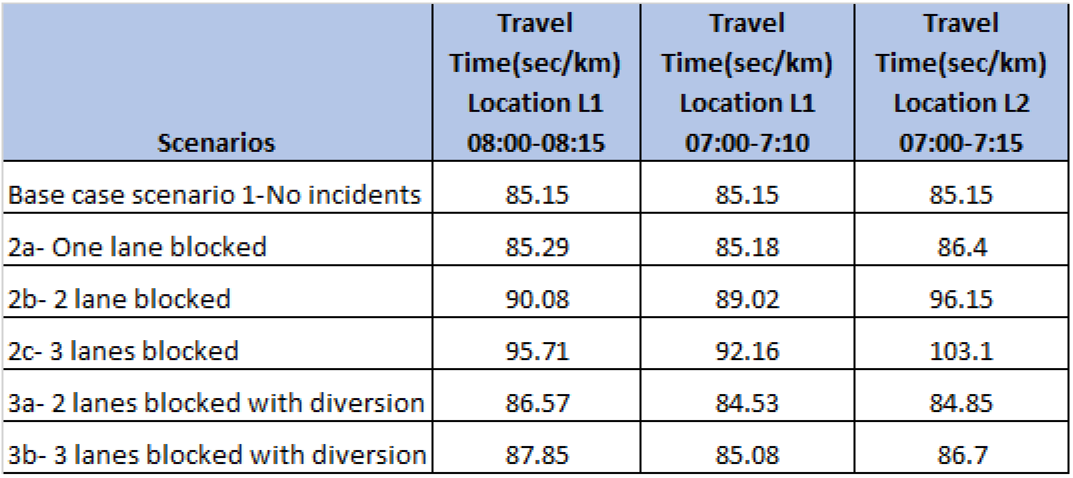
Figure 32: Graph representing the effect on travel time during three lanes blocked and during traffic detour in location L2 during 07:00AM-07:15AM.

The break line on the graph suggests that no traffic flows through the region as a result of all lanes blockages. The traffic detouring significantly reduces the travel time during incident and the traffic flow resumes to normal in less than 20 minutes after the incident is cleared. However, the total network performance has been reduced increasing the queue length and travel time at the other locations as a consequence of diverted traffic. Thus, detailed analysis of network needs to be performed to determine the maximum level of diversion that can be achieved maintaining the maximum capacity of network.

4.1.1.5 Travel time comparison of whole network

As previously mentioned, the travel time in all incident locations is highest during three lane blockages. In addition, the three lane blockages scenario has the highest impact on travel time of the entire network of 17.95 sec/km as quantified in Table 9. The table shows that use of Variable Message Sign (scenario 3a and 3b) is most effective traffic management strategy to reduce the travel time of the entire network.

Table 9: Total travel time comparison of whole network during incident at all locations



Scenarios	Travel Time(sec/km) Location L1 08:00-08:15	Travel Time(sec/km) Location L1 07:00-7:10	Travel Time(sec/km) Location L2 07:00-7:15
Base case scenario 1-No incidents	85.15	85.15	85.15
2a- One lane blocked	85.29	85.18	86.4
2b- 2 lane blocked	90.08	89.02	96.15
2c- 3 lanes blocked	95.71	92.16	103.1
3a- 2 lanes blocked with diversion	86.57	84.53	84.85
3b- 3 lanes blocked with diversion	87.85	85.08	86.7

4.1.2 Delay time:

From the results of the incident modelling, insignificant increase in delay time is observed in the network as a result of one lane blockage, which suggests that no vehicle diversion is required in this scenario as a result of response to Traffic Incident Management during incident occurrence. However, as the lane blockage severity increases the delay time escalates significantly.

The delay time of the entire network increases by 17.85sec/km in incident location L2 as well as 10.49 sec/km in location L1 as seen on Table 10. The vehicle diversion considerably reduced the delay time of the entire network by 12.3 times and 4 times respectively but has not eliminated, indicating that, the entire network performance is reduced during vehicle diversion from the incident area to other roads in the study area.

Table 10: Delay time of whole network during incident at all locations

Scenarios	Delay Time (sec/km) Location L1 08:00-08:15	Delay Time (sec/km) Location L1 07:00-7:10	Delay Time (sec/km) Location L2 07:00-7:15
Base case scenario 1-No incidents	30.26	30.26	30.26
2a- One lane blocked	30.41	30.3	31.51
2b- 2 lane blocked	35.18	34.14	41.25
2c- 3 lanes blocked	40.75	37.27	48.11
3a- 2 lanes blocked with diversion	31.6	29.59	29.88
3b- 3 lanes blocked with diversion	32.89	30.12	31.71

Figure 33 represents the graph of delay time comparison of all incident locations and duration for each lane blockage severity and during application of traffic management strategies.

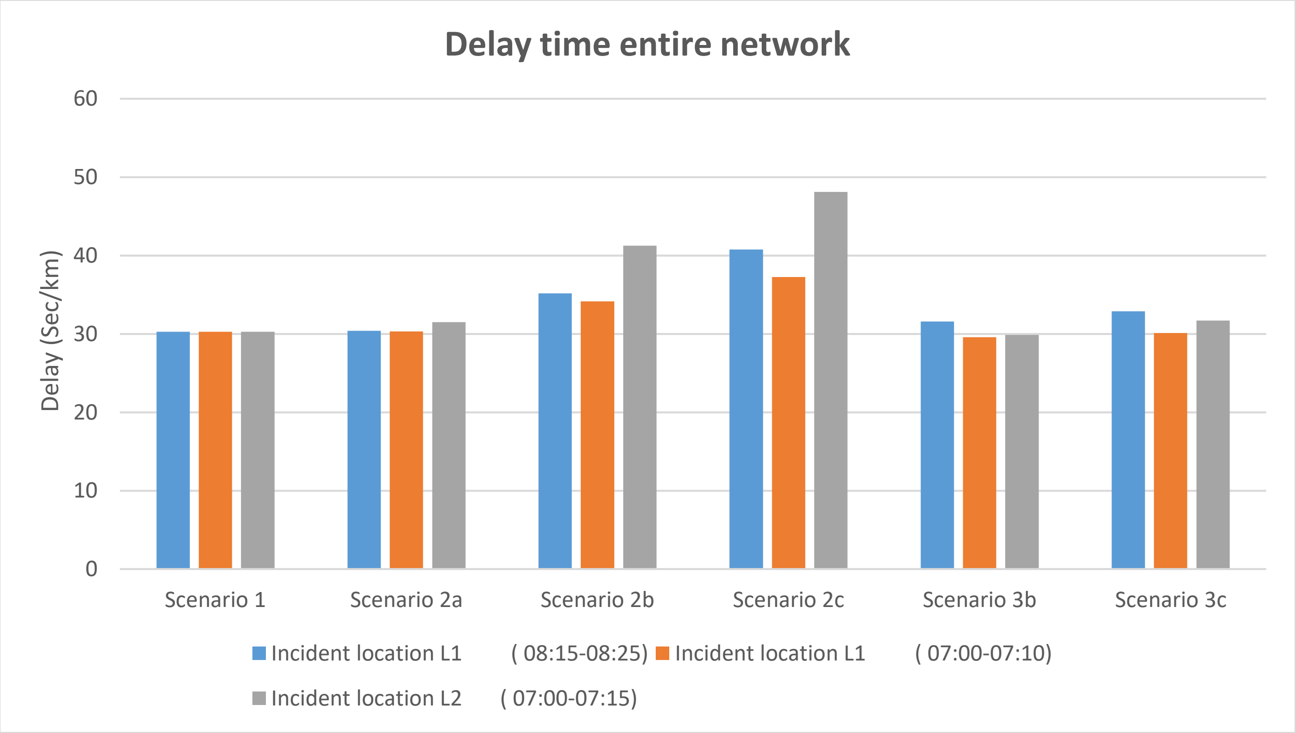


Figure 33: Graph representing the delay time for entire network during incident for all incident locations.

4.1.3 Queue length

The queue generated in the entire network from the different severity scenarios of lane blockage from Table 11 shows that the queue length increases by 212 vehicles at the worst case of incident occurrence and three lanes blockage in location L2 as well as by 160 vehicles in location L1. Also, from the vehicle diversion scenario, it is evident that queue length is reduced by 4 times at incident location L1 and by 19 times in incident location L2.

Excess queue can cause a network gridlock due to insufficient capacity, thus the network capacity needs to be assessed to evaluate the maximum allowable diversion as a response to efficient traffic incident management.

Table 11: Queue length comparison of whole network during incident at all locations

Scenarios	Mean Queue (veh) Location L1 08:00-08:15	Mean Queue (veh) Location L1 07:00-7:10	Mean Queue (veh) Location 2 07:00-7:15
Base case scenario 1-No incidents	263.81	263.81	263.81
2a- One lane blocked	263.43	261.93	266.15
2b- 2 lane blocked	316.98	282.79	370.74
2c- 3 lanes blocked	423.6	344.79	474.96
3a- 2 lanes blocked with diversion	293.79	264.04	267.08
3b- 3 lanes blocked with diversion	304.16	268.48	274.91

Figure 34 demonstrates the mean queue (congestion) in the entire network before and during incidents as well as during use of traffic management strategies.

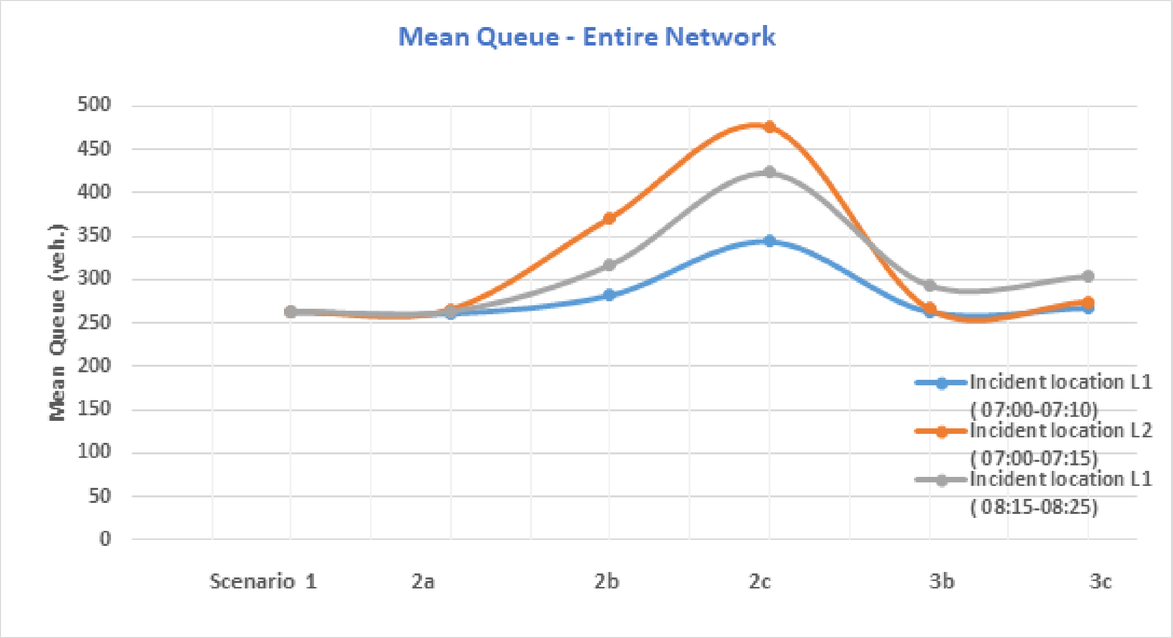


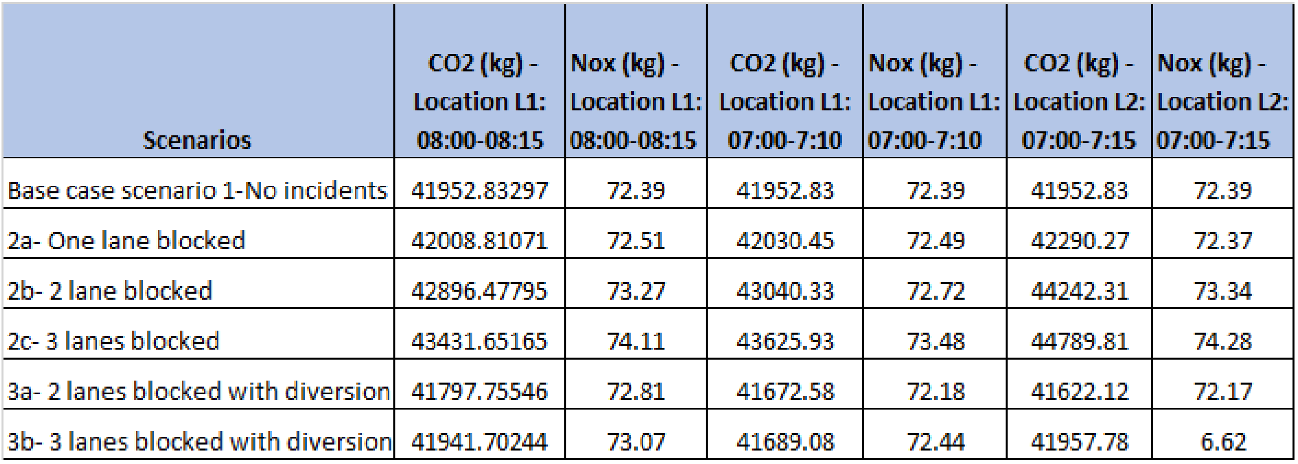
Figure 34: Queue generated in the entire network during different severity scenarios

4.1.4 Emissions

Several environmental issues occur due to congestion and delay in a road network. The non-recurrent traffic incidents on freeways increases the unnecessary fuel consumption and emissions of dangerous pollutants thereby having negative impacts on mobility and safety (Chou, et al., 2010). Carbon dioxide emission and Nitrogen Oxide emissions generated as a result of incident occurrence contributes to environmental pollution and adversely impact on health. Thus, the necessity of quantifying the emissions is extreme so as to determine the level of application of traffic management strategies to reduce the impact of emissions.

