Analysis and Prevention of Road Crashes at Signalised Intersections in Adelaide Metropolitan Area

A thesis presented by

Wing Yin NG

Supervisor: Mr Branko Stazic

Co-supervisor: Dr Nicholas Holyoak

Keywords: Road Safety, Signalised Intersections, SIDRA Modelling, Mitigation Measures, Cost-Benefit Analysis

Submitted to Flinders University

for the partial fulfilment of the requirements of the degree of

Master of Engineering (Civil)

College of Science and Engineering,

Flinders University, South Australia

June 2022

DECLARATION

I certify that this thesis:

1. does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university
2. and the research within will not be submitted for any other future degree or diploma without the permission of Flinders University; and
3. to the best of my knowledge and belief, does not contain any material previously published or written by another person except where due reference is made in the text.

Signature of student...

Print name of student....Wing Yin Ng....................

Date.....3/6/2022..............................

I certify that I have read this thesis. In my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Engineering (Civil). Furthermore, I confirm that I have provided feedback on this thesis and the student has implemented it fully.

Signature of Principal Supervisor............ Starco ....

Print name of Principal Supervisor....Branko Stazic...

Date.......16/o6/2o22...

Acknowledgements

I could not have undertaken this journey without the assistance and input from numerous individuals.

I would like to express my deepest gratitude to my supervisor Mr Branko Stazic for his patience and enthusiasm. His immense knowledge and valuable experience have encouraged me all the time in my study. The door to Mr Stazic's office was always open when I had a question about my study. This study cannot be complete without his enormous assistance in software modelling.

I am extremely grateful to my co-supervisor, Dr Nicholas Holyoak, for his guidance and support in preparing the thesis presentation and report. His kind words motivated me when I was in a tough time.

I also want to thank my classmates, Weiqi, Eliana, Jinal, Saif, Matt and Long, who have always been helping with the group project and encouraging me. Special thanks to Leo Zou, who inspired me to undertake the thesis.

I am also thankful to my housemates and friends for the entertainment and support when I needed it the most. Thanks should go to Dr Sherlock Tai, who kindly shared his experience in writing his thesis.

Finally, I would be remiss in not mentioning my family for their unconditional love and emotional support throughout this journey.

Executive Summary

Fatalities and serious injuries are the least things road users want to see. South Australia failed to meet the road safety target of fatalities. Statistics showed that most fatal crashes occurred at intersections in the metropolitan area. Improving intersection safety should be the top priority.

The literature review showed that the current intersection ranking system adopted by the Department of Transport and Infrastructure (DIT) omits the accident cost and exposure, resulting in poor investment decisions. Various authors showed that incorporating cost and exposure improves the accuracy of identifying the worst-performing intersections, which justifies the need for this study. Further, the concept of accident cost and exposure were reviewed.

The road crashes at signalised intersections in metropolitan Adelaide were studied. Road crash data from 2018 to 2020 were analysed to construct a new intersection ranking system based on accident cost per 10 million vehicles. The top ten intersections in this list were modelled in SIDRA Intersection 9. Mitigating measures were introduced based on the crash types identified in the intersections. A simple cost-benefit analysis was performed to check if the intersection upgrade was beneficial and feasible.

Results showed that these measures could save over 10 million dollars and reduce almost 40 accidents per year. However, some measures increased the overall costs of the intersections. It was the limitation of SIDRA that not every mitigation measure could be reflected in the model. It was found that some fatal accidents were not avoidable with the applied mitigating measures. The study can be improved by extending each intersection into a case study. Then, a more detailed analysis can be done before suggesting mitigating measures that target fatal accidents.

The study's outcome would be beneficial for jurisdictions and road practitioners to establish a framework for identifying the worst-performing intersections and improving them with interventions. It could save millions of dollars and reduce the number of accidents. The money saved could have a better use to improve the people's life further.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

AAA	Australian Automobile Association
AADT	Annual Average Daily Traffic
ATC	Australian Transport Council
BITRE	Bureau of Infrastructure and Transport Research Economics
BTCE	Bureau of Transport and Communications Economics
DIT	Department of Infrastructure and Transport
DITRDC	Department of Infrastructure, Transport, Regional Development and Communications
DTEI	Department of Transport, Energy and Infrastructure
EC	Economics Connections
NRSS	National Road Safety Strategy
OECD	Organisation for Economic Co-operation and Development
RSAC	Road Safety Advisory Council
SCATS	Sydney Coordinated Adaptive Traffic System
WALGA	West Australia Local Government Association

1 Introduction

1.1 Background

Traditionally, we designed our road networks for maximum speed and capacity. Casualties were the price we had to pay. In 1997, Sweden wrote 'Vision Zero' into the law. 'Vision Zero' philosophy is, "No one should be killed and seriously injured for using the road network" (WALGA 2019b). Since then, 'Vision Zero' has been adopted in different countries. The Swedish introduced the Safe system approach to fulfil the vision of zero deaths and major injuries on the roads (WALGA 2019a).

In 2009, the Australian Government formally adopted the Safe System approach under the National Road Safety Strategy (NRSS) 2001-2010 (ATC 2011). The ultimate goal is zero deaths and major injuries on Australian roads in 2050. In NRSS 2011-2020, the target was to reduce fatalities and serious injuries on Australian roads by 30% (ATC 2011).

In response to NRSS, South Australian Government initiated the 'Towards Zero Together' campaign in 2011, aiming for at least a 30% reduction in severe casualties in South Australia – to less than 80 fatalities and less than 800 serious injuries per year by 2020 (Department of Transport 2011). In 2020, 93 lives were lost, and 715 people were seriously injured in 11534 crashes (DIT 2021a). Despite the decreasing trend, the result fell short of the target.

In South Australia, 44% of fatal crashes and 64% of crashes with serious injury occurred in Adelaide metropolitan area over the past ten years. 41% of the above crashes occurred at intersections (DIT 2021b). Therefore, it is important to identify the worst-performing intersections and apply preventive measures to reduce the number of crashes. In South Australia, the top intersections are ranked based on the number of accidents (DIT 2021a). However, ranking intersections with this indicator could undermine the impact of other factors, such as exposure to the intersection, the severity and the cost of accidents.

In 2015, the annual economic cost of crashes in Australia was estimated at $30 billion using the Willingness to Pay approach (EC 2017). There were more than 1,200 deaths and 30,000 serious injuries across Australia in the same year (EC 2017). In 2018, Australia ranked 14 of the 36 OECD countries in the fatality rate per 100,000 population (BITRE 2020).

In 2019, the Australian Government announced to deliver an extra $2.2 billion in road safety funding as keeping Australians safe is the task with the highest priority (Morrison, S (Prime Minister) et al. 2019). In the latest SA Road Safety Strategies survey, 44% of respondents agreed that the road safety approach and culture need to change over the next ten years in South Australia (DIT 2021b). Both the Government and the public desire to reduce road crashes and casualties in the future.

The above findings clearly show that additional crash data analysis of intersections in the Adelaide metropolitan area would be beneficial. Developing new and more comprehensive ranking lists would enable road safety investments to be applied to more appropriate locations than those currently targeted using a simple, total number of accidents approach.

1.2 Project Aims

In this research, the South Australia road crash data from 2018 to 2020 were visualised and analysed using ArcGIS and Excel. Intersection rankings will be created and compared based on the number of accidents with casualties, crash index, cost of accidents, and cost of accidents per exposure. The best ranking will be justified. The top 10 intersections from the best-ranking list were selected for SIDRA modelling.

A knowledge gap was identified after a thorough literature review on the topic. DIT's current intersection ranking system cannot identify the intersections with the highest cost of accidents per exposure. As a result, the safety of those intersections is yet to be improved. The following aims were established to guide the research towards a better outcome.

This research aims:

- To collate road crash data for all intersections in the Adelaide Metropolitan area and sort the data based on different accident types
- To develop a method to identify and rank the worst-performing intersections in SA metropolitan area based on accident severity, cost and intersection exposure measures.
- To propose accident prevention and mitigation measures to the selected intersections
- To use SIDRA and AIMSUN modelling to evaluate proposed change and to estimate potential benefits
- To investigate new innovative intersection designs and the feasibility of applying them to selected intersections.

The main focus of this research is on improving the safety of intersections. It can be achieved through delivering the stated aims and considering the results presented in the thesis. Due to time constraints, only accidents that occurred at signalised intersections were investigated in this research.

1.3 Report Structure

This research paper consists of six chapters divided into different sections and sub-sections.

Chapter 1 is the Introduction, which provides a basic overview of the project.

Chapter 2 is the Literature Review, which summarises the findings throughout the literature review and identifies the knowledge gap from the previous work. It covers the research background and concepts involved in this research, such as the current intersection ranking system, cost of accidents, and exposure. A case study of using SIDRA for intersection modelling is reviewed.

Chapter 3 is Methodology. It provides a detailed step-to-step procedure on how the road crash data are analysed, how intersection rankings are created and how the intersections are modelled in SIDRA INTERSECTION 9. In addition, an AIMSUN model was prepared for the presentation to demonstrate traffic movements in an intersection.

Chapter 4 is Results. It presents the intersection rankings and the results generated from the SIDRA model for ten selected intersections. Mitigation measures for each intersection will be suggested based on the major accident types in that intersection. A simple benefit-cost analysis will be included here.

Chapter 5 is Discussion. It provides a brief description of the generated results. The measures applied according to the crash type are discussed. In addition, a late-included study on the impact of COVID on traffic is described here. The limitations of the research are discussed.

Chapter 6 is the Conclusion. This chapter concludes the research and the practical application of the research results. Furthermore, future research directions are recommended based on the limitations realised during the research.

2 Literature Review

This chapter summarises the findings and identifies the knowledge gap that justifies this research's need. The concept of the Safe System Approach is reviewed. The impacts of road crashes are discussed. Then, Existing intersection rankings and proposed rankings from previous works are reviewed. Different approaches to determining the cost of accidents and accident exposures are compared. Further, the choice of traffic analytical software is discussed. Finally, the research gap is identified from the above findings.

2.1 Safe System Approach

The Safe System is the core idea of improving road safety. It has been adopted by all jurisdictions in Australia and worldwide to create better road safety outcomes. (WALGA 2019a) listed four major principles in the Safe System as below:

1. Humans are fallible – they make mistakes that can lead to crashes.
2. The human body has a limited physical ability to tolerate crash forces before harm occurs.
3. A shared responsibility exists among those who design, build, manage and use roads and vehicles and provide post-crash care to prevent crashes resulting in serious injury or death.
4. All system parts must be strengthened to multiply their effects, so road users are still protected if one part fails.

The Safe System approach was reviewed by various authors, including Austroads (2016), Kimber (2003), Larsson and Tingvall (2013), Mooren, Grzebieta and Job (2011), Green et al. (2021), Candappa et al. (2015), and Job, Truong and Sakashita (2022).

Larsson and Tingvall (2013) explained that the Safe System is built based on human capability, implying human beings cannot always cope with the complex changes on the road, which leads to errors. Mooren, Grzebieta and Job (2011) studied the implementation of the Safe System in three jurisdictions in Australia. The study found that Victoria and New South Wales made improvements to infrastructure but lacked community support. West Australia gained community support but lacked investment in infrastructure. It concluded that a good implementation requires the support of the community and stakeholders. Financial support to refit the existing network is vital.

Kimber (2003) compared the traditional and Safe System approaches toward road safety. The traditional approach emphasises the driver's contribution to the road crash. On the other hand, the Safe System considers drivers part of the system. Road crashes are caused by roads and vehicle systems that allow driver errors to cause serious injury and fatality. Stigson, Krafft and Tingvall (2008) backed Kimber's idea by analysing the fatal crashes in Sweden in 2004. The author found that the road system caused 32.6% of fatal crashes individually. The driver factor contributed about 18.7% of fatal crashes individually. More fatal crashes were caused by combinations of factors. He concluded that the road and the roadside significantly impacted the severity outcome. Austroads (2016) commented on the perspectives of the traditional and the Safe System approach toward design requirements and addressing crash severities. The traditional approach often treated the Benefit-Cost Ratio (BCR) as the major design requirement. Total crashes on the site were used to identify problematic sites. Meanwhile, the Safe System approach focused on reducing serious injury and fatality in both aspects.

Green et al. (2021) reviewed the Safe System's impact on the road safety policy in Victoria. The authors found that it provided a framework to address road safety issues. However, further explanations of the Safe System concepts are required for the Safe System to be successfully incorporated into public policy. Job, Truong and Sakashita (2022) pointed out the system's two weaknesses that the definition of 'shared responsibility' was not clear. Another weakness was the measures of Safe Systems missed the fundamental principles. A typical example was that improved signage could not reduce the crash severity when the driver committed the mistake. The author suggested revising the Safe System by including definitions of shared responsibility and practical implications.

Candappa et al. (2015) based the alternative intersection designs on Safe System principles, including the impact of speed and angle on the overall kinetic energy of the crash. Most traditional intersections failed to meet the Safe System Principles. One of the reasons was that the 90° collision between two vehicles travelling at 50km/h or above generates the transferable kinetic energy above the biomechanical threshold, which harms the road users. The authors suggested using raised intersections to lower speed limits and new roundabouts (Cut-Through) that minimise impact angle.

2.2 Social Cost of Road Crashes

Evaluating the social cost of accidents helps stakeholders in policy development. Also, it is important in benefit-cost analysis for road safety projects. The 'Willingness-to-pay' and 'human capital' approaches are alternative ways to estimate the cost of fatalities and injuries in road crashes. The former estimates the possible lifetime earnings of the foregone (Austroads 2015). The latter estimates the maximum price a person is willing to pay to avoid death, which is done by surveying the community (Austroads 2015). The Australian Transport Assessment and Planning Guidelines provide the values of crashes calculated using both methods as in Table 2.1 (DITRDC 2021). Note that the cost of fatal crashes calculated by the WTP approach is three times that of the human capital approach.

Table 2.1 Cost of fatalities and injuries in road crashes

	Modified Human Capital Value ($ in 2013)	Willingness to Pay Value ($ in 2013)
Fatal Injuries	2,463,432	7,573,412
Serious Injuries	629,484	526,606
Minor Injuries	22,992	100,431
Property Damage Only $9257 ($ in 2013)		

Risbey, Cregan and De Silva (2010) explained the cost estimation methodology adopted by BITRE and the social cost components of road crashes. BITRE adopted a modified human capital approach. It included a notional amount for 'quality of life', losses due to the death and suffering endured by the family and relatives of the deceased.

There are three components of road crash costs: human, vehicle, and other costs. Figure 2.1 shows the breakdown of the social cost of road crashes (BITRE 2010). Note that the human cost takes up 60% of the total cost in a modified capital approach.

Image removed due to copyright restriction

Figure 2.1 Social cost of road crashes by component, 2006

(Austroads 2015) reported an in-depth analysis of the direct cost of road crashes, including ambulance transfer, in-hospital treatment, rehabilitation and property damage. They are included as part of the human capital approach.

Australian Automobile Association evaluated the cost of road crashes in a modified willingness-to-pay approach (EC2017). The values were based on the fatality and casualties in 2015. The cost of a fatality was $4.39 million in 2015 values. There is no right or wrong to using either approach. The Office of Best Practice Regulation (OBPR) (2020) released a guidance note on the value of statistical life, restating that

"Willingness to pay is the appropriate way to estimate the value of statistical life". They estimated the value of statistical life as $5.0 million in 2020 value. Yet, the abovementioned willingness to pay approach from various researchers estimated different values of a statistical life.

2.3 Current Intersection Rankings

DIT currently rank the intersection with the highest number of Casualty Crashes (DIT 2021a). It is still transitioning from the traditional approach to the Safe System Approach, which suggests focusing on crashes with serious injuries and fatalities. Other jurisdictions in Australia do not publish any intersection rankings. Bureau of Transport and Communications Economics (1995) reported the 'Crash Index Method', adopted in Canada and some states in the United States. (Note: EMD stands for equivalent material damage.)

Image removed due to copyright restriction

Figure 2.2 Crash Index Method Calculation

(Ogden 1994) reported using the 'Crash Index' method in Australia in the early 1980s, as shown in Table 2.2. Jurisdictions applied different but arbitrary weightings to crashes, which helped identify more severe sites. However, it could lead to varying results, such as identifying a site with low risk.

Table 2.2 Australian Road Crash Severity Weightings in the early 1980s

Image removed due to copyright restriction

Hobday et al. (2017) and Afghari, Haque and Washington (2020) introduced alternative methods to identify risky sites. Hobday et al. (2017) selected the intersections in a matrix of crash rate and crash density, followed by a comparative study on crash rates. Then, it ranked the worst performing intersections by the KSI metric (Kill and Serious Injury). This equation adds the number of KSI crashes and the product of the number of medical crashes and the KSI/casualty crashes ratio. Afghari, Haque and

Washington (2020) used a joint econometric model of crash severity and crash count to identify high-risk road segments. The result showed improved accuracy in identifying high-risk sites compared to the individual crash count model. Hobday's approach is straightforward, and it does not require a lot of mathematical operations. On the contrary, Afghari's approach requires a lot of experience in econometric modelling. An easier approach would be more suitable for this study.

Austroads (2016) established the assessment framework that assesses the road segment or intersection by determining the exposure, likelihood and severity scores of different crash types, ranging from 0-to 4. There are seven categories, the score of each category is the product of the scores of the exposure, likelihood and severity. It is good to evaluate the safety intersection by crash types as it provides insights for road practitioners to focus on appropriate countermeasures. However, this assessment indicates the risk but does not correspond directly to a crash rate or frequency. As the South Australian Government provides comprehensive road crash data to the public, it is easy to determine the cost of accidents, a more objective approach.

2.4 Accident Exposure

Exposure is closely related to the accident rate. The accident rate is defined as the following equation:

$$\text{Accident Rate} = \frac{\text{The average number of accidents in a specified time}}{\text{Amount of exposure in a specified time}}$$

Equation 1 Accident Rate Equation

Exposure is the denominator. Hauer (1995) criticised the misuse of accident rates to prove some interventions improved road safety. As exposure may change after the intervention, lowered accident rates can be caused by either the interventions or the change in exposure. The author doubted using the 'number of entering traffic vehicles' in intersection accident rate calculation. Instead, intersection accidents could be a function of some power of the conflicting flows, supported by empirical evidence.

Ogden (1994) and Austroads (2010) suggested using total entering traffic for intersection crash rate. In addition, Ogden (1994) also suggested the following equation to determine the exposure at a 4-leg intersection.

$$\text{Exposure} = 2\sqrt{\frac{\text{V1} + \text{V3}}{2} \times \frac{\text{V2} + \text{V4}}{2}}$$

Equation 2 Exposure Equation

Where V1, V2, V3 and V4 are the entering flows.