Table 12 shows the amount of CO_2 and NO_X emissions for all incident scenarios considered in the study.

Table 12: CO2 and NOx Emissions at all incident locations



Scenarios	CO2 (kg) - Location L1: 08:00-08:15	Nox (kg) - Location L1: 08:00-08:15	CO2 (kg) - Location L1: 07:00-7:10	Nox (kg) - Location L1: 07:00-7:10	CO2 (kg) - Location L2: 07:00-7:15	Nox (kg) - Location L2: 07:00-7:15
Base case scenario 1-No incidents	41952.83297	72.39	41952.83	72.39	41952.83	72.39
2a- One lane blocked	42008.81071	72.51	42030.45	72.49	42290.27	72.37
2b- 2 lane blocked	42896.47795	73.27	43040.33	72.72	44242.31	73.34
2c- 3 lanes blocked	43431.65165	74.11	43625.93	73.48	44789.81	74.28
3a- 2 lanes blocked with diversion	41797.75546	72.81	41672.58	72.18	41622.12	72.17
3b- 3 lanes blocked with diversion	41941.70244	73.07	41689.08	72.44	41957.78	6.62

The results have demonstrated that the CO_2 emissions as well as NO_X emissions increased by 6.76% and 4% respectively during three lane blockages in location L2 and 3.5% and 2% respectively during the worst case of lane closure in location L1 than the normal traffic flow. Use of VMS has significantly reduced the CO_2 emissions in worst case of L2 by 6.74% as shown in Table 12. Thus, incident management strategies like use of VMS highly reduces the emissions which has negative economic and environmental impacts.

Figure 35 demonstrates the emissions generated in the entire network as a result of incident for every incident characteristic like duration, location and lane blockage severity in AM peak.

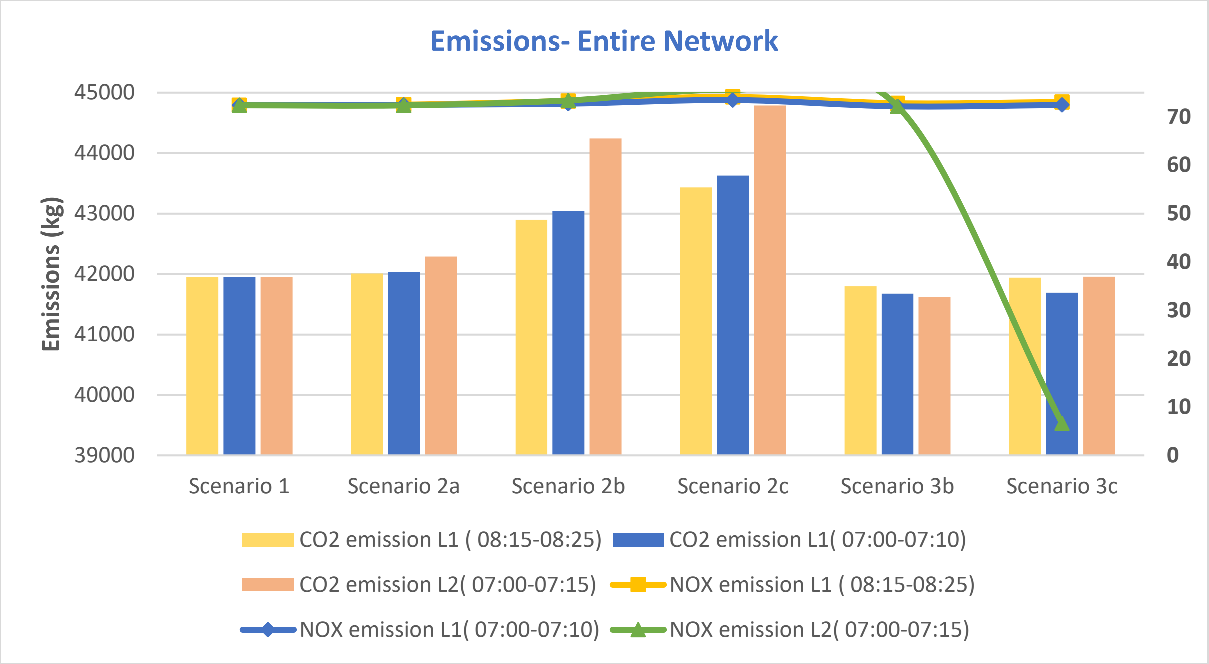


Figure 35: Emissions (CO_2 and NO_X) generated in the entire network for different severity scenarios

4.2 Intersection Evaluation from SIDRA

This section demonstrates the intersection evaluation in terms of level of service of Marion Road-Sturt Road intersection and the effect of diversion of vehicles (0-100%) is discussed.

4.2.1 Intersection Level of Service

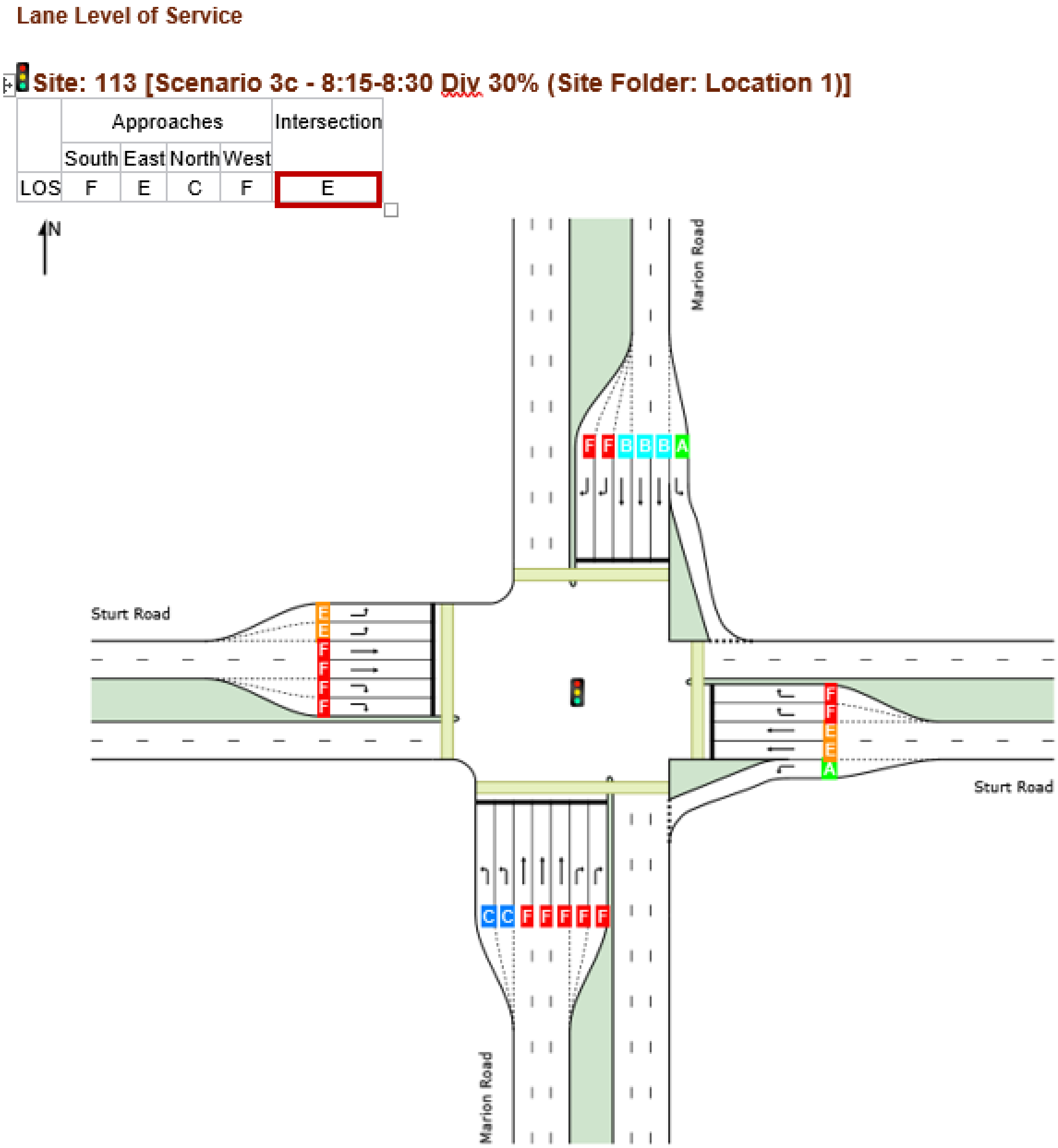
According to SIDRA user's guide 2020 on Figure 36, the control delay per vehicle of 80 seconds or less is termed as acceptable level of service E, delay of more than 80 seconds denotes that intersection is running at a poor level of service having more delay, more travel time, more queue length and reduced network capacity.

Image removed due to copyright restriction.

Figure 36: Level of Service definitions based on delay and degree of saturation of vehicles from SIDRA (SIDRA User's Guide,2020)

Results generated from SIDRA intersection, tabulated in Table 13, indicates that the network would operate with poor LOS (i.e. LOS=F), when the diversion percentage of vehicles exceeds 30 percent from Location L1, during the busiest morning peak. Similarly, diverted vehicles from location L2 will be absorbed by the intersection nearly up to 60 percent, the network performance eventually reduces to LOS=F beyond that stage.

The level of service of Sturt Road-Marion Road intersection during 30% of vehicle diversion during 10-minute incident at location L1 (08:15AM-08:25AM) is presented in Figure 37, beyond which the intersection would operate at Level of service of F. The SIDRA summary reports are presented in Appendix B.



Lane Level of Service

Site: 113 [Scenario 3c - 8:15-8:30 Div 30% (Site Folder: Location 1)]

	Approaches				Intersection
	South	East	North	West	
LOS	F	E	C	F	E

Figure 37: Level of Service of Intersection during 30% vehicle diversion from Freeway during incident location 1, 08:15AM-08:25AM

Table 13 demonstrates the average vehicle delays for each percentage of vehicle diversion for incident occurrence at all locations.

Table 13: Average Vehicle delays (sec.) for all scenarios

Average Vehicle Delays [sec]			
Diversion to Marion Rd	**Location 1**	**Location 2**	**LOS E**
0%	43	36	80
10%	45	38	80
20%	56	42	80
30%	75	45	80
40%	100	53	80
50%	130	67	80
60%	163	84	80
70%	199	104	80
80%	234	126	80
90%	268	150	80
100%	310	177	80

Figure 38 is the graphical representation for average vehicle delays for the different level of percentage diversion of vehicles on Marion Road from the freeway during incident.