Hughes (cited in Ogden et al. 1994) studied three typical measures of exposure, including total entering traffic, the product of average traffic on intersection roads, and the square root of the previous product. The author made a detailed comparison and concluded that there were no great differences among the measures. But the total entering traffic was suggested as it was the simplest measure.

Wundersitz and Hutchinson (2008) reviewed the exposures related to road safety and how the South Australian Government collected exposure data. The author suggested using annual average daily traffic (AADT) for metropolitan traffic volume. Looped detectors are installed at the legs of signalised intersections to count the traffic, and the data are used to calculate the AADT for strategic modelling purposes.

2.5 Micro-analytical software – SIDRA

SIDRA Intersection is a microanalytical traffic evaluation tool used to aid in designing and evaluating individual intersections and networks of intersections. DIT suggested using SIDRA for individual intersection analysis (DIT 2021c). The City of Nedlands in West Australia used SIDRA to analyse options to upgrade the West Coast Highway/North Street/Servetus Street intersection for better capacity (Selby 2013). Then, the Benefit-cost ratio was determined to check whether the upgrade met the State requirement. It is particularly useful in this study to estimate the intersection operation cost for direct comparison.

2.6 Research Gap

The Safe System Approach provides the framework for intersection designs and upgrades. Measures applied to the intersection should adhere to the principles. Otherwise, they cannot reduce the risk and the severity of road crashes. Since OBPR suggested the willingness-to-pay approach as the appropriate way to estimate the value of statistical life, the AAA values are adopted in this study. They were the median values among the approaches.

Currently, DIT ranks the intersection by the highest number of casualty crashes. The literature review shows that accident exposure and the cost of accidents should be included in identifying the worst-performing intersections. As the road crash data is analysed yearly, it is fair to use the traffic volume data for the whole year as the exposure. In this study, SIDRA was used to model the selected intersections. The operation cost of the intersection before and after intervention could be compared.

3 Methodology

This chapter outlines the methodologies adopted in this research. It includes the data collection process, the road crash data analysis, the creation of an intersection ranking list in an Excel spreadsheet, and the detailed procedure of modelling intersections using SIDRA INTERSECTION 9.

In addition, in the result seminar, the AIMSUN model demonstrated the difference between a protected right turn and a filtered right turn. A brief description of the creation of the AIMSUN model is included.

3.1 Data Collection

This research involves collecting road crash data, traffic volume, intersection geometry and traffic signal operations. This section presents the steps of collecting the above data and a detailed description of the above data.

3.1.1 Road Crash Data

The first step is to collect road crash data. They are available on the DATA SA website for free. In this research, data from 2018 to 2020 were investigated. Figure 3.1 shows that road crash data has a 3-file data structure. There are three separate spreadsheets in the road crash data: ' Crash Type', 'Unit', and 'Casualty'. They are linked with 'REPORT_ID', a unique number for each accident. 'Crash Type' records all the traffic accidents reported to SA Police. It gives an overview of the accident, such as date, time, location, weather, number of units involved, the severity of the crash and crash type. 'Unit' provides details of the units involved in the accidents, including vehicles and objects at the accident location. Details of the drivers and passengers in the vehicles are also included. 'Casualty' provides information about the casualties in the accidents. The metadata of the road crash data provides a brief description of each field and the coordinate system used in the dataset.

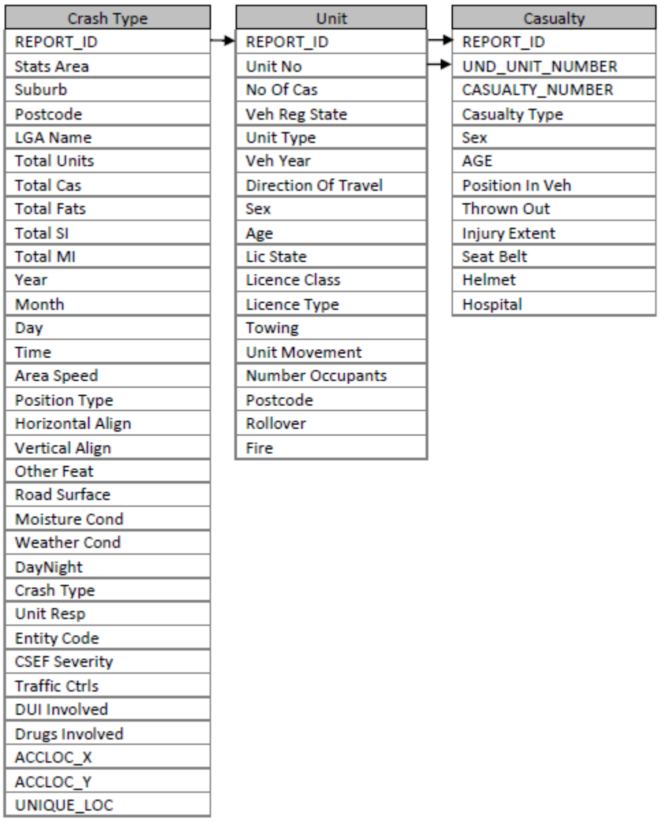


Figure 3.1 Data Structure of Road Crash Data

The focus of this research is the crash type. The related fields in the 'Crash Type' spreadsheet are described below.

Table 3.1 Description of fields

Field Name	Meaning
Stats Area	It defines whether the road crash occurred within City, metropolitan or country area.
Total Units	Number of vehicles and objects involved in a road crash
Total Cas	Number of casualties (fatalities and treated injuries) as a result of a road crash
Total Fats	Number of fatalities as a result of a road crash
Total SI	Number of injured people admitted to hospital with overnight stays
Total MI	Number of injured people not admitted to hospital
Position Type	It identifies whether the location of the crash location was an intersection or mid-block
Crash Type	It defines the type of road crash
Traffic Ctrls	It defines the type of traffic controls at the road crash location. e.g., Signals, Roundabouts, Give-way or Stop.
ACCLOC_X	x-coordinate of a road crash.
ACCLOC_Y	y-coordinate of a road crash.
UNIQUE_LOC	The combined number of X and Y coordinates used as a unique identifier for road crash locations.

Since the road crash data contain X and Y coordinates, it can be imported to ArcGIS software, which combines database and software tools to analyse and visualise geographic data. The unique location was effectively used in Excel to sort the road crash data and create intersection lists.

3.1.2 Traffic Volumes

Traffic volume is the key component in determining the exposure of the intersection. There were three sources of traffic volume data used in this research.

3.1.2.1 Flinders SCATS Database

Flinders University held a SCATS database which contains the vehicle survey (VS) data of the signalised intersections in metropolitan Adelaide from 2013 to 2017. The figure below is the SCATS database's user interface as a map of metropolitan Adelaide.

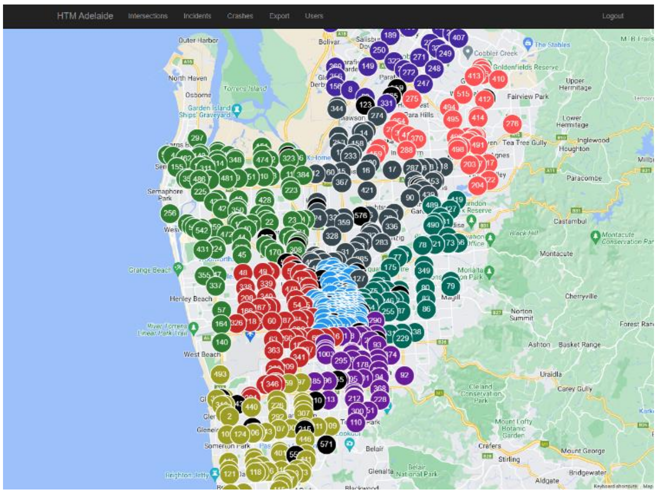


Figure 3.2 Flinders SCATS Database User Interface

The number in the circle indicates the SCATS ID of the signalised intersection. SCATS ID is a unique identifier for signalised intersections that helps to combine intersection data from different years. It is discussed in a later section. The colour of the circle indicates the region of the intersection. The 'Export' feature of the database allows users to extract the traffic data of the intersection of interest by inputting the date range. Figure 3.3 shows an extract of the traffic count data.

	A	B	C	D	E	F	G	H	I	J	K
1	datetime	site_no	0	1	2	3	4	5	6	7	8
24191	2017-03-05T23:45:00	73		2	2	0	1	7	0	1	8
24192	2017-03-05T23:50:00	73		5	4	0	2	2	1	2	5
24193	2017-03-05T23:55:00	73		3	0	0	1	1	1	0	2
24194	2017-03-06T00:00:00	73		2	4	0	4	3	1	0	3
24195	2017-03-06T00:05:00	73		2	4	0	5	2	0	0	8
24196	2017-03-06T00:10:00	73		1	3	1	3	1	3	1	5
24197	2017-03-06T00:15:00	73		0	0	0	4	2	2	1	4
24198	2017-03-06T00:20:00	73		1	4	0	2	4	0	2	6
24199	2017-03-06T00:25:00	73		2	3	0	2	4	0	1	0
24200	2017-03-06T00:30:00	73		0	3	1	6	4	1	0	4
24201	2017-03-06T00:35:00	73		1	2	1	1	3	1	1	6

Figure 3.3 SCATS VS Data

It is read in conjunction with the SCATS diagram, as shown below.