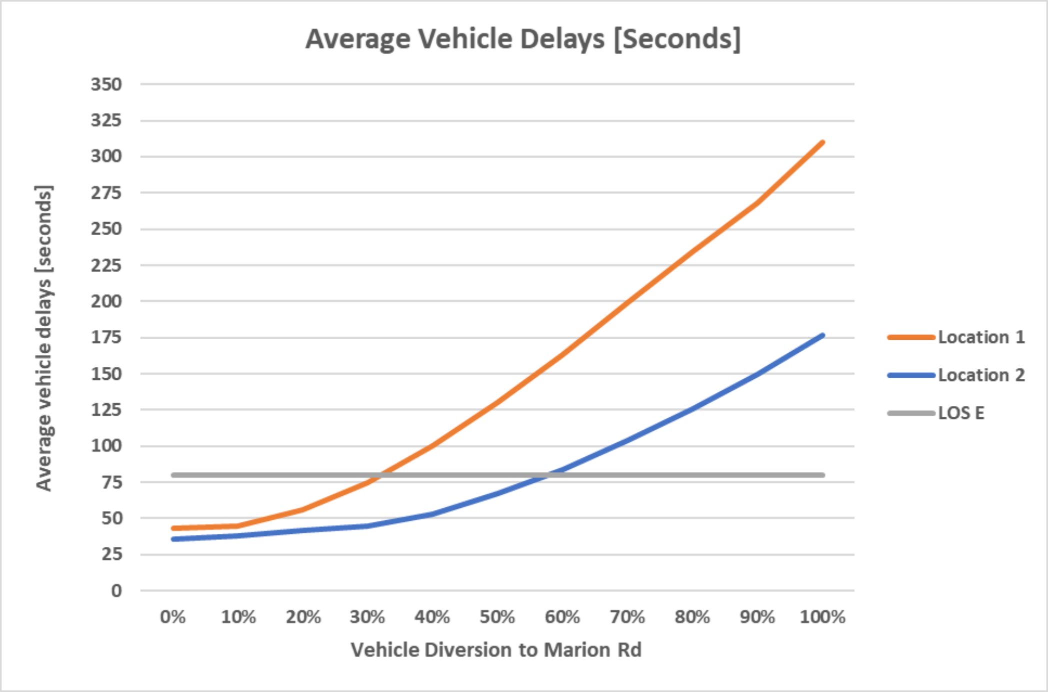


Figure 38: Characteristic graph for percentage diversion of vehicles into Marion Road against average vehicle delays

Hence, the SIDRA results indicate that some extra strategy is required to divert 70 percent of the vehicles outside the study area during incident occurrence for 10-minute duration at location L1, during the busiest AM peak 08:15AM-08:25AM.

Similarly, during incident of 15 minutes at 07:00AM-07:15AM in location L2, around 40 percent of vehicle needs to be diverted from the incident area to maintain the capacity of entire network in the study area during incident occurrence.

The capacity maintenance strategies of may include the earlier traffic detour, maybe at Brighton Road or some other roads from the freeway exit ramp. The extent of vehicle diversion in the busiest duration needs to be investigated in a larger scale.

Chapter 5

Discussion

In this chapter, the microsimulation outputs as well as the intersection modelling outputs from incident modelling scenarios for morning peak (AM) in Darlington Freeway using AIMSUN and SIDRA are assessed and the results are deliberated based on performance indicators for serviceability of the road such as travel time, queue length and delay. Additionally, the capability and significance of use of Variable Message Signs in this research is argued.

5.1 Incident impact on freeway performance indicators:

The impact of incident is discussed for different performance indicators like:

- Vehicular travel time
- Mean Queue
- Delay time and
- Emissions

From the incident modelling, the results revealed that the incident duration of 15 minutes during morning peak 7:00-7:15 AM at location L2 on the freeway will cause significant increase in travel time for all incident severity types and lane blockages. For incident response as a consequence of increased travel time, certain number of vehicles needs to be detoured from their original route to the adjacent arterial roads to maintain a reasonable freeway operation. Referring to the AIMSUN results, 80 percent to 100 percent of the vehicles needs to be diverted via detouring routes for two or three(all) lanes blockages in freeway during the incident occurrence.

Requirement for maintenance of similar traffic reduction pattern was observed for 10-minute incident durations in locations L1 during busiest peak at 8:15-8:25 AM and 7:00-7:10 AM for the entire duration of incident occurrence.

The results generated from incident modelling demonstrated that the freeway network will have enough capacity if one lane blockage occurs from incident, even at the busiest time period. Thus, there is no need for vehicle diversion. However, in the worst case, sudden incidents such as accidents, vehicular breakdowns and collisions on freeway increases the delay time of freeway network from 30.26 seconds/km to 48.11 seconds/km causing the free-flowing traffic to run slow.

Results illustrate that, the vehicle queue tends to go up by 160 vehicles in the busiest morning peak in incident location L1 and by 212 vehicles in incident location L2 than in normal traffic flow conditions if no traffic strategies are implemented for increasing the capacity or reducing the traffic volumes of road network. The negative impacts of the queue length, congestion, travel time and delay time can be mitigated by implementing proper measures for incident management.

5.2 Incident impact mitigation on Freeway using ITS/VMS

Variable Message Sign (VMS) system is a highly sophisticated system for traffic incident management. VMS, utilizing ITS technology, focuses on finding solutions to mitigate the risk and improve the freeway performance by providing Emergency Incident Management Systems with preparedness plans and real-time traffic detours for achieving a better serviceability of the road and to make best use of the road capacity during incident occurrence providing uninterrupted traffic flow without delay, congestion and travel time reduction.

In this research, three different cases were considered for the incident modelling, the first one is the freeway performance indication without any incident occurrence, second one is the incident impact evaluation for different incident severity cases of lane blockages, in different locations at different duration and time of the day in to the Freeway network and the third one is the impact of introducing VMS for each lane blockage severity into the freeway network as a response for Incident Management.

For the worst-case scenario of incident modelling at location L2 without having access to freeway exit ramp leading to Ayliffes Road, traffic detour through Marion Road for the was assigned for the traffic flow during incident occurence. Similarly, for the incident location L1, a certain portion of vehicle was assigned to Marion Road and remaining was assigned towards Ayliffes Road for improvement of the operational efficiency and the capacity of the freeway by using VMS.

Results show that during the worst case of lane blockage, the delay time for the whole network was reduced by the use of VMS by 12.3 times and the total travel time is reduced by 11.5 times. Similarly, the CO_2 emissions was reduced by 6.74% and the mean queue length was reduced by 17.6 times as a result of VMS.

Hence, the results show that the use of VMS is significantly effective to mitigate the impact on freeway during incident occurrence. The use of Variable Message Sign for traffic detour enhances the performance of the freeway as of normal condition without any incident occurrence providing a smooth flow of traffic with substantial reduction in delay, travel time, congestion as well as emissions.

5.3 Effect on Level of Service of Marion Road-Sturt Road Intersection

As a significant portion of traffic from a fully operational freeway was diverted to the Marion Road via the southern exit-ramp on freeway, the level of service of the intersection was evaluated to determine the maximum percentage of diverted traffic Intersection could hold without declining own operational capacity. Thus, SIDRA intersection was used to evaluate the performance and capability of intersection to accommodate the diverted traffic without causing congestion.

SIDRA modelling results demonstrated that diversion of vehicles to Marion Road in order of 30 percent in the busiest peak 8:15AM-8:25AM and around 60 percent outside that time for 7:00AM-7:10AM in location L1 and for 7:00AM-7:15AM in location L2 will be absorbed fine by Marion Road-Sturt Raod intersection. Beyond this level of vehicle diversion, the intersection will exceed the capacity which in turn creates a network gridlock in the whole network.

Therefore, the remaining diversion will need to be achieved outside the study network (e.g. Brighton Rd). However, in this research, an attempt to evaluate the road performance outside of the study area has not been made due to time constraints and due to being out of scope.

5.4 Research implications:

In this research, an investigation has been conducted in order to determine the impacts of non-recurring incidents on freeway and the use of Variable Message Signs to reduce the negative impacts of unexpected vehicular breakdowns and collisions, and the major aim of this research is to determine the impact of incidents and to identify potential measures for the smooth traffic flow in the Darlington Freeway during incident occurrence.

This study provides an insight of how the introduction of ITS in an existing road network affects the movement of people and the other road users. The limitations of the DPTI reports (as mentioned in the literature review section 2.4 Case Study Selection) has been alleviated to an extent from this research. This research is believed to aid in implementing Traffic Incident Management Strategies in Freeway to alleviate congestion, for efficient planning and operation of freeway network more efficiently and effectively during incident occurrence.

Chapter 6

Conclusion

An incident occurrence on a freeway has a negative impact on the vehicle travel times, increases delay, creates congestion and creates environmental threats by increasing emissions. Thus, traffic incident management is of extreme importance to maintain the serviceability of infrastructure and safety and comfort of the road users.

Therefore, this study serves the purpose by analyzing the impact of incidents on a section on Darlington Freeway, the impact on travel time, emissions and delay for partial and full lane closure scenarios on the freeway, during different durations, time of the day (AM peak), different locations on the freeway has been determined. The methodologies implemented include the incident modelling of the road section using AIMSUN (base model provided by DIT) and the SIDRA modelling of the adjacent intersection in the network to evaluate the performance of intersection during vehicle diversion.

The impact of incident location, incident duration and time of occurrence in selected sections in Darlington Freeway section has been quantified in terms of travel times, LOS, queue length (congestion) and emissions during morning peak and the solutions are suggested based on the modelled incident scenarios. VMS was introduced to the freeway section during incident occurrence as a response to traffic incident management to alert and to divert the vehicles. The impact of incident with and without using VMS were analyzed and discussed.

Results demonstrated that if a 10-15 minutes' incident occurred blocking one lane in the north-bound tunnel in Darlington Freeway with or without access to freeway exit ramp, there will be enough capacity for the network to operate properly even during the busiest time of the day and no vehicle diversion is required for the scenario. On the contrary, if two or three lanes were blocked as a result of incident, significant number of vehicles; more than 80 to 100 percentage of the total traffic flow through the freeway requires to be diverted towards the adjacent arterial roads.

Results also showed that the incident duration of 15 minutes in incident location L2, in 7:00AM-7:15AM without having access to freeway exit ramp will have significant increase in the travel time for all incident severity types compared to those having access to freeway exit ramp.

Results exhibited that during the busiest time at L1 08:15-08:25 and worst location of incident occurrence in L2 07:00-07:15, while all three lanes blocked due to incidents, the travel time increases by 10.56 sec/km and 17.85sec/km than during normal flow conditions, which is reduced by 5 times and 12.3 times respectively after the vehicle diversion using VMS which shows the importance of Intelligent Transport System to enhance the performance of freeway during incident occurrence.

Additionally, the SIDRA results revealed that the equilibrium condition of acceptable level of service (LOS=E) of adjacent intersection and the freeway capacity was met when the diversion percentage of the vehicle onto Marion Road did not exceed 30 percent during incident at the busiest morning peak and around 60 percent during other times at both locations, which implies that the vehicle diversion will need to be achieved outside of the study area for the network to function properly during two or more lane blockages in north-bound tunnel due to incidents.

From this research, the effectiveness of VMS is revealed as a sophisticated method for accurate flow of information for preplanning response for any probable incident occurrence. Preplanned Traffic Incident management provides economic benefits by reducing the emissions, alleviates travel time, delay time, congestion and provides safety.

6.1 Future Research

Further approaches from the study can be undertaken to determine the fuel consumption and the cost of delays as these are the important parameters of analyzing impact of incidents on Freeway. Furthermore, similar analysis for afternoon peak incident modelling in the North-bound tunnel can be performed. Similarly, testing incident scenarios at different locations, duration and time of the day in the South-bound tunnel is recommended to determine the level of impact of incident on Southbound Freeway during AM and PM peak.

The research has indicated that 70% of vehicle diversion for traffic incident management during the worst case of morning peak and about 40% during the other time for morning peak hour should be specified outside the study area in order to maintain the capacity of the freeway and the overall network capacity during any incident occurrence on Northbound Freeway tunnel. As this research has not attempted to investigate the level of vehicle diversion outside of current study area due to being out of scope, AIMSUN modelling of a wider network can be performed to investigate the vehicle diversion outside of the current study area. In addition, the suitability of application of other components of Intelligent transport systems (ITS) such as Variable Speed Limits (VSL), Advanced Warning Systems, Connected Vehicle (CV) technology can be assessed in the same study area.

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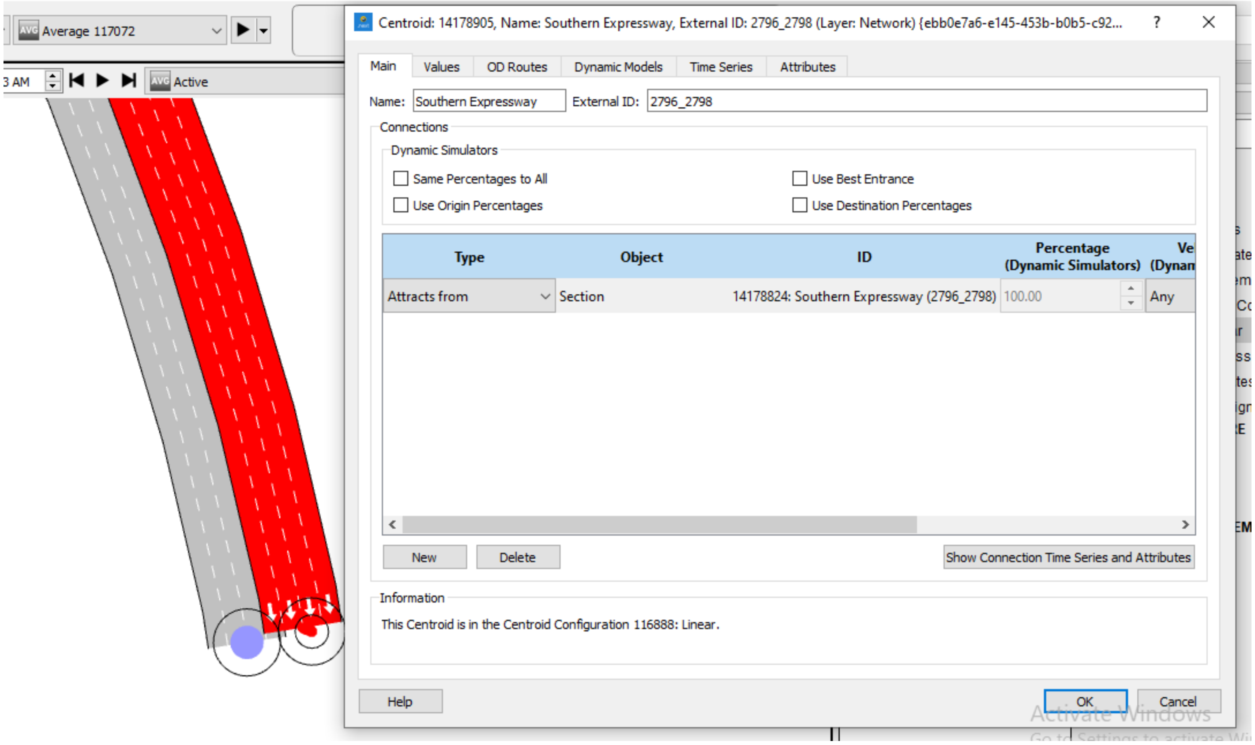
Appendices

Appendix A

AIMSUN inputs



Centroid: 14178905, Name: Southern Expressway, External ID: 2796_2798 (Layer: Network) {ebb0e7a6-e145-453b-b0b5-c92...

Name: Southern Expressway External ID: 2796_2798

Connections

Dynamic Simulators

☐ Same Percentages to All ☐ Use Best Entrance

☐ Use Origin Percentages ☐ Use Destination Percentages

Type	Object	ID	Percentage (Dynamic Simulators)	Ve (Dynan
Attracts from	Section	14178824: Southern Expressway (2796_2798)	100.00	Any

Information

This Centroid is in the Centroid Configuration 116888: Linear.

Figure 39: Indicative image of Centroid specification in AIMSUN

Section Incident: 14191917, Name: Section Incident Ayelifess {27808f9a-0330...

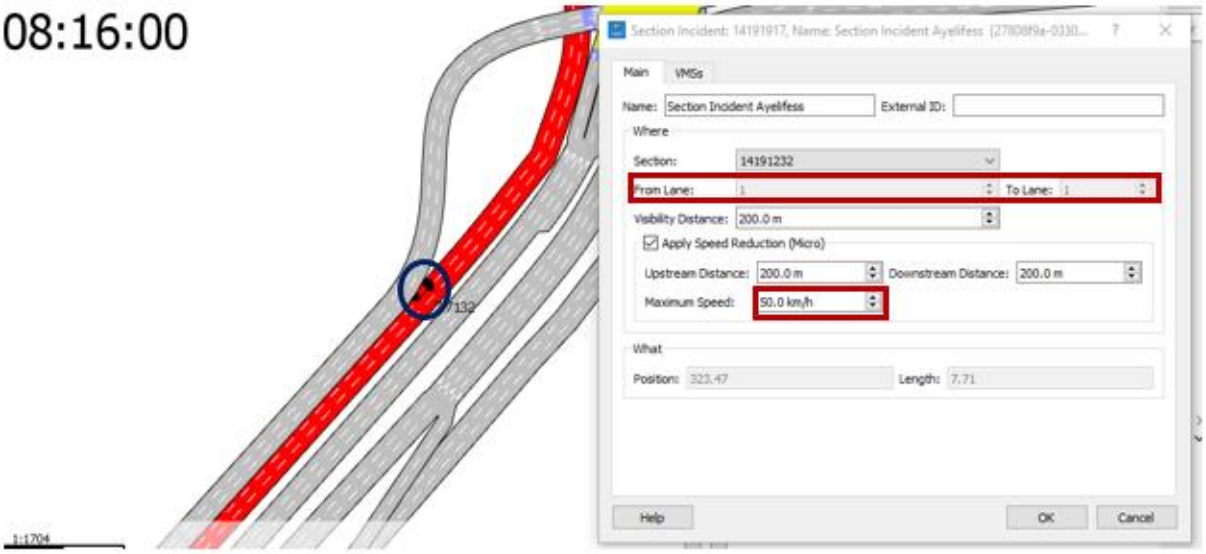
Main | VMSs

Name: Section Incident Ayelifess
External ID:

Where
Section: 14191232
From Lane: 1 To Lane: 2
Visibility Distance: 200.0 m
☑ Apply Speed Reduction (Micro)
Upstream Distance: 200.0 m Downstream Distance: 200.0 m
Maximum Speed: 50.0 km/h

What
Position: 315.88 Length: 9.05

Figure 40: Modelling of 2 lane blocking scenario; blocked lanes (1-2).



Section Incident: 14191917, Name: Section Incident Ayelifess {27808f9a-0330...

Main | VMSs

Name: Section Incident Ayelifess
External ID:

Where
Section: 14191232
From Lane: 1 To Lane: 1
Visibility Distance: 200.0 m
☑ Apply Speed Reduction (Micro)
Upstream Distance: 200.0 m Downstream Distance: 200.0 m
Maximum Speed: 50.0 km/h

What
Position: 323.47 Length: 7.71

Figure 41: Modelling of 1 lane blocking scenario; blocked lane 1.

AIMSUN Results

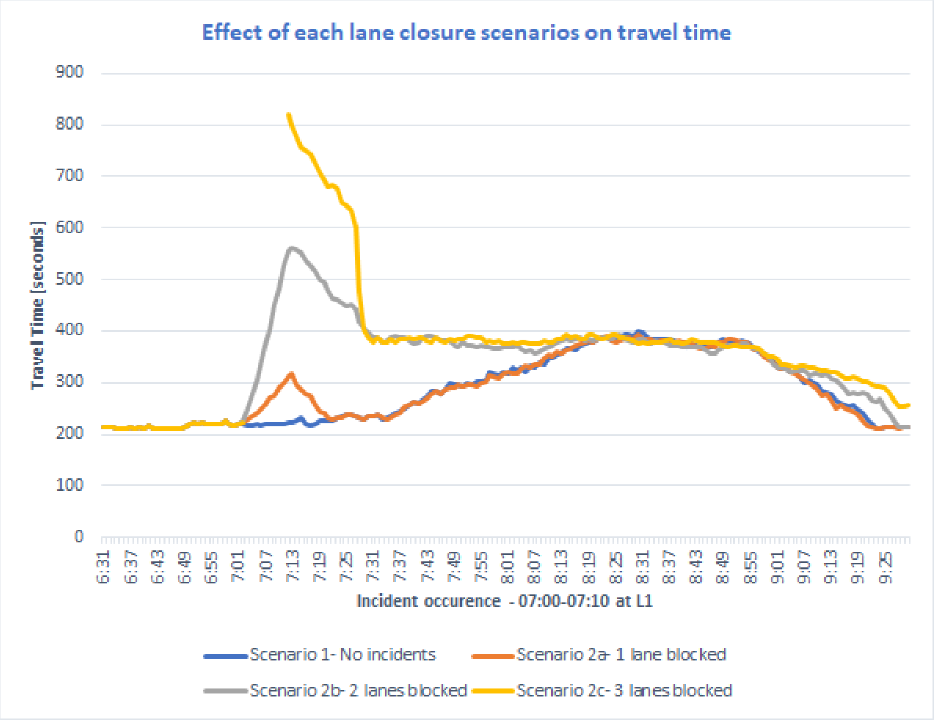


Figure 42: Graph representing the effect of each lane closure in location L1 during 07:00AM-07:10AM.

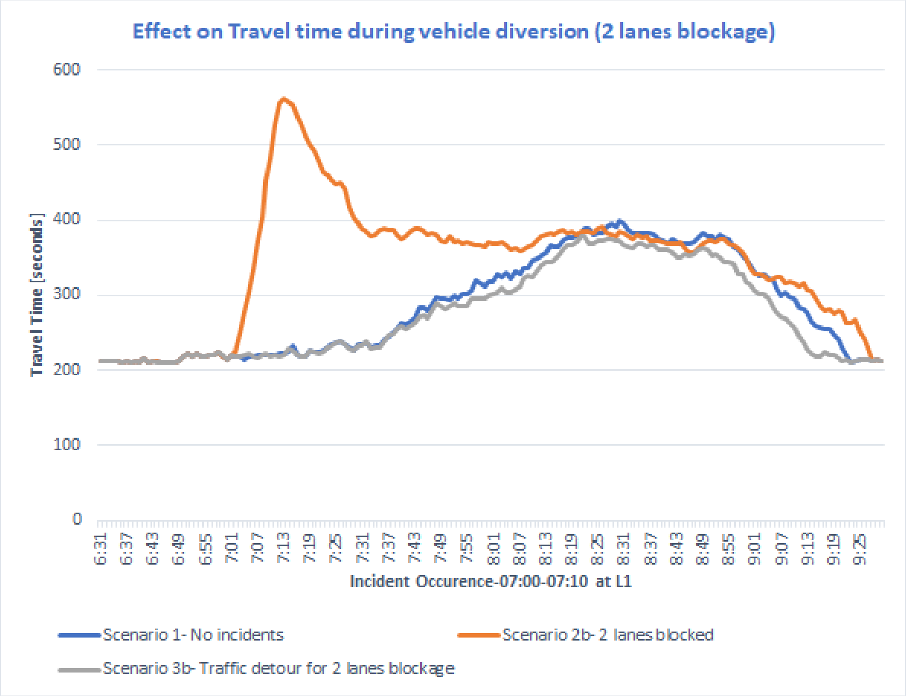


Figure 43: Graph representing the effect on travel time during two lanes blocked and during traffic detour in location L1 during 07:00AM-07:10AM.

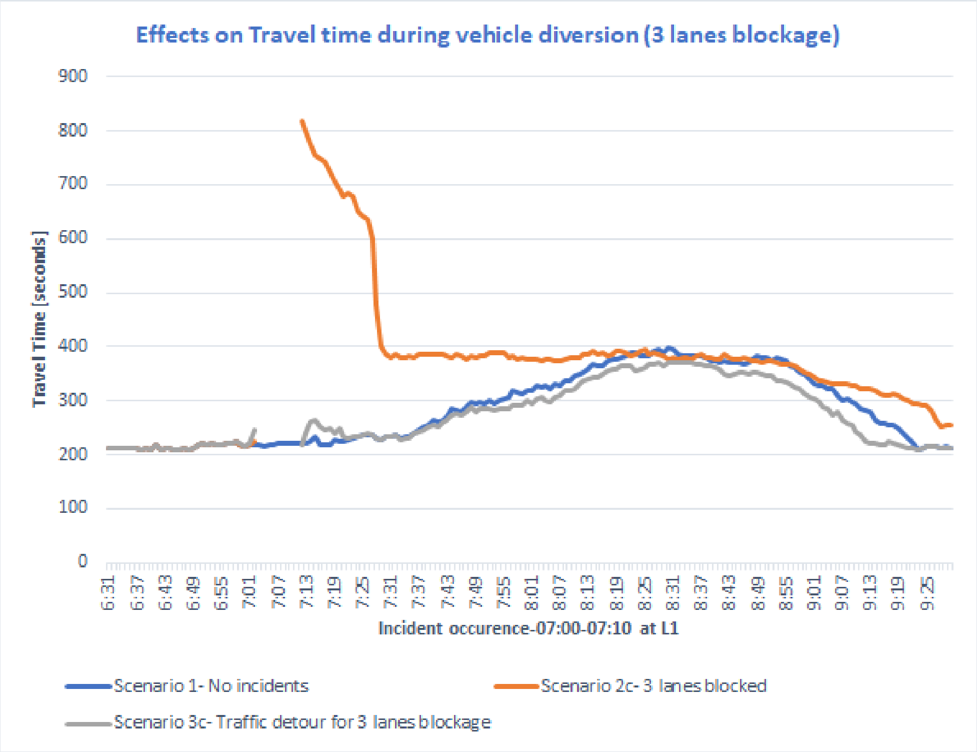


Figure 44: Graph representing the effect on travel time during three lanes blocked and during traffic detour in location L1 during 07:00AM-07:10AM.