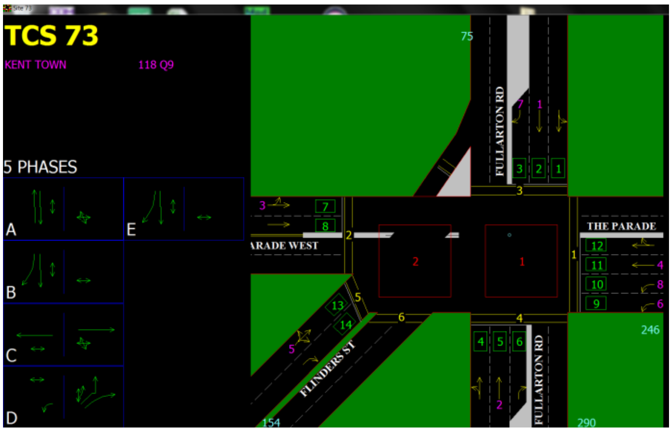


Figure 3.4 SCATS diagram

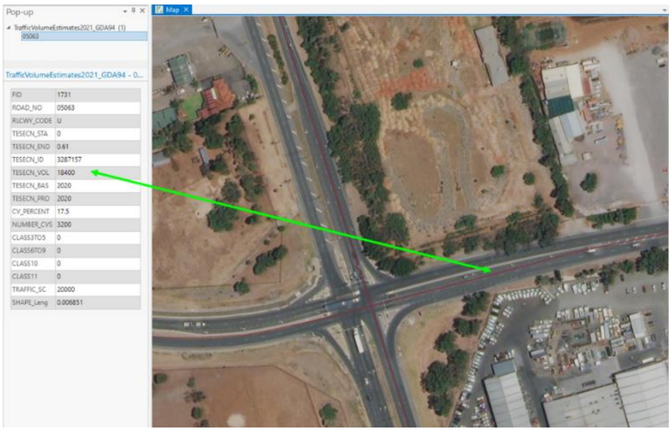


Figure 3.5 Screenshot of ArcGIS (Traffic Volume Estimates)

Figure 3.4 shows the schematic diagram of the intersection. The number in the green boxes indicates the detector number. It refers back to the first row of the VS data. The first column of VS data is the time and date of the traffic count. The numbers under the detector number are the traffic count of the detector every five minutes. For instance, annual traffic volume is the sum of the traffic counts under the corresponding detector numbers of a year of data.

3.1.2.2 Traffic Volume Estimates

This research required the annual traffic volume from 2018 to 2020. Flinders SCATS database was not updated. As a result, Traffic Volume Estimates were used to approximate the traffic volumes from 2018 to 2020. DIT prepares traffic volume estimates annually. They are available on the DATA SA website and can be visualised in ArcGIS and Location SA Map Viewer. The latter is an online data mapping tool managed by the Government of South Australia that visualises the geographic data. ArcGIS was used in the research because it is easier to process data from multiple years and combine it with other datasets.

From Figure 3.5, the daily two-way traffic volume (under the field 'TESECN_VOL') of the east approach of the intersection is 18400. The daily entering traffic was estimated as half of the sum of the daily two-way traffic volume of all legs of the intersection. The last sum times 365 becomes the annual traffic volume of the intersection. The drawback of using the traffic volume estimates is that not all the legs of the intersections have their traffic estimated. Some minor roads were omitted from the data.

3.1.2.3 SCATS Traffic Reporter

New SCAT VS data (updated to 15/3/2022) were obtained later in the research. However, due to resource constraints, they cannot be processed and uploaded to the Flinders SCATS Database. Instead, the VS data was extracted using a specific program, namely 'SCATS Traffic Reporter (Version 6.3.10)'. Figure 3.6 shows the window that prompts the user to select the sites and configure the display options. The software can display the traffic counts using different timing intervals. However, it is not important in this research. It was set to the largest interval (1 hour). The numbers in the sites are the SCATS ID. The intersection of interest was selected. The detector numbers were selected based on the SCATS diagram (Figure 3.4). For instance, there were 14 detectors on the site (no. 1 to no. 14). The results are shown in Figure 3.7. The daily total was the daily traffic entering the intersection.

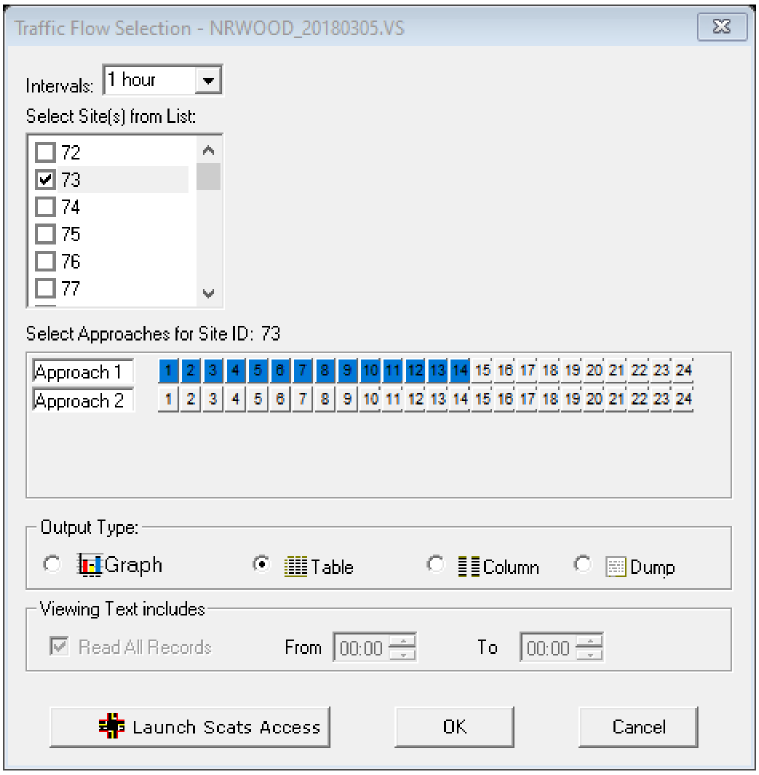


Figure 3.6 Data Selection Options from SCATS Traffic Reporter

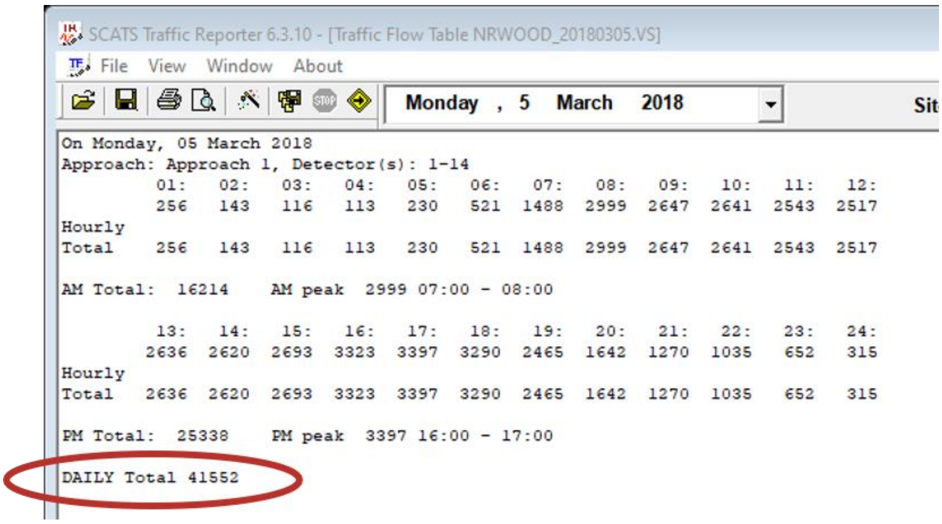


Figure 3.7 Daily Traffic Total from SCATS Traffic Reporter

Theoretically, the accurate annual traffic volume can be determined by extracting VS data for every single day of a year. However, the main drawback of this method was that we could only read one VS data at a time. The VS data were recorded each day according to the region of the intersections. Since our research involved intersection data from multiple regions and years, it would take a long time to gather all the data.

Instead, the traffic data for the first week of March were selected each year. The sum of the daily totals was the weekly entering traffic. The annual traffic volume was estimated using the following formula.

$$\text{2020 Volume} = \text{2017 Volume} \times \frac{\text{1st week of March 2020 Volume}}{\text{1st week of March 2017 Volume}}$$

Equation 3 2020 Volume Estimation

3.1.3 Intersection Geometry

This research involved base modelling of ten intersections. First, the top-view image of the intersection was obtained from Google Earth. It has a feature to retrieve satellite images from previous years. The measuring tool is another feature of Google Earth that helps measure the intersection's dimension. It provides detail such as the number of lanes, lane width, lane length, presence of slip lanes, and medians. Intersection drawings were obtained from DIT via formal email request. The drawing provides precise dimensions of the intersections and the possible phases of the traffic signals.

3.1.4 Other Modelling Parameters

Besides the intersection drawing, other modelling parameters can be obtained from the SCATS Operation Summary, Phasing Summary and Vehicle Turning Movement Survey. These documents were obtained from DIT via formal email request.

SCATS Operation Summary describes how the traffic signals operate in an intersection at different peak times, including phasing operation, turning movement operation, phase percentages, inter-green time and cycle time. These parameters were input to the SIDRA and AIMSUN base models.

Phase is defined as the green, yellow and red time assigned to a set of traffic movements. Phase Sequence is the configuration of phases in a cycle which is usually based on the intersection geometry and the traffic condition. Cycle time is the time required to run a phase sequence.

Phasing Summary is a daily record of the percentage of each phase run in each cycle. For example, by extracting the data of an AM peak hour, the average percentage of each phase run in the peak hour could be determined. The AM peak cycle time was obtained from the SCATS Operation Summary. The average time of the phases can be determined and input into the SIDRA model.

Vehicle Turning Movement Survey is a manual traffic count record of an intersection on a particular day. Every 15 minutes, surveyors count the number of vehicles entering and leaving the particular approach to determine the number of vehicles in each movement (left turn, through or right turn). They categorise the vehicle types to determine the percentage of commercial or heavy vehicles. This count is very useful, especially when the detector is not installed in slip lanes. It acts as a complement to VS data. The drawback of doing a vehicle turning movement survey is that it is very expensive because it requires extensive human resources counting vehicles on site for 24 hours. Because of that, DIT did not do it regularly, and the survey result is not up to date.

In this research, however, traffic volumes of each movement were determined from VS data because the vehicle turning movement survey data were obtained very late in the project. The details of the input parameters will be explained later section.

3.2 Road Crash Data Analysis

3.2.1 Import to ArcGIS

Road crash data were imported to ArcGIS using the 'XY Point Data' function. Figure 3.8 shows an options window that prompts the user to enter the detail of the dataset. '2020_DATA_SA_Crash.csv' was the 2020 road crash data file. The fields 'ACCLOC_X' and 'ACCLOC_Y' were selected as the X Field and Y Field, respectively. They represent the XY coordinates of the dataset. According to the metadata, the coordinate system used in the road crash data is 'X and Y Lambert Coordinate Projection (GDA94)'. This coordinate system was included in the GIS software.

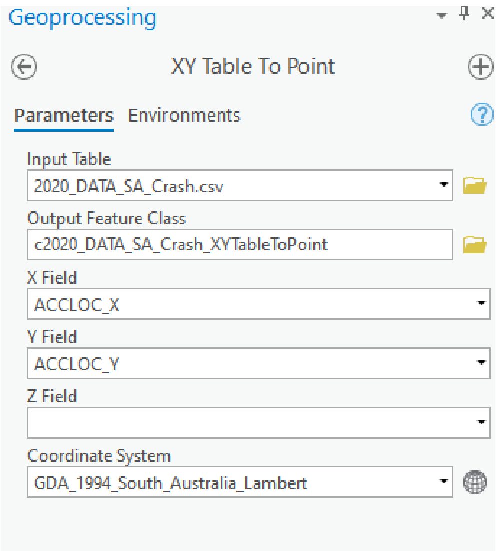


Figure 3.8 Import Data to ArcGIS

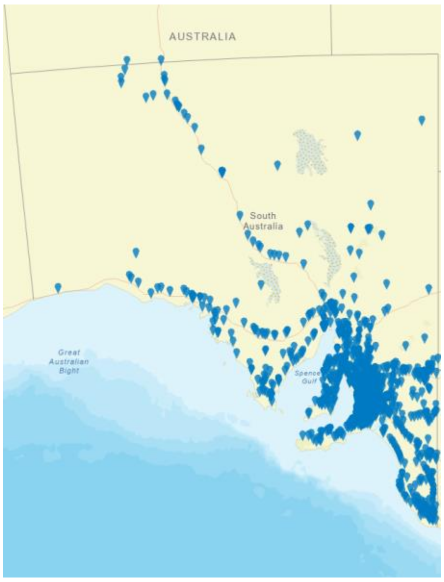


Figure 3.9 South Australia Map in ArcGIS

As shown in Figure 3.9, road crash data points were scattered across the South Australia Map, a built-in base map provided by Flinders University; they showed the location of road crashes in 2020. Since our research focused on the signalised intersections in metropolitan Adelaide, the unwanted data points were removed using the ‘Query’ function.

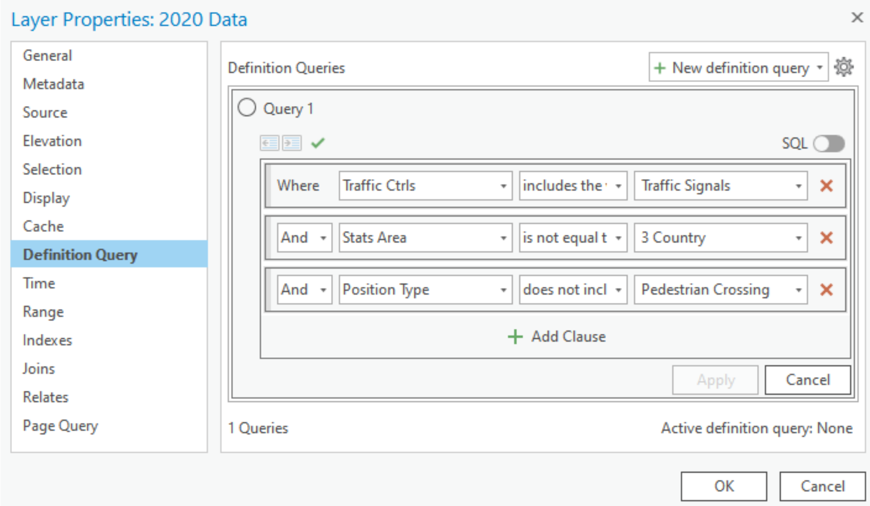


Figure 3.10 Query function in ArcGIS

Figure 3.10 shows the criteria to filter the query results. The traffic control was selected to include traffic signals only. This criterion removed data points at roundabouts and intersections with give-way and stop controls. Next, the statistical area was selected not to include the country. This clause removed the data points outside the metropolitan area. Then, data points at the pedestrian crossing were excluded. This criterion excluded the accidents involving pedestrian crossing, which were out of the scope, such that the remaining data points were the accidents that occurred at signalised intersections only. 1871 road crashes were selected from over 11500 road crashes in 2020.

Figure 3.11 Fitered Result

Figure 3.12 Filtered Result around CBD (Zoomed in)

Figures 3.11 and 3.12 show the result after the query. The data points were shown in every signalised intersection. Note that there were multiple data points in a single intersection. The number of accidents and the UNIQUE_LOC were displayed in a pop-up window by clicking on the data points. In addition, the SCATS ID and intersection name were also recorded. The naming of the intersection is the name of the roads in alphabetical order.

Figure 3.13 presents the entry in the intersection list. The map was examined from South to North and left to right to avoid overlooking data points. In addition, the map was zoomed in and out in case there were overlapping data points. More than 500 sites were identified in the data from each year.

SCAT ID	Intersection Name	No. of Accidents	UNIQUE_LOC	
68	Greenhill Rd, Unley Rd	6	13290571668982	13290571668964

Figure 3.13 Road crash data by intersections

A copy of the road crash data file was created. A list of shortlisted accidents, the same as the filtered results in ArcGIS, was duplicated in a new spreadsheet, namely 'Shortlist'. The intersection list was also included in this file. Creating intersection lists and rankings in the road crash data file makes referring to the original road crash data easier.

3.2.2 Create Intersection Rankings

Five different intersection rankings were developed in this research. The following sub-sections describe the step of creating every intersection ranking.

3.2.2.1 Number of Accidents

The intersection list prepared in the previous section was the intersection ranking based on the number of accidents. Using the sorting feature in Excel, the top intersections with the highest number of accidents were identified. Alternatively, the COUNTIF function aims to count the number of cells in a specific range that meets the criterion input by the user. The counting formula was the following:

COUNTIF(Shortlist!$AG$2:$AG$1872,J2)

'J2' was the cell containing the UNIQUE_LOC, and column AG in the 'Shortlist' was the column of UNIQUE_LOC. COUNTIF function counts the occurrence of UNIQUE_LOC in the 'Shortlist'. It was applied to all UNIQUE_LOCs of an intersection. The total was the number of accidents.

3.2.2.2 Number of Accidents with Casualties

An accident with casualties is defined as an accident with at least one person injured.

COUNTIFS function aims to count the number of cells in a specific range that meets multiple criteria input by the user. The counting formula was the following:

COUNTIFS(Shortlist!$AG$2:$AG$1872,J2,Shortlist!$G$2:$G$1872,">0")

Column G in the 'Shortlist' was the number of total casualties. COUNIFS function counts the occurrence of UNIQUE_LOC in the 'Shortlist', where the number of total casualties of that accident was greater than zero. It was applied to all UNIQUE_LOCs of an intersection. The total was the number of accidents with casualties.

The results were put in the column next to the number of accidents for easy comparison. The top intersections with the number of accidents with casualties were sorted.

3.2.2.3 Crash Index

Before creating the intersection rankings, the 'Shortlist' was expanded by adding the 'Crash index' column. The crash index assigned to the crash severity was based on the crash index method adopted in the BTCE report.

Table 3.2 Crash Index of various Road Crash Severities

Crash Severity	Fatalities	Serious Injuries	Minor Injuries	Property Damage Only
Fatalities	9.5	9.5	3.5	1

The formula of the crash index was the following.

IF(AA2 = "1: PDO", 1, IF(AA2= "2: MI", 3.5, 9.5))

Note: "1: PDO" and "2: MI" were the severity of the road crash, recorded in column AA. If the accident is property damage only, the crash index is 1. If the accident has minor injuries, the crash index becomes 3.5. The remaining accidents have a crash index of 9.5.