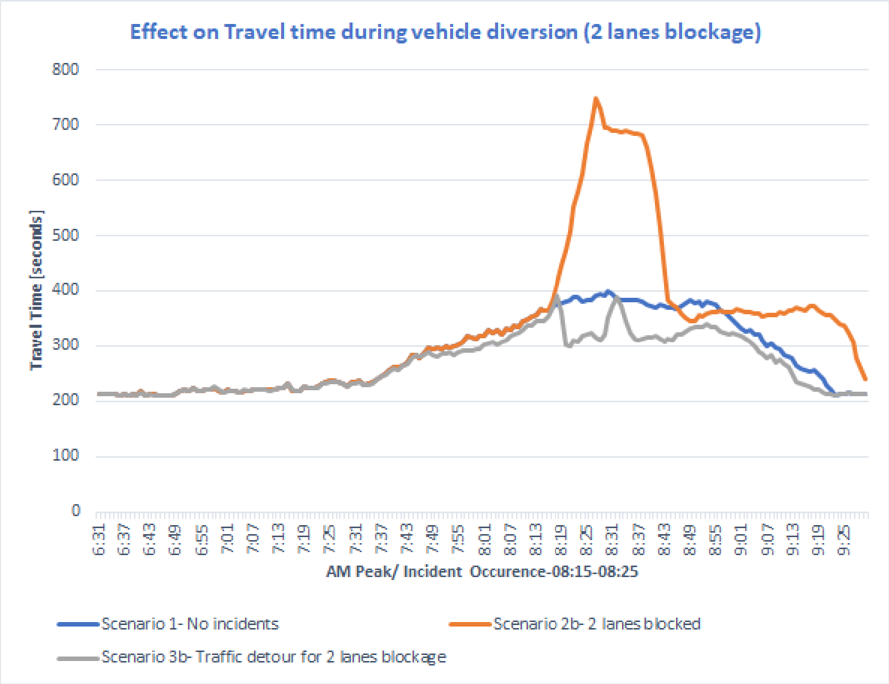


Figure 45: Graph representing the effect on travel time during two lanes blocked and during traffic detour in location L1 during 08:15AM-08:25AM.

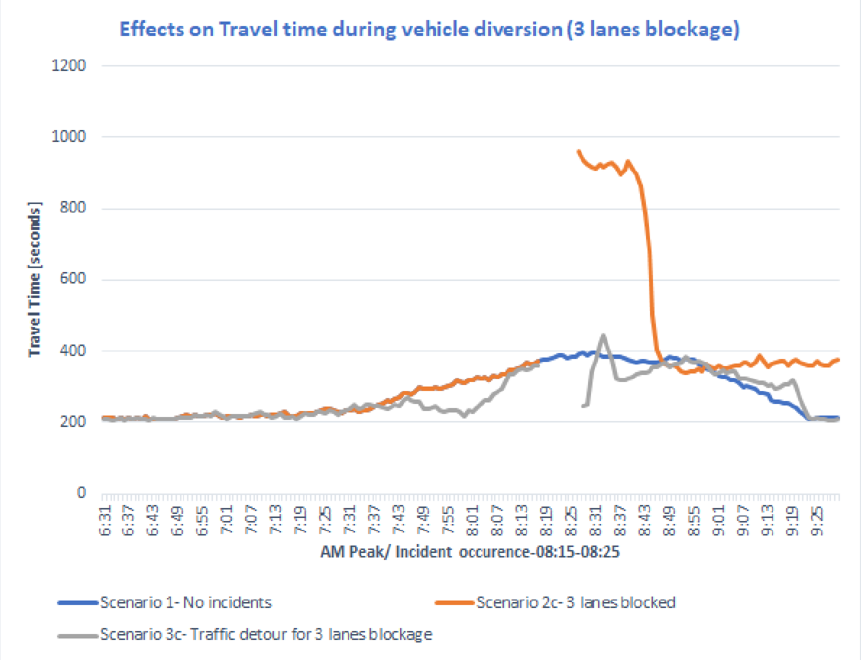


Figure 46: Graph representing the effect on travel time during three lanes blocked and during traffic detour in location L1 during 08:15AM-08:25AM.

Appendix B

SIDRA Intersection Summary:

INTERSECTION SUMMARY

Site: 113 [Scenario 1- No incidents 8:15-8:30 (Site Folder: Location 1)]

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated Cycle Time = 120 seconds (Site Optimum Cycle Time - Minimum Delay)

Intersection Performance - Hourly Values

Performance Measure	Vehicles	Pedestrians	Persons
Travel Speed (Average)	42.0 km/h	3.6 km/h	36.1 km/h
Travel Distance (Total)	9821.2 veh-km/h	183.5 ped-km/h	11969.0 pers-km/h
Travel Time (Total)	233.9 veh-h/h	51.3 ped-h/h	332.0 pers-h/h
Desired Speed (Program)	60.0 km/h		
Speed Efficiency	0.70		
Travel Time Index	6.67		
Congestion Coefficient	1.43		
Demand Flows (Total)	6032 veh/h	800 ped/h	8038 pers/h
Percent Heavy Vehicles (Demand)	4.6 %		
Degree of Saturation	0.904	0.333	
Practical Spare Capacity	-0.4 %		
Effective Intersection Capacity	6674 veh/h		
Control Delay (Total)	72.05 veh-h/h	12.13 ped-h/h	98.60 pers-h/h
Control Delay (Average)	43.0 sec	54.6 sec	44.2 sec
Control Delay (Worst Lane)	74.9 sec		
Control Delay (Worst Movement)	74.9 sec	54.6 sec	74.9 sec
Geometric Delay (Average)	2.0 sec		
Stop-Line Delay (Average)	41.0 sec		
Idling Time (Average)	34.6 sec		
Intersection Level of Service (LOS)	LOS D	LOS E	
95% Back of Queue - Vehicles (Worst Lane)	44.2 veh		
95% Back of Queue - Distance (Worst Lane)	324.3 m		
Ave. Queue Storage Ratio (Worst Lane)	0.25		
Total Effective Stops	5028 veh/h	766 ped/h	6800 pers/h
Effective Stop Rate	0.83	0.96	0.85
Proportion Queued	0.86	0.96	0.87
Performance Index	420.2	55.6	475.8
Cost (Total)	9846.97 $/h	1417.21 $/h	11264.17 $/h
Fuel Consumption (Total)	934.0 L/h		
Carbon Dioxide (Total)	2221.7 kg/h		
Hydrocarbons (Total)	0.189 kg/h		
Carbon Monoxide (Total)	2.447 kg/h		
NOx (Total)	4.005 kg/h		

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Intersection LOS value for Vehicles is based on average delay for all vehicle movements.
Intersection LOS value for Pedestrians is based on average delay for all pedestrian movements.
Delay Model: SIDRA Standard (Geometric Delay is included).
Queue Model: SIDRA Standard.
Site Model Variability Index (Iterations 3 to N): 0.0 %
Number of Iterations: 2 (Maximum: 10)
Largest change in Lane Degrees of Saturation for the last three Main (Timing-Capacity) Iterations: 19.7% 12.1% 0.0%

Intersection Performance - Annual Values

Performance Measure	Vehicles		Pedestrians		Persons	
Demand Flows (Total)	2,895,360	veh/y	384,000	ped/y	3,858,433	pers/y
Delay	34,585	veh-h/y	5,825	ped-h/y	47,327	pers-h/y
Effective Stops	2,413,294	veh/y	367,866	ped/y	3,263,818	pers/y
Travel Distance	4,714,187	veh-km/y	88,090	ped-km/y	5,745,113	pers-km/y
Travel Time	112,252	veh-h/y	24,647	ped-h/y	159,350	pers-h/y
Cost	4,726,543	$/y	680,260	$/y	5,406,803	$/y
Fuel Consumption	448,333	L/y				
Carbon Dioxide	1,066,423	kg/y				
Hydrocarbons	90	kg/y				
Carbon Monoxide	1,175	kg/y				
NOx	1,923	kg/y				

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INTERSECTION SUMMARY

Site: 113 [Scenario 3c - 8:15-8:30 Div 30% (Site Folder: Location 1)]

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated Cycle Time = 150 seconds (Site Optimum Cycle Time - Minimum Delay)

Intersection Performance - Hourly Values

Performance Measure	Vehicles	Pedestrians	Persons
Travel Speed (Average)	33.6 km/h	3.4 km/h	30.1 km/h
Travel Distance (Total)	11816.0 veh-km/h	183.5 ped-km/h	14362.7 pers-km/h
Travel Time (Total)	352.1 veh-h/h	54.7 ped-h/h	477.2 pers-h/h
Desired Speed (Program)	60.0 km/h		
Speed Efficiency	0.56		
Travel Time Index	5.10		
Congestion Coefficient	1.79		
Demand Flows (Total)	7256 veh/h	800 ped/h	9507 pers/h
Percent Heavy Vehicles (Demand)	4.9 %		
Degree of Saturation	1.071	0.417	
Practical Spare Capacity	-16.0 %		
Effective Intersection Capacity	6775 veh/h		
Control Delay (Total)	151.89 veh-h/h	15.49 ped-h/h	197.76 pers-h/h
Control Delay (Average)	75.4 sec	69.7 sec	74.9 sec
Control Delay (Worst Lane)	128.2 sec		
Control Delay (Worst Movement)	128.2 sec	69.7 sec	128.2 sec
Geometric Delay (Average)	1.7 sec		
Stop-Line Delay (Average)	73.7 sec		
Idling Time (Average)	68.3 sec		
Intersection Level of Service (LOS)	LOS E	LOS F	
95% Back of Queue - Vehicles (Worst Lane)	110.3 veh		
95% Back of Queue - Distance (Worst Lane)	809.9 m		
Ave. Queue Storage Ratio (Worst Lane)	0.62		
Total Effective Stops	7275 veh/h	774 ped/h	9504 pers/h
Effective Stop Rate	1.00	0.97	1.00
Proportion Queued	0.87	0.97	0.88
Performance Index	665.1	59.0	724.1
Cost (Total)	14451.71 $/h	1509.80 $/h	15961.51 $/h
Fuel Consumption (Total)	1240.5 L/h		
Carbon Dioxide (Total)	2950.4 kg/h		
Hydrocarbons (Total)	0.266 kg/h		
Carbon Monoxide (Total)	3.176 kg/h		
NOx (Total)	5.369 kg/h		

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Intersection LOS value for Vehicles is based on average delay for all vehicle movements.
Intersection LOS value for Pedestrians is based on average delay for all pedestrian movements.
Delay Model: SIDRA Standard (Geometric Delay is included).
Queue Model: SIDRA Standard.
Site Model Variability Index (Iterations 3 to N): 0.0 %
Number of Iterations: 2 (Maximum: 10)
Largest change in Lane Degrees of Saturation for the last three Main (Timing-Capacity) Iterations: 20.3% 0.0% 0.0%

Intersection Performance - Annual Values

Performance Measure	Vehicles		Pedestrians		Persons	
Demand Flows (Total)	3,482,880	veh/y	384,000	ped/y	4,563,456	pers/y
Delay	72,908	veh-h/y	7,435	ped-h/y	94,924	pers-h/y
Effective Stops	3,491,840	veh/y	371,738	ped/y	4,561,946	pers/y
Travel Distance	5,671,668	veh-km/y	88,090	ped-km/y	6,894,091	pers-km/y
Travel Time	168,993	veh-h/y	26,257	ped-h/y	229,050	pers-h/y
Cost	6,936,822	$/y	724,702	$/y	7,661,524	$/y
Fuel Consumption	595,448	L/y				
Carbon Dioxide	1,416,180	kg/y				
Hydrocarbons	128	kg/y				
Carbon Monoxide	1,524	kg/y				
NOx	2,577	kg/y				

INTERSECTION SUMMARY

Site: 113 [Scenario 3c - 8:15-8:30 Div 100% (Site Folder: Location 1)]

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated Cycle Time = 150 seconds (Site Optimum Cycle Time - Minimum Delay)