SUMIF function aims to add up the numbers in the cell in a specific range that meets the criterion input by the user. The formula was the following.

SUMIF(Shortlist!$AG$2:$AG$1872,J2,Shortlist!$AI$2:$AI$1872)

Column AI in 'Shortlist' was the 'Crash Index' column.

SUMIF function added the crash indexes under UNIQUE_LOC in the 'Shortlist'. By applying the SUMIF function to all UNIQUE_LOCs of an intersection, the sum of the formula results was the total crash index.

3.2.2.4 Cost of Accidents

The 'Cost of accidents' column was added to the 'Shortlist'. The cost of injuries was based on the values in 2015 times the ratio of the Consumer Price Index rate on the ATO website (ATO 2022). The cost of the property-damage-only accident was obtained from the Australian Transport Assessment and Planning Guidelines.

Table 3.3 Cost of Injuries per person

	2015 ECON Report Values ($ mil)	2020 Estimates ($ mil)
46	4.339	4.691
Hospitalised Injury	0.239	0.258
Non-hospitalised Injury	0.012	0.013
	2013 Estimates ($)	2020 Estimates ($)
PDO	9257	10352

Table 3.4 CPI Year-ending rates (extract)

Year	CPI Year-ending rates
2013	104.8
2015	108.4
2018	114.1
2019	116.2
2020	117.2

For instance, the cost of each accident in 2020 was calculated by the estimated value from Table 3.3 times the number of people/units in the corresponding category. The assumption was that all the units involved in the accident were vehicles. SUMIF function was used to add up the cost of accidents at the same UNIQUE_LOC under the 'Shortlist'. By applying the SUMIF function to all UNIQUE_LOC of an intersection, the sum of the formula results was the total cost of accidents.

3.2.2.5 Merging Intersection Ranking List

SCATS ID is the universal column to merge three years of data into a new spreadsheet. As the intersections were slightly different in different years, it was necessary to synchronise the intersection list. The SCATS IDs of each year were added to the same column, and the duplicates were removed using the Excel feature 'Remove Duplicates'. This complete SCATS ID list was used to compare each year's intersection list. Any missing SCATS IDs were added back to the list, and all the ranking values of that SCATS ID were set to zero as there were no accidents reported. Then, each year shared the same SCATS ID list. After that, the SCATS IDs were sorted in ascending order and copied to the new spreadsheet. The final rankings were based on the total sum of the three years.

3.2.2.6 Cost of Accidents per 10 million vehicles

Due to time constraints, only the top 50 intersections with the highest cost of accidents were ranked for this ranking. Their traffic volumes were determined as described in Section 3.1.2. The cost of accidents per 10 million vehicles was calculated by

$$\text{Cost per 10 million vehicles} = \frac{\text{Cost of Accidents}}{\text{Annual Traffic Volume}} \times 10000000$$

Equation 4 Accident cost per 10 million vehicles

The final ranking was based on the average cost of accidents per 10 million vehicles across three years (2018-2020). The top 10 intersections in this list were chosen for SIDRA Modelling.

3.3 SIDRA Modelling

SIDRA Intersection is a microanalytical traffic evaluation tool used to aid in designing and evaluating individual intersections and networks of intersections. This section outlines the steps to model the Fullarton Road-The Parade intersection (TS073) to evaluate annual operation costs. Other intersections were modelled in the same way. The modelling steps followed the DIT Traffic Modelling Guidelines.

3.3.1 Intersection Geometry

Figure 3.14 shows the Fullarton Road-The Parade intersection site layout. It was based on the intersection drawing.

Figure 3.15 shows the intersection parameters dialogue box. The names of the intersection and the approaches were added for recognition. The approaches were established by assigning the 'Leg Geometry'.The length of the approaches was measured in Google Earth. The extra bunching was added based on the length of the approaches.

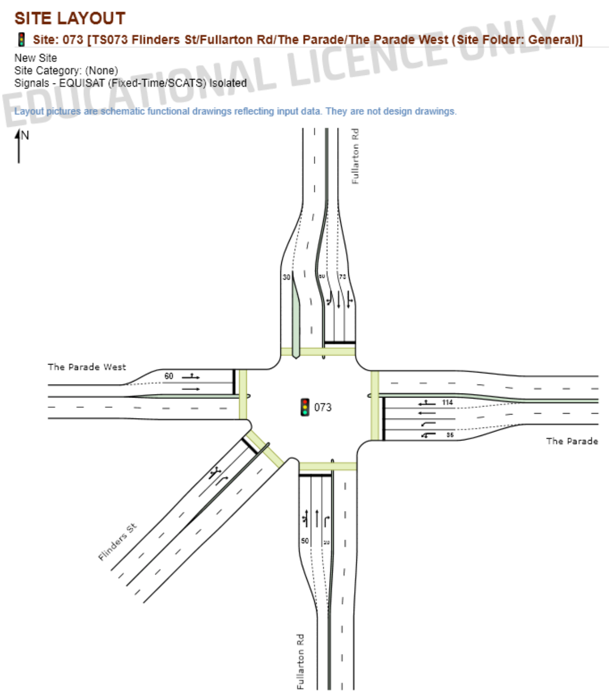


Figure 3.14 Fullarton Road-The Parade Intersection Site Layout

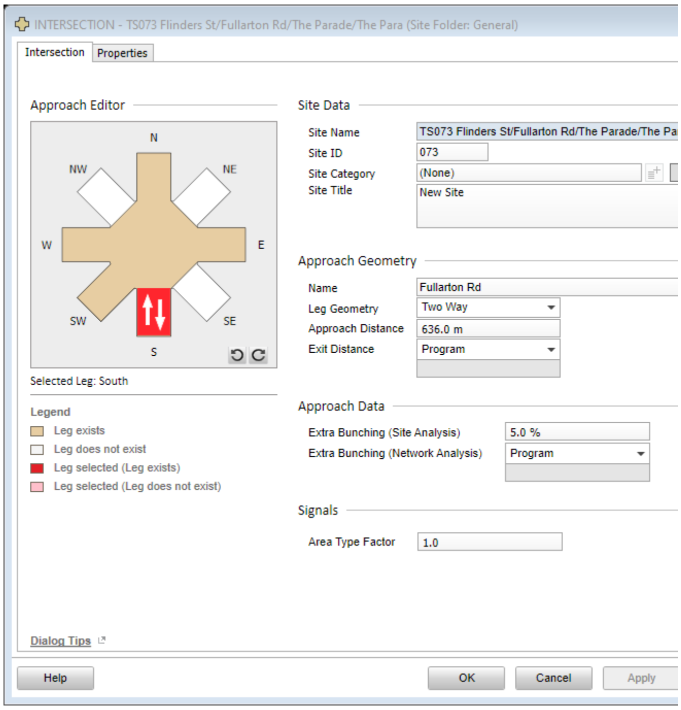


Figure 3.15 Intersection Parameters Dialogue Box

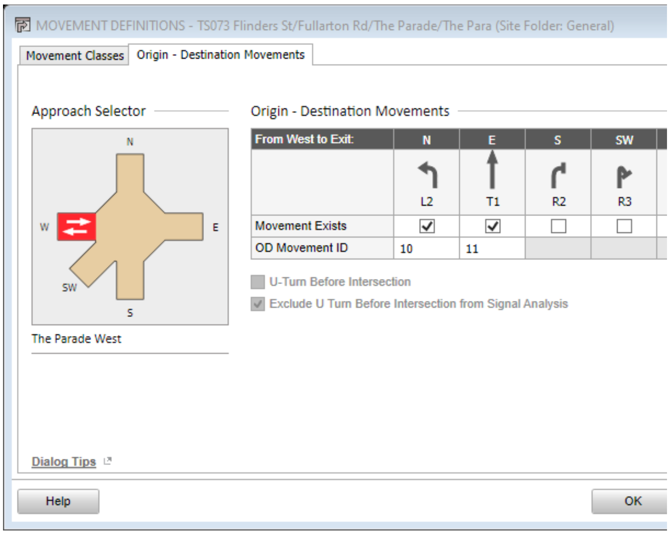


Figure 3.16 Movement Definitions Dialogue Box

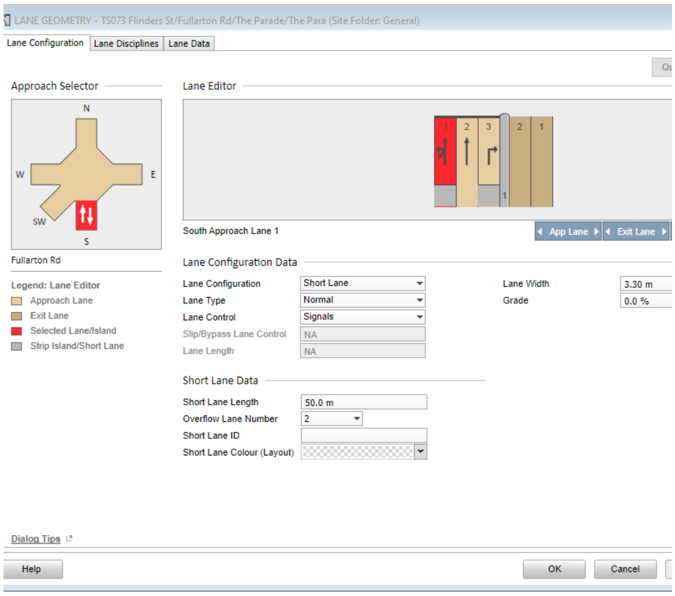


Figure 3.17 Lane Geometry Dialogue Box

Figure 3.16 shows the Movement Definition Dialogue Box. The specific traffic movements of the approaches were defined here. For instance, the intersection drawing showed that no right turn was allowed on the west approach. Therefore the right turn 'R2' movement was unchecked.

As shown in Figure 3.17, lane features were defined in the Lane Geometry dialogue box. They include the number of lanes, grade, lane length, lane width, lane configuration (short/full), lane type (normal/slip lane) and lane control (signal, give-way, stop or continuous). The grade and the lane length were measured in Google Earth, and the remaining parameters were obtained in the intersection drawing.

3.3.2 Traffic Volumes

The volume of the AM Peak hour (8-9 am) on a Wednesday was extracted from the VS data as described in Section 3.1.2.3. As some lanes allowed multiple movements (e.g. left turns and through), the numbers of vehicles for each movement were assigned based on the engineering judgement.

South				East				North				West		South-West		
Left 1	Left 2	Through	Right	Left 1	Left 2	Through	Right	Left	Through	Right 1	Right 2	Left	Through	Left	Through	Right
5	5	580	67	195	195	344	10	100	602	145	50	10	135	5	50	150

Figure 3.18 Traffic volume count of the intersection

Figure 3.18 shows the total number of vehicles of every movement in the intersection. The percentage of heavy vehicles of each approach was included in the traffic volume estimates data as 'Cv Percent'. The total vehicle and heavy vehicle percentage were input in the Volumes Dialogue Box.

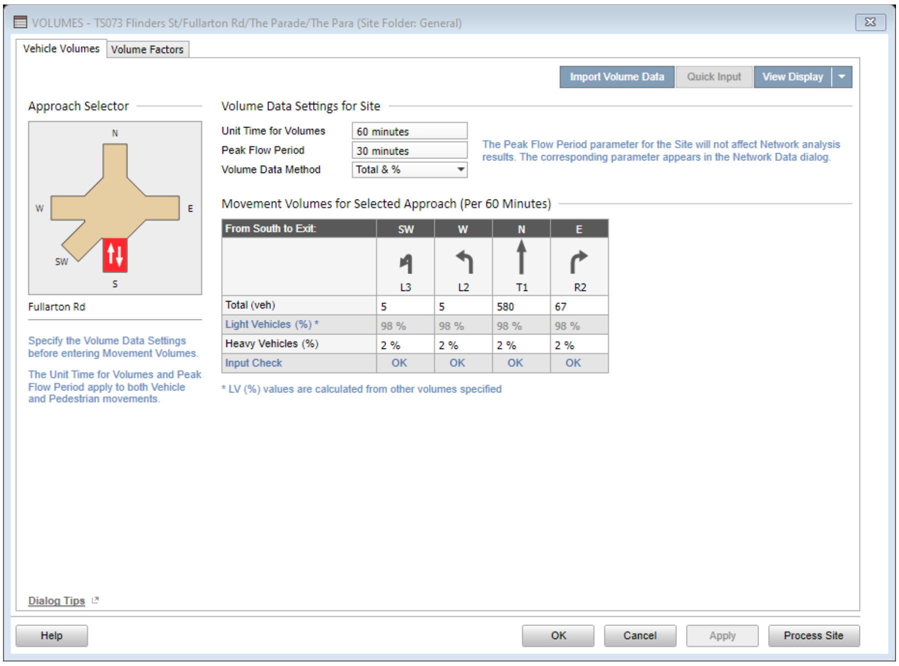
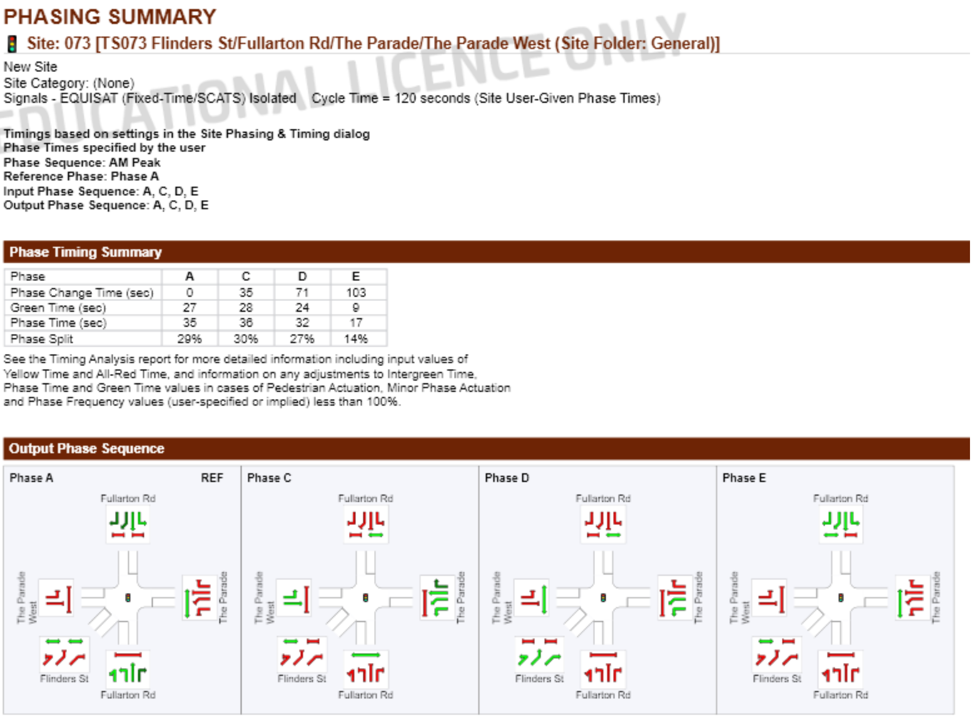


Figure 3.19 Volumes Dialogue Box

3.3.3 Phasing and Timing

Based on the SCATS Operation Summary and the intersection drawing, the phasing and timing of the intersection were input in the Phasing & Timing Dialogue Box. Figure 3.20 shows the phasing summary of the intersection, including the specific movements in each phase and the green, the inter-green time.


PHASING SUMMARY

Site: 073 [TS073 Flinders St/Fullarton Rd/The Parade/The Parade West (Site Folder: General)]

New Site
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated Cycle Time = 120 seconds (Site User-Given Phase Times)

Timings based on settings in the Site Phasing & Timing dialog
Phase Times specified by the user
Phase Sequence: AM Peak
Reference Phase: Phase A
Input Phase Sequence: A, C, D, E
Output Phase Sequence: A, C, D, E

Phase Timing Summary

Phase	A	C	D	E
Phase Change Time (sec)	0	35	71	103
Green Time (sec)	27	28	24	9
Phase Time (sec)	35	36	32	17
Phase Split	29%	30%	27%	14%

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 3.20 Phasing Summary

3.3.4 Other parameters

Other parameters such as pedestrians and gap acceptance remained default values as no data were obtained. The lane priority was set as the default setting where the right turn must give way to the opposite through and left-turn movements. After that, the model was processed, and the intersection summary was created.

3.3.5 Alternative Scenarios

The alternative scenario included the mitigation strategies proposed for the intersection. It was based on the frequent crash types that occurred in the intersection. Figure 3.21 shows the list of scenarios created in this intersection.

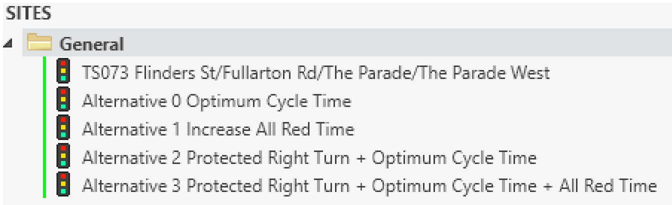


Figure 3.21 Scenario list created in SIDRA Intersection for different mitigation measures

3.3.6 Intersection Summary

The focus of the research was intersection safety. However, it cannot be reflected directly in the model. Instead, the annual operation cost of the intersection could be compared.

3.4 AIMSUN Modelling

AIMSUN Next is a modelling software that simulates mobility in networks of all sizes at macro, meso and microscopic levels. Due to time constraints, only the model of Fullarton Road-The Parade intersection was created. The model was used in the result seminar to show the difference between a protected right turn and a filtering right turn. Figure 3.25 shows the screenshot of the model.

Figure 3.22 AIMSUN Model

4 Results

The chapter presents the intersection rankings generated from the road crash data analysis and the summary of the benefit-cost analysis of the ten selected intersections. The case study of Fullarton Road-The Parade Intersection is presented here to demonstrate the steps to estimate the benefit of the mitigation measures. The results of other intersections are presented in the Appendix.

4.1 Intersection ranking based on the Number of Accidents

The intersections were ranked based on the total accidents between 2018 and 2020. Two intersections at Grand Junction Road ranked top two, with over 60 accidents across three years.