Intersection Performance - Hourly Values

Performance Measure	Vehicles	Pedestrians	Persons
Travel Speed (Average)	14.0 km/h	3.4 km/h	13.6 km/h
Travel Distance (Total)	16470.4 veh-km/h	183.5 ped-km/h	19948.0 pers-km/h
Travel Time (Total)	1177.2 veh-h/h	54.7 ped-h/h	1467.3 pers-h/h
Desired Speed (Program)	60.0 km/h		
Speed Efficiency	0.23		
Travel Time Index	1.48		
Congestion Coefficient	4.29		
Demand Flows (Total)	10112 veh/h	800 ped/h	12934 pers/h
Percent Heavy Vehicles (Demand)	5.1 %		
Degree of Saturation	1.950	0.417	
Practical Spare Capacity	-53.8 %		
Effective Intersection Capacity	5186 veh/h		
Control Delay (Total)	871.14 veh-h/h	15.49 ped-h/h	1060.86 pers-h/h
Control Delay (Average)	310.1 sec	69.7 sec	295.3 sec
Control Delay (Worst Lane)	482.6 sec		
Control Delay (Worst Movement)	482.6 sec	69.7 sec	482.6 sec
Geometric Delay (Average)	1.2 sec		
Stop-Line Delay (Average)	308.9 sec		
Idling Time (Average)	306.1 sec		
Intersection Level of Service (LOS)	LOS F	LOS F	
95% Back of Queue - Vehicles (Worst Lane)	366.9 veh		
95% Back of Queue - Distance (Worst Lane)	2696.0 m		
Ave. Queue Storage Ratio (Worst Lane)	2.07		
Total Effective Stops	16503 veh/h	774 ped/h	20578 pers/h
Effective Stop Rate	1.63	0.97	1.59
Proportion Queued	0.91	0.97	0.91
Performance Index	1836.4	59.0	1895.4
Cost (Total)	45127.75 $/h	1509.80 $/h	46637.55 $/h
Fuel Consumption (Total)	2728.9 L/h		
Carbon Dioxide (Total)	6481.0 kg/h		
Hydrocarbons (Total)	0.739 kg/h		
Carbon Monoxide (Total)	6.580 kg/h		
NOx (Total)	10.988 kg/h		

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Intersection LOS value for Vehicles is based on average delay for all vehicle movements.

Intersection LOS value for Pedestrians is based on average delay for all pedestrian movements.
Delay Model: SIDRA Standard (Geometric Delay is included).
Queue Model: SIDRA Standard.
Site Model Variability Index (Iterations 3 to N): 0.0 %
Number of Iterations: 2 (Maximum: 10)
Largest change in Lane Degrees of Saturation for the last three Main (Timing-Capacity) Iterations: 20.3% 0.0% 0.0%

Intersection Performance - Annual Values

Performance Measure	Vehicles	Pedestrians	Persons
Demand Flows (Total)	4,853,760 veh/y	384,000 ped/y	6,208,513 pers/y
Delay	418,148 veh-h/y	7,435 ped-h/y	509,213 pers-h/y
Effective Stops	7,921,267 veh/y	371,738 ped/y	9,877,257 pers/y
Travel Distance	7,905,791 veh-km/y	88,090 ped-km/y	9,575,038 pers-km/y
Travel Time	565,041 veh-h/y	26,257 ped-h/y	704,306 pers-h/y
Cost	21,661,320 $/y	724,702 $/y	22,386,020 $/y
Fuel Consumption	1,309,856 L/y		
Carbon Dioxide	3,110,863 kg/y		
Hydrocarbons	355 kg/y		
Carbon Monoxide	3,159 kg/y		
NOx	5,274 kg/y		

QUEUE ANALYSIS

Site: 113 [Scenario 3c - 8:15-8:30 Div 30% (Site Folder: Location 1)]

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated Cycle Time = 150 seconds (Site Optimum Cycle Time - Minimum Delay)

Lane Queues (Distance)

Lane Number	Contin. Lane	Deg. Satn	Prog. Factor (Queue)	Overflow Queue (m)	Back of Queue (m)		Queue at Start of Green (m)		Cycle Average Queue (m)		Queue Storage Ratio		Prob. Block.	Prob. SL Ov.	Ov. Lane No.
		v/c			Av.	95%	Av.	95%	Av.	95%	Av.	95%	%	%	
South: Marion Road															
Lane 1		0.351	1.000	0.0	60.8	99.2	50.3	82.1	15.4	32.2	1.01	1.65	NA	51.2	2
Lane 2		0.351	1.000	0.0	60.8	99.2	50.3	82.1	15.4	32.2	0.28	0.45	NA	0.0	3
Lane 3		1.071	1.000	116.2	465.1	759.1	267.6	436.7	199.1	416.0	0.58	0.95	0.3	NA	NA
Lane 4		1.071	1.000	122.1	496.3	809.9	284.6	464.5	210.7	440.3	0.62	1.01	6.1	NA	NA
Lane 5		1.071	1.000	119.8	484.0	789.9	277.9	453.5	206.2	430.8	0.61	0.99	3.9	NA	NA
Lane 6		0.707	1.000	0.2	23.2	37.9	22.3	36.4	11.0	23.1	0.13	0.22	NA	0.0	5
Lane 7		0.707	1.000	0.2	23.2	37.9	22.3	36.4	11.0	23.1	0.18	0.29	NA	0.0	6
Approach		1.071			496.3	809.9	284.6	464.5	210.7	440.3	0.62	1.01			
East: Sturt Road															
Lane 1		0.023	1.000	0.0	0.5	0.8	0.5	0.8	0.0	0.0	0.00	0.00	NA	0.0	2
Lane 2		0.703	1.000	0.0	88.8	144.9	75.0	122.5	34.6	72.4	0.11	0.18	0.0	NA	NA
Lane 3		0.703	1.000	0.0	88.8	144.9	75.0	122.5	34.6	72.4	0.11	0.18	0.0	NA	NA
Lane 4		0.969	1.000	2.3	27.1	44.2	25.7	42.0	14.1	29.4	0.15	0.24	NA	0.0	3
Lane 5		0.969	1.000	2.3	27.1	44.2	25.7	42.0	14.1	29.4	0.27	0.44	NA	0.0	4
Approach		0.969			88.8	144.9	75.0	122.5	34.6	72.4	0.11	0.18			
North: Marion Road															
Lane 1		0.273	1.000	0.0	7.7	12.6	5.8	9.5	0.3	0.6	0.03	0.05	NA	0.0	2
Lane 2		0.195	1.000	0.0	33.0	53.9	29.6	48.3	7.8	16.3	0.04	0.07	0.0	NA	NA
Lane 3		0.195	1.000	0.0	33.0	53.9	29.6	48.3	7.8	16.3	0.04	0.07	0.0	NA	NA
Lane 4		0.195	1.000	0.0	33.0	53.9	29.6	48.3	7.8	16.3	0.09	0.14	NA	0.0	3
Lane 5		1.061	1.000	8.6	45.2	73.8	42.5	69.4	25.4	53.0	0.23	0.37	NA	0.0	4
Lane 6		1.061	1.000	8.6	45.2	73.8	42.5	69.4	25.4	53.0	0.45	0.74	NA	0.0	5
Approach		1.061			45.2	73.8	42.5	69.4	25.4	53.0	0.04	0.07			
West: Sturt Road															
Lane 1		0.651	1.000	0.0	66.6	108.6	58.5	95.4	27.1	56.5	0.51	0.84	NA	0.0	2
Lane 2		0.651	1.000	0.0	66.6	108.6	58.5	95.4	27.1	56.5	0.51	0.84	NA	0.0	3
Lane 3		1.005	1.000	28.4	173.2	282.7	134.9	220.2	82.9	173.2	0.22	0.35	0.0	NA	NA
Lane 4		1.005	1.000	28.4	173.2	282.7	134.9	220.2	82.9	173.2	0.22	0.35	0.0	NA	NA
Lane 5		0.892	1.000	1.0	24.0	39.2	22.9	37.4	11.9	24.8	0.12	0.20	NA	0.0	4
Lane 6		0.892	1.000	1.0	24.0	39.2	22.9	37.4	11.9	24.8	0.27	0.44	NA	0.0	5
Approach		1.005			173.2	282.7	134.9	220.2	82.9	173.2	0.22	0.35			

Intersection		1.071			496.3	809.9	284.6	464.5	210.7	440.3	0.62	1.01			

Queue Model: SIDRA Standard.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

Lane Queues (Vehicles)

Lane Number	Contin. Lane	Deg. Satn	Prog. Factor (Queue)	Overflow Queue (veh)	Back of Queue (veh)		Queue at Start of Green (veh)		Cycle Average Queue (veh)		Queue Storage Ratio		Prob. Block.	Prob. SL Ov.	Ov. Lane No.
		v/c			Av.	95%	Av.	95%	Av.	95%	Av.	95%	%	%	
South: Marion Road															
Lane 1		0.351	1.000	0.0	8.5	13.8	7.0	11.4	2.1	4.5	1.01	1.65	NA	51.2	2
Lane 2		0.351	1.000	0.0	8.5	13.8	7.0	11.4	2.1	4.5	0.28	0.45	NA	0.0	3
Lane 3		1.071	1.000	15.8	63.3	103.4	36.4	59.5	27.1	56.7	0.58	0.95	0.3	NA	NA
Lane 4		1.071	1.000	16.6	67.6	110.3	38.8	63.3	28.7	60.0	0.62	1.01	6.1	NA	NA
Lane 5		1.071	1.000	16.3	65.9	107.6	37.8	61.8	28.1	58.7	0.61	0.99	3.9	NA	NA
Lane 6		0.707	1.000	0.0	3.3	5.4	3.2	5.2	1.6	3.3	0.13	0.22	NA	0.0	5
Lane 7		0.707	1.000	0.0	3.3	5.4	3.2	5.2	1.6	3.3	0.18	0.29	NA	0.0	6
Approach		1.071			67.6	110.3	38.8	63.3	28.7	60.0	0.62	1.01			
East: Sturt Road															
Lane 1		0.023	1.000	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.00	0.00	NA	0.0	2
Lane 2		0.703	1.000	0.0	12.0	19.7	10.2	16.6	4.7	9.8	0.11	0.18	0.0	NA	NA
Lane 3		0.703	1.000	0.0	12.0	19.7	10.2	16.6	4.7	9.8	0.11	0.18	0.0	NA	NA
Lane 4		0.969	1.000	0.3	3.9	6.3	3.7	6.0	2.0	4.2	0.15	0.24	NA	0.0	3
Lane 5		0.969	1.000	0.3	3.9	6.3	3.7	6.0	2.0	4.2	0.27	0.44	NA	0.0	4
Approach		0.969			12.0	19.7	10.2	16.6	4.7	9.8	0.11	0.18			
North: Marion Road															
Lane 1		0.273	1.000	0.0	1.1	1.8	0.8	1.3	0.0	0.1	0.03	0.05	NA	0.0	2
Lane 2		0.195	1.000	0.0	4.4	7.1	3.9	6.4	1.0	2.2	0.04	0.07	0.0	NA	NA
Lane 3		0.195	1.000	0.0	4.4	7.1	3.9	6.4	1.0	2.2	0.04	0.07	0.0	NA	NA
Lane 4		0.195	1.000	0.0	4.4	7.1	3.9	6.4	1.0	2.2	0.09	0.14	NA	0.0	3
Lane 5		1.061	1.000	1.1	5.9	9.7	5.6	9.1	3.3	7.0	0.23	0.37	NA	0.0	4
Lane 6		1.061	1.000	1.1	5.9	9.7	5.6	9.1	3.3	7.0	0.45	0.74	NA	0.0	5
Approach		1.061			5.9	9.7	5.6	9.1	3.3	7.0	0.04	0.07			
West: Sturt Road															
Lane 1		0.651	1.000	0.0	9.2	15.0	8.1	13.2	3.7	7.8	0.51	0.84	NA	0.0	2
Lane 2		0.651	1.000	0.0	9.2	15.0	8.1	13.2	3.7	7.8	0.51	0.84	NA	0.0	3
Lane 3		1.005	1.000	4.0	24.4	39.7	19.0	31.0	11.7	24.4	0.22	0.35	0.0	NA	NA
Lane 4		1.005	1.000	4.0	24.4	39.7	19.0	31.0	11.7	24.4	0.22	0.35	0.0	NA	NA
Lane 5		0.892	1.000	0.1	3.2	5.2	3.0	4.9	1.6	3.3	0.12	0.20	NA	0.0	4
Lane 6		0.892	1.000	0.1	3.2	5.2	3.0	4.9	1.6	3.3	0.27	0.44	NA	0.0	5
Approach		1.005			24.4	39.7	19.0	31.0	11.7	24.4	0.22	0.35			
Intersection		1.071			67.6	110.3	38.8	63.3	28.7	60.0	0.62	1.01			

Queue Model: SIDRA Standard.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

Pedestrian Queues

Mov ID	Description	Dem. Flow	AVERAGE BACK OF QUEUE [Ped	Dist]

		ped/h	ped	m
South: Marion Road				
P1	Full	200	0.8	0.8
East: Sturt Road				
P2	Full	200	0.8	0.8
North: Marion Road				
P3	Full	200	0.8	0.8
West: Sturt Road				
P4	Full	200	0.8	0.8
All Pedestrians		800	0.8	0.8

Incident Location 2

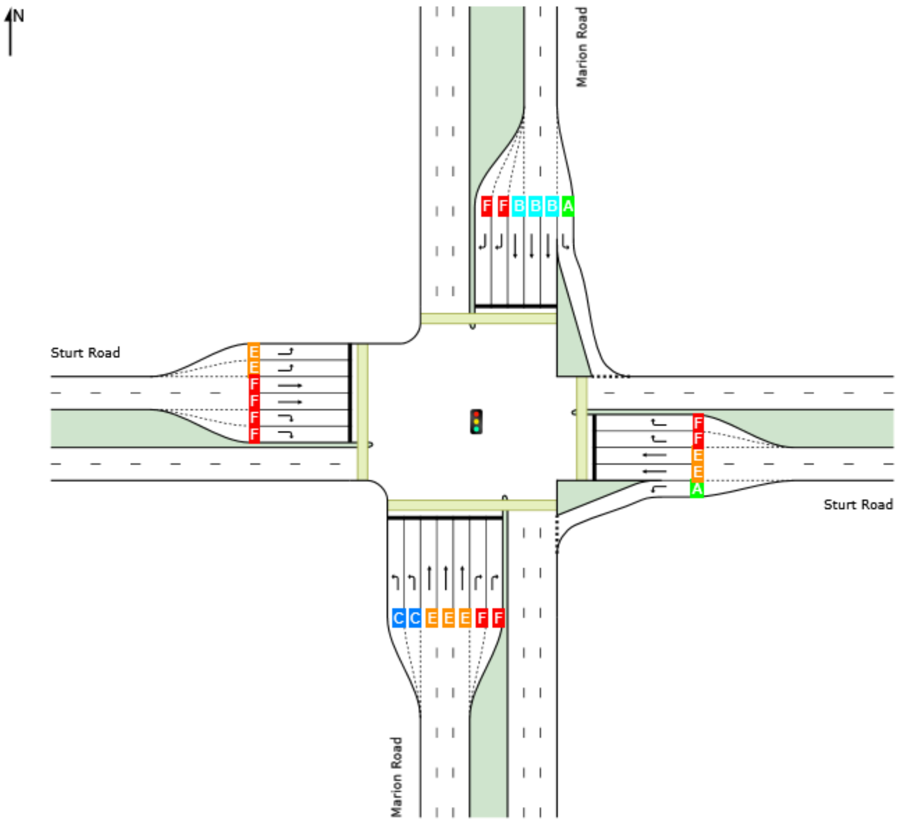
LANE LEVEL OF SERVICE

Lane Level of Service

Site: 113 [Scenario 3c - 7:00-7:15 Div 50% (Site Folder: Location 2)]

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated Cycle Time = 150 seconds (Site Optimum Cycle Time - Minimum Delay)

	Approaches				Intersection
	South	East	North	West	
LOS	E	E	C	F	E



Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Lane LOS values are based on average delay per lane.

Intersection and Approach LOS values are based on average delay for all lanes.
Delay Model: SIDRA Standard (Geometric Delay is included).

INTERSECTION SUMMARY

Site: 113 [Scenario 1- No incidents 7:00-7:15 (Site Folder: Location 2)]

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated Cycle Time = 100 seconds (Site Optimum Cycle Time - Minimum Delay)

Intersection Performance - Hourly Values

Performance Measure	Vehicles	Pedestrians	Persons
Travel Speed (Average)	43.7 km/h	3.7 km/h	37.1 km/h
Travel Distance (Total)	9019.4 veh-km/h	183.5 ped-km/h	11006.8 pers-km/h
Travel Time (Total)	206.5 veh-h/h	49.1 ped-h/h	296.9 pers-h/h
Desired Speed (Program)	60.0 km/h		
Speed Efficiency	0.73		
Travel Time Index	6.98		
Congestion Coefficient	1.37		
Demand Flows (Total)	5540 veh/h	800 ped/h	7448 pers/h
Percent Heavy Vehicles (Demand)	4.5 %		
Degree of Saturation	0.943	0.278	
Practical Spare Capacity	-4.6 %		
Effective Intersection Capacity	5872 veh/h		
Control Delay (Total)	55.99 veh-h/h	9.90 ped-h/h	77.08 pers-h/h
Control Delay (Average)	36.4 sec	44.6 sec	37.3 sec
Control Delay (Worst Lane)	73.5 sec		
Control Delay (Worst Movement)	73.5 sec	44.6 sec	73.5 sec
Geometric Delay (Average)	2.2 sec		
Stop-Line Delay (Average)	34.2 sec		
Idling Time (Average)	29.0 sec		
Intersection Level of Service (LOS)	LOS D	LOS E	
95% Back of Queue - Vehicles (Worst Lane)	27.2 veh		
95% Back of Queue - Distance (Worst Lane)	198.7 m		
Ave. Queue Storage Ratio (Worst Lane)	0.15		
Total Effective Stops	4488 veh/h	758 ped/h	6144 pers/h
Effective Stop Rate	0.81	0.95	0.82
Proportion Queued	0.85	0.95	0.86
Performance Index	351.5	53.3	404.8
Cost (Total)	8730.42 $/h	1355.55 $/h	10085.97 $/h
Fuel Consumption (Total)	841.1 L/h		
Carbon Dioxide (Total)	2000.2 kg/h		
Hydrocarbons (Total)	0.168 kg/h		
Carbon Monoxide (Total)	2.216 kg/h		
NOx (Total)	3.550 kg/h		

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Intersection LOS value for Vehicles is based on average delay for all vehicle movements.

Intersection LOS value for Pedestrians is based on average delay for all pedestrian movements.

Delay Model: SIDRA Standard (Geometric Delay is included).

Queue Model: SIDRA Standard.

Site Model Variability Index (Iterations 3 to N): 0.0 %

Number of Iterations: 2 (Maximum: 10)

Largest change in Lane Degrees of Saturation for the last three Main (Timing-Capacity) Iterations: 19.0% 0.0% 0.0%

Intersection Performance - Annual Values

Performance Measure	Vehicles	Pedestrians	Persons
Demand Flows (Total)	2,659,200 veh/y	384,000 ped/y	3,575,040 pers/y
Delay	26,874 veh-h/y	4,752 ped-h/y	37,001 pers-h/y
Effective Stops	2,154,162 veh/y	363,993 ped/y	2,948,987 pers/y
Travel Distance	4,329,317 veh-km/y	88,090 ped-km/y	5,283,269 pers-km/y
Travel Time	99,101 veh-h/y	23,575 ped-h/y	142,496 pers-h/y
Cost	4,190,604 $/y	650,662 $/y	4,841,265 $/y
Fuel Consumption	403,720 L/y		
Carbon Dioxide	960,076 kg/y		
Hydrocarbons	81 kg/y		
Carbon Monoxide	1,064 kg/y		
NOx	1,704 kg/y		

INTERSECTION SUMMARY

Site: 113 [Scenario 3c - 7:00-7:15 Div 50% (Site Folder: Location 2)]

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated Cycle Time = 150 seconds (Site Optimum Cycle Time - Minimum Delay)

Intersection Performance - Hourly Values

Performance Measure	Vehicles	Pedestrians	Persons
Travel Speed (Average)	35.5 km/h	3.4 km/h	31.6 km/h
Travel Distance (Total)	11548.7 veh-km/h	183.5 ped-km/h	14042.0 pers-km/h
Travel Time (Total)	325.3 veh-h/h	54.7 ped-h/h	445.0 pers-h/h
Desired Speed (Program)	60.0 km/h		
Speed Efficiency	0.59		
Travel Time Index	5.46		
Congestion Coefficient	1.69		
Demand Flows (Total)	7092 veh/h	800 ped/h	9310 pers/h
Percent Heavy Vehicles (Demand)	4.8 %		
Degree of Saturation	1.061	0.417	
Practical Spare Capacity	-15.2 %		
Effective Intersection Capacity	6682 veh/h		
Control Delay (Total)	131.25 veh-h/h	15.49 ped-h/h	172.98 pers-h/h
Control Delay (Average)	66.6 sec	69.7 sec	66.9 sec
Control Delay (Worst Lane)	128.2 sec		
Control Delay (Worst Movement)	128.2 sec	69.7 sec	128.2 sec
Geometric Delay (Average)	1.7 sec		
Stop-Line Delay (Average)	64.9 sec		
Idling Time (Average)	59.2 sec		
Intersection Level of Service (LOS)	LOS E	LOS F	
95% Back of Queue - Vehicles (Worst Lane)	95.8 veh		
95% Back of Queue - Distance (Worst Lane)	702.8 m		
Ave. Queue Storage Ratio (Worst Lane)	0.54		
Total Effective Stops	6791 veh/h	774 ped/h	8923 pers/h
Effective Stop Rate	0.96	0.97	0.96
Proportion Queued	0.87	0.97	0.88
Performance Index	620.0	59.0	679.0
Cost (Total)	13429.64 $/h	1509.80 $/h	14939.44 $/h
Fuel Consumption (Total)	1180.5 L/h		

Carbon Dioxide (Total)	2807.7 kg/h
Hydrocarbons (Total)	0.249 kg/h
Carbon Monoxide (Total)	3.039 kg/h
NOx (Total)	5.082 kg/h

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Intersection LOS value for Vehicles is based on average delay for all vehicle movements.

Intersection LOS value for Pedestrians is based on average delay for all pedestrian movements.

Delay Model: SIDRA Standard (Geometric Delay is included).

Queue Model: SIDRA Standard.

Site Model Variability Index (Iterations 3 to N): 0.0 %

Number of Iterations: 2 (Maximum: 10)

Largest change in Lane Degrees of Saturation for the last three Main (Timing-Capacity) Iterations: 20.3% 1.2% 0.0%

Intersection Performance - Annual Values

Performance Measure	Vehicles	Pedestrians	Persons
Demand Flows (Total)	3,404,160 veh/y	384,000 ped/y	4,468,992 pers/y
Delay	62,998 veh-h/y	7,435 ped-h/y	83,032 pers-h/y
Effective Stops	3,259,608 veh/y	371,738 ped/y	4,283,268 pers/y
Travel Distance	5,543,378 veh-km/y	88,090 ped-km/y	6,740,143 pers-km/y
Travel Time	156,138 veh-h/y	26,257 ped-h/y	213,623 pers-h/y
Cost	6,446,229 $/y	724,702 $/y	7,170,931 $/y
Fuel Consumption	566,644 L/y		
Carbon Dioxide	1,347,678 kg/y		
Hydrocarbons	120 kg/y		
Carbon Monoxide	1,459 kg/y		
NOx	2,439 kg/y		

INTERSECTION SUMMARY

Site: 113 [Scenario 3c - 7:00-7:15 Div 100% (Site Folder: Location 2)]

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated Cycle Time = 150 seconds (Site Optimum Cycle Time - Minimum Delay)

Intersection Performance - Hourly Values

Performance Measure	Vehicles	Pedestrians	Persons
Travel Speed (Average)	20.8 km/h	3.4 km/h	19.7 km/h
Travel Distance (Total)	14078.0 veh-km/h	183.5 ped-km/h	17077.1 pers-km/h
Travel Time (Total)	677.0 veh-h/h	54.7 ped-h/h	867.1 pers-h/h
Desired Speed (Program)	60.0 km/h		
Speed Efficiency	0.35		
Travel Time Index	2.74		
Congestion Coefficient	2.89		
Demand Flows (Total)	8644 veh/h	800 ped/h	11173 pers/h
Percent Heavy Vehicles (Demand)	5.0 %		
Degree of Saturation	1.504	0.417	
Practical Spare Capacity	-40.2 %		
Effective Intersection Capacity	5747 veh/h		
Control Delay (Total)	424.98 veh-h/h	15.49 ped-h/h	525.47 pers-h/h
Control Delay (Average)	177.0 sec	69.7 sec	169.3 sec
Control Delay (Worst Lane)	282.1 sec		
Control Delay (Worst Movement)	281.7 sec	69.7 sec	281.7 sec
Geometric Delay (Average)	1.4 sec		
Stop-Line Delay (Average)	175.6 sec		
Idling Time (Average)	171.9 sec		
Intersection Level of Service (LOS)	LOS F	LOS F	
95% Back of Queue - Vehicles (Worst Lane)	237.0 veh		
95% Back of Queue - Distance (Worst Lane)	1740.3 m		
Ave. Queue Storage Ratio (Worst Lane)	1.33		
Total Effective Stops	11681 veh/h	774 ped/h	14792 pers/h
Effective Stop Rate	1.35	0.97	1.32
Proportion Queued	0.89	0.97	0.90
Performance Index	1157.5	59.0	1216.5
Cost (Total)	26617.99 $/h	1509.80 $/h	28127.79 $/h
Fuel Consumption (Total)	1864.8 L/h		
Carbon Dioxide (Total)	4431.7 kg/h		

Hydrocarbons (Total)	0.458 kg/h
Carbon Monoxide (Total)	4.603 kg/h
NOx (Total)	7.839 kg/h

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).

Intersection LOS value for Vehicles is based on average delay for all vehicle movements.

Intersection LOS value for Pedestrians is based on average delay for all pedestrian movements.

Delay Model: SIDRA Standard (Geometric Delay is included).

Queue Model: SIDRA Standard.

Site Model Variability Index (Iterations 3 to N): 0.0 %

Number of Iterations: 2 (Maximum: 10)

Largest change in Lane Degrees of Saturation for the last three Main (Timing-Capacity) Iterations: 20.3% 0.0% 0.0%

Intersection Performance - Annual Values

Performance Measure	Vehicles		Pedestrians		Persons	
Demand Flows (Total)	4,149,120	veh/y	384,000	ped/y	5,362,946	pers/y
Delay	203,991	veh-h/y	7,435	ped-h/y	252,224	pers-h/y
Effective Stops	5,606,916	veh/y	371,738	ped/y	7,100,036	pers/y
Travel Distance	6,757,439	veh-km/y	88,090	ped-km/y	8,197,016	pers-km/y
Travel Time	324,959	veh-h/y	26,257	ped-h/y	416,208	pers-h/y
Cost	12,776,640	$/y	724,702	$/y	13,501,340	$/y
Fuel Consumption	895,109	L/y				
Carbon Dioxide	2,127,213	kg/y				
Hydrocarbons	220	kg/y				
Carbon Monoxide	2,209	kg/y				
NOx	3,763	kg/y				

QUEUE ANALYSIS

Site: 113 [Scenario 3c - 7:00-7:15 Div 50% (Site Folder: Location 2)]

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated Cycle Time = 150 seconds (Site Optimum Cycle Time - Minimum Delay)

Lane Queues (Distance)

Lane Number	Contin. Lane	Deg. Satn	Prog. Factor (Queue)	Overflow Queue (m)	Back of Queue (m)		Queue at Start of Green (m)		Cycle Average Queue (m)		Queue Storage Ratio		Prob. Block.	Prob. SL Ov.	Ov. Lane No.
		v/c			Av.	95%	Av.	95%	Av.	95%	Av.	95%	%	%	
South: Marion Road															
Lane 1		0.351	1.000	0.0	60.8	99.2	50.3	82.1	15.4	32.2	1.01	1.65	NA	51.2	2
Lane 2		0.351	1.000	0.0	60.8	99.2	50.3	82.1	15.4	32.2	0.28	0.45	NA	0.0	3
Lane 3		1.015	1.000	75.3	403.3	658.1	218.3	356.2	150.3	314.0	0.50	0.82	0.0	NA	NA
Lane 4		1.015	1.000	78.0	430.7	702.8	232.0	378.6	158.5	331.2	0.54	0.88	0.0	NA	NA
Lane 5		1.015	1.000	77.0	419.8	685.1	226.6	369.7	155.3	324.4	0.52	0.86	0.0	NA	NA
Lane 6		0.707	1.000	0.2	23.2	37.9	22.3	36.4	11.0	23.1	0.13	0.22	NA	0.0	5
Lane 7		0.707	1.000	0.2	23.2	37.9	22.3	36.4	11.0	23.1	0.18	0.29	NA	0.0	6
Approach		1.015			430.7	702.8	232.0	378.6	158.5	331.2	0.54	0.88			
East: Sturt Road															
Lane 1		0.023	1.000	0.0	0.5	0.8	0.5	0.8	0.0	0.0	0.00	0.00	NA	0.0	2
Lane 2		0.703	1.000	0.0	88.8	144.9	75.0	122.5	34.6	72.4	0.11	0.18	0.0	NA	NA
Lane 3		0.703	1.000	0.0	88.8	144.9	75.0	122.5	34.6	72.4	0.11	0.18	0.0	NA	NA
Lane 4		0.969	1.000	2.3	27.1	44.2	25.7	42.0	14.1	29.4	0.15	0.24	NA	0.0	3
Lane 5		0.969	1.000	2.3	27.1	44.2	25.7	42.0	14.1	29.4	0.27	0.44	NA	0.0	4
Approach		0.969			88.8	144.9	75.0	122.5	34.6	72.4	0.11	0.18			
North: Marion Road															
Lane 1		0.273	1.000	0.0	7.7	12.6	5.8	9.5	0.3	0.6	0.03	0.05	NA	0.0	2
Lane 2		0.195	1.000	0.0	33.0	53.9	29.6	48.3	7.8	16.3	0.04	0.07	0.0	NA	NA
Lane 3		0.195	1.000	0.0	33.0	53.9	29.6	48.3	7.8	16.3	0.04	0.07	0.0	NA	NA
Lane 4		0.195	1.000	0.0	33.0	53.9	29.6	48.3	7.8	16.3	0.09	0.14	NA	0.0	3
Lane 5		1.061	1.000	8.6	45.2	73.8	42.5	69.4	25.4	53.0	0.23	0.37	NA	0.0	4
Lane 6		1.061	1.000	8.6	45.2	73.8	42.5	69.4	25.4	53.0	0.45	0.74	NA	0.0	5
Approach		1.061			45.2	73.8	42.5	69.4	25.4	53.0	0.04	0.07			
West: Sturt Road															
Lane 1		0.651	1.000	0.0	66.6	108.6	58.5	95.4	27.1	56.5	0.51	0.84	NA	0.0	2
Lane 2		0.651	1.000	0.0	66.6	108.6	58.5	95.4	27.1	56.5	0.51	0.84	NA	0.0	3
Lane 3		1.005	1.000	28.4	173.2	282.7	134.9	220.2	82.9	173.2	0.22	0.35	0.0	NA	NA
Lane 4		1.005	1.000	28.4	173.2	282.7	134.9	220.2	82.9	173.2	0.22	0.35	0.0	NA	NA
Lane 5		0.892	1.000	1.0	24.0	39.2	22.9	37.4	11.9	24.8	0.12	0.20	NA	0.0	4
Lane 6		0.892	1.000	1.0	24.0	39.2	22.9	37.4	11.9	24.8	0.27	0.44	NA	0.0	5
Approach		1.005			173.2	282.7	134.9	220.2	82.9	173.2	0.22	0.35			
Intersection		1.061			430.7	702.8	232.0	378.6	158.5	331.2	0.54	0.88			

Queue Model: SIDRA Standard.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

Lane Queues (Vehicles)

Lane Number	Contin. Lane	Deg. Satn	Prog. Factor (Queue)	Overflow Queue (veh)	Back of Queue (veh)		Queue at Start of Green (veh)		Cycle Average Queue (veh)		Queue Storage Ratio		Prob. Block.	Prob. SL Ov.	Ov. Lane No.
		v/c			Av.	95%	Av.	95%	Av.	95%	Av.	95%	%	%	
South: Marion Road															
Lane 1		0.351	1.000	0.0	8.5	13.8	7.0	11.4	2.1	4.5	1.01	1.65	NA	51.2	2
Lane 2		0.351	1.000	0.0	8.5	13.8	7.0	11.4	2.1	4.5	0.28	0.45	NA	0.0	3
Lane 3		1.015	1.000	10.3	55.0	89.7	29.7	48.5	20.5	42.8	0.50	0.82	0.0	NA	NA
Lane 4		1.015	1.000	10.6	58.7	95.8	31.6	51.6	21.6	45.1	0.54	0.88	0.0	NA	NA
Lane 5		1.015	1.000	10.5	57.2	93.4	30.9	50.4	21.2	44.2	0.52	0.86	0.0	NA	NA
Lane 6		0.707	1.000	0.0	3.3	5.4	3.2	5.2	1.6	3.3	0.13	0.22	NA	0.0	5
Lane 7		0.707	1.000	0.0	3.3	5.4	3.2	5.2	1.6	3.3	0.18	0.29	NA	0.0	6
Approach		1.015			58.7	95.8	31.6	51.6	21.6	45.1	0.54	0.88			
East: Sturt Road															
Lane 1		0.023	1.000	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.00	0.00	NA	0.0	2
Lane 2		0.703	1.000	0.0	12.0	19.7	10.2	16.6	4.7	9.8	0.11	0.18	0.0	NA	NA
Lane 3		0.703	1.000	0.0	12.0	19.7	10.2	16.6	4.7	9.8	0.11	0.18	0.0	NA	NA
Lane 4		0.969	1.000	0.3	3.9	6.3	3.7	6.0	2.0	4.2	0.15	0.24	NA	0.0	3
Lane 5		0.969	1.000	0.3	3.9	6.3	3.7	6.0	2.0	4.2	0.27	0.44	NA	0.0	4
Approach		0.969			12.0	19.7	10.2	16.6	4.7	9.8	0.11	0.18			
North: Marion Road															
Lane 1		0.273	1.000	0.0	1.1	1.8	0.8	1.3	0.0	0.1	0.03	0.05	NA	0.0	2
Lane 2		0.195	1.000	0.0	4.4	7.1	3.9	6.4	1.0	2.2	0.04	0.07	0.0	NA	NA
Lane 3		0.195	1.000	0.0	4.4	7.1	3.9	6.4	1.0	2.2	0.04	0.07	0.0	NA	NA
Lane 4		0.195	1.000	0.0	4.4	7.1	3.9	6.4	1.0	2.2	0.09	0.14	NA	0.0	3
Lane 5		1.061	1.000	1.1	5.9	9.7	5.6	9.1	3.3	7.0	0.23	0.37	NA	0.0	4
Lane 6		1.061	1.000	1.1	5.9	9.7	5.6	9.1	3.3	7.0	0.45	0.74	NA	0.0	5
Approach		1.061			5.9	9.7	5.6	9.1	3.3	7.0	0.04	0.07			
West: Sturt Road															
Lane 1		0.651	1.000	0.0	9.2	15.0	8.1	13.2	3.7	7.8	0.51	0.84	NA	0.0	2
Lane 2		0.651	1.000	0.0	9.2	15.0	8.1	13.2	3.7	7.8	0.51	0.84	NA	0.0	3
Lane 3		1.005	1.000	4.0	24.4	39.7	19.0	31.0	11.7	24.4	0.22	0.35	0.0	NA	NA
Lane 4		1.005	1.000	4.0	24.4	39.7	19.0	31.0	11.7	24.4	0.22	0.35	0.0	NA	NA
Lane 5		0.892	1.000	0.1	3.2	5.2	3.0	4.9	1.6	3.3	0.12	0.20	NA	0.0	4
Lane 6		0.892	1.000	0.1	3.2	5.2	3.0	4.9	1.6	3.3	0.27	0.44	NA	0.0	5
Approach		1.005			24.4	39.7	19.0	31.0	11.7	24.4	0.22	0.35			
Intersection		1.061			58.7	95.8	31.6	51.6	21.6	45.1	0.54	0.88			

Queue Model: SIDRA Standard.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).

Continuous Lane Performance

Lane Number	Deg. Satn	Unint. Speed	Unint. Travel Delay	Hdwy	Spacing	Aver. Vehicle Length	Occup. Time	Space Time	Space Occup. Ratio	Time Occup. Ratio	Density		LOS (Density Method)
	v/c	km/h	sec	sec	m	m	sec	sec	%	%	veh/km	pc/km	
South: Marion Road													
This approach does not have any continuous lanes													
East: Sturt Road													

This approach does not have any continuous lanes
North: Marion Road
This approach does not have any continuous lanes
West: Sturt Road
This approach does not have any continuous lanes

Midblock Effective Detection Zone Length = 2 m

Pedestrian Queues

Mov ID	Description	Dem. Flow ped/h	AVERAGE BACK OF QUEUE [Ped ped	Dist] m
South: Marion Road				
P1	Full	200	0.8	0.8
East: Sturt Road				
P2	Full	200	0.8	0.8
North: Marion Road				
P3	Full	200	0.8	0.8
West: Sturt Road				
P4	Full	200	0.8	0.8
All Pedestrians		800	0.8	0.8

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