Table 4.1 Intersection Ranking based on the Number of Accidents

SCATS ID	Intersection Name	Year 2018	Year 2019	Year 2020	Total
15	Grand Junction Rd, Main North Rd, Port Wakefield Rd	25	22	18	65
16	Briens Rd, Grand Junction Rd, Hampstead Rd	14	22	25	61
77	Lower Portrush Rd, Payneham Rd, Portrush Rd	14	24	15	53
25	Main North Rd, Regency Rd	16	19	16	51
113	Marion Rd, Sturt Rd	20	15	12	47
55	Henley Beach Rd, Marion Rd	18	12	15	45
108	Daws Rd, South Rd	11	17	15	43
92	Cross Rd, Glen Osmond Rd, Portrush Rd, S Eastern Hwy	11	16	15	42
100	Cross Rd, Marion Rd	12	15	11	38
277	Main North Rd, Montague Rd	10	18	10	38

4.2 Intersection ranking based on the Number of Accidents with Casualties

DIT used this ranking in their publication Statistical Summary of Road Crashes & Casualties in 2020. It was compared with the ranking prepared in this research. Note that the table includes intersections with five or more casualty crashes. The differences between the two tables are highlighted in yellow.

Table 4.2 DIT Intersection Ranking

Table 25: Top Intersections with highest number of Casualty Crashes 2020

	Current Year	Previous Years			
Intersection	2020	2019	2018	2017	2016
STEBONHEATH - STH OF CURTIS ROAD - WOMMA ROAD	12	5	6	11	7
PEACHEY ROAD - CURTIS ROAD	10	6	5	8	5
HAMPSTEAD ROAD - GRAND JUNCTION ROAD	9	3	7	6	5
GLYNBURN ROAD - MONTACUTE - ATHELSTONE ROAD	7	6	2	6	7
STURT ROAD - MARION ROAD	7	9	11	8	6
MAIN NORTH ROAD - MONTAGUE ROAD	6	9	3	1	6
ST BERNARD'S ROAD - MONTACUTE - ATHELSTONE ROAD	6	0	0	3	2
ADAM STREET - PORT ROAD	5	3	3	0	4
ANZAC HIGHWAY - GRAY STREET	5	2	1	0	2
FULLARTON ROAD - DEQUETTEVILLE TERRACE	5	6	11	7	8
GOODWOOD ROAD - GREENHILL ROAD	5	2	4	1	3
PROSPECT ROAD - FITZROY TERRACE	5	4	6	4	4
SIR DONALD BRADMAN DRIVE - SOUTH RD / MAIN SOUTH ROAD	5	1	1	1	5
SOUTH RD / MAIN SOUTH ROAD - RICHMOND ROAD	5	2	6	4	4
SUDHOLZ ROAD - NORTH EAST ROAD	5	5	1	2	4
WATERLOO CNR INTERCHANGE CONNECT - PT WAKEFIELD ROAD	5	2	4	3	4
WEST LAKES BOULEVARD - SUNRISE COURT	5	1	2	1	1
WILLIAMSTOWN - BIRDWOOD - LUCKY HIT ROAD	5	0	1	1	0

Table 4.3 Top Intersections with the highest number of accidents with casualties in 2020

SCATS ID	Intersection Name	Year 2020
432	Curtis Rd, Peachey Rd	9
16	Briens Rd, Grand Junction Rd, Hampstead Rd	9
113	Marion Rd, Sturt Rd	7
78	Glynburn Rd, Lower North East Rd, Montacute Rd, Payneham Rd	7
277	Main North Rd, Montague Rd	6
173	Montacute Rd, Newton Rd, St Bernards Rd	6
130	Fitzroy Ter, Prospect Rd	5
64	Richmond Rd, South Rd	5
37	Adam St, Park Ter, Port Rd	5
53	Port Wakefield Rd, Waterloo Corner Rd	5
67	Goodwood Rd, Greenhill Rd	5
206	North East Rd, Sudholz Rd	5
518	Commercial Rd, Main St, Tiller Dr	5
209	Anzac Hwy, Beckman St, Gray St	5
257	Turner Dr, West Lakes Blvd	5
61	Sir Donald Bradman Dr, South Rd	5

DIT included roundabouts and un-signalised intersections across South Australia in the table. For instance, Stebonheath Road – Womma Road and Fullarton Road – Dequetteville Terrace are roundabouts, and Birdwood – Lucky Hit Road is an un-signalised intersection in the country area. On the other hand, the number is different at Curtis Road – Peachey Road intersection between two tables. Commercial Road – Main Street intersection is missing in the DIT table. Data entry mistakes may cause these differences. The same comparison was made for 2018 and 2019 data with the rankings prepared in this research. They were the same except for the inclusion of roundabouts and un-signalised intersections.

In this research, the intersections were ranked based on the total accidents with casualties between 2018 and 2020. The top two intersections in Table 4.3 drop to rank 3 and 10, respectively. Marion Road – Sturt Road intersection takes the first place.

Table 4.4 Intersection Ranking based on the Number of Accidents with Casualties

SCATS ID	Intersection Name	Year 2018	Year 2019	Year 2020	Total
113	Marion Rd, Sturt Rd	11	9	7	27
432	Curtis Rd, Peachey Rd	5	6	9	20
16	Briens Rd, Grand Junction Rd, Hampstead Rd	7	3	9	19
277	Main North Rd, Montague Rd	3	9	6	18
25	Main North Rd, Regency Rd	7	6	4	17
55	Henley Beach Rd, Marion Rd	6	5	4	15
78	Glynburn Rd, Lower North East Rd, Montacute Rd, Payneham Rd	2	6	7	15
100	Cross Rd, Marion Rd	6	7	2	15
130	Fitzroy Ter, Prospect Rd	6	4	5	15
15	Grand Junction Rd, Main North Rd, Port Wakefield Rd	8	2	4	14

4.3 Intersection ranking based on Crash Index

This ranking was compiled using the same approach. The intersections were ranked based on the total crash index across three years. Marion Road – Sturt Road intersection remains in the first place. The two Grand Junction Road intersections rank 2 and 3.

Table 4.5 Intersection Ranking based on Crash Index

SCATS ID	Intersection Name	2018	2019	2020	Total
113	Marion Rd, Sturt Rd	53.5	49.5	35.5	138.5
16	Briens Rd, Grand Junction Rd, Hampstead Rd	31.5	29.5	53.5	114.5
15	Grand Junction Rd, Main North Rd, Port Wakefield Rd	45	33	34	112
25	Main North Rd, Regency Rd	33.5	34	32	99.5
277	Main North Rd, Montague Rd	23.5	46.5	25	95
432	Curtis Rd, Peachey Rd	21.5	34	37.5	93
77	Lower Portrush Rd, Payneham Rd, Portrush Rd	19	39	31	89
55	Henley Beach Rd, Marion Rd	33	24.5	31	88.5
100	Cross Rd, Marion Rd	33	32.5	16	81.5
108	Daws Rd, South Rd	18.5	35.5	20	74

4.4 Intersection ranking based on Cost of Accidents

Intersections were ranked based on the total cost of accidents across three years. All top 10 intersections in previous rankings were replaced. Cross Road – Fullarton Road intersection became rank 1.

Table 4.6 Intersection ranking based on the cost of accidents

SCATS ID	Intersection Name	2018 ($ mil)	2019 ($ mil)	2020 ($ mil)	Total ($ mil)
94	Cross Rd, Fullarton Rd	0.109	0.053	9.829	9.991
53	Port Wakefield Rd, Waterloo Corner Rd	0.547	0.226	5.495	6.268
116	Diagonal Rd, Finniss St, Sturt Rd	0.471	0.186	4.95	5.607
10	Grand Junction Rd, Hanson Rd	0.333	4.999	0.08	5.412
325	Grand Junction Rd, Nelson Ave	0.195	4.99	0.175	5.36
252	Main North Rd, Saints Rd, The Grove Way	0.252	4.88	0.173	5.305
315	Francis St, Perkins Dr	0.206	4.774	0.099	5.079
73	Flinders St, Fullarton Rd, The Parade, The Parade W	0.123	0.09	4.814	5.027
449	Brodie Rd North, Sherriffs Rd, Southern Expy	0.043	4.757	0.113	4.913
3166	George St, Port Rd	4.706	0.05	0.05	4.806
236	Fife St, Findon Rd, Trimmer Pde	4.607	0	0.166	4.773

4.5 Intersection ranking based on the Cost of Accidents per 10 million vehicles

The top 50 intersections with the highest cost of accidents were ranked based on the cost of accidents per 10 million vehicles. The annual traffic volume of these intersections from 2018 to 2020 was determined as described in the methodology. The top 10 intersections were similar to the table of the cost of accidents, but the rankings were changed.

Table 4.7 Intersection ranking based on the cost of accidents per 10 million vehicles

SCATS ID	Intersection Name	2018 ($ mil)	2019 ($ mil)	2020 ($ mil)	Average ($ mil)
325	Grand Junction Rd, Nelson Rd	0.259	6.488	0.218	2.322
53	Port Wakefield Rd, Waterloo Corner Rd	0.272	0.190	6.116	2.193
94	Cross Rd, Fullarton Rd	0.060	0.029	5.418	1.836
449	Brodie Rd North, Sherriffs Rd, Southern Expy	0.042	4.425	0.110	1.526
236	Fife St, Findon Rd, Trimmer Pde	3.850	0.000	0.144	1.331
73	Flinders St, Fullarton Rd, The Parade, The Parade W	0.084	0.063	3.421	1.190
315	Francis St, Perkins Dr	0.136	3.350	0.071	1.186
10	Grand Junction Rd, Hanson Rd	0.215	3.195	0.052	1.154
116	Diagonal Rd, Finniss St, Sturt Rd	0.274	0.110	2.861	1.081

* The traffic volume data are presented in the Appendix.

4.6 Intersections Summary

Figure 4.1 shows the location of the selected intersections.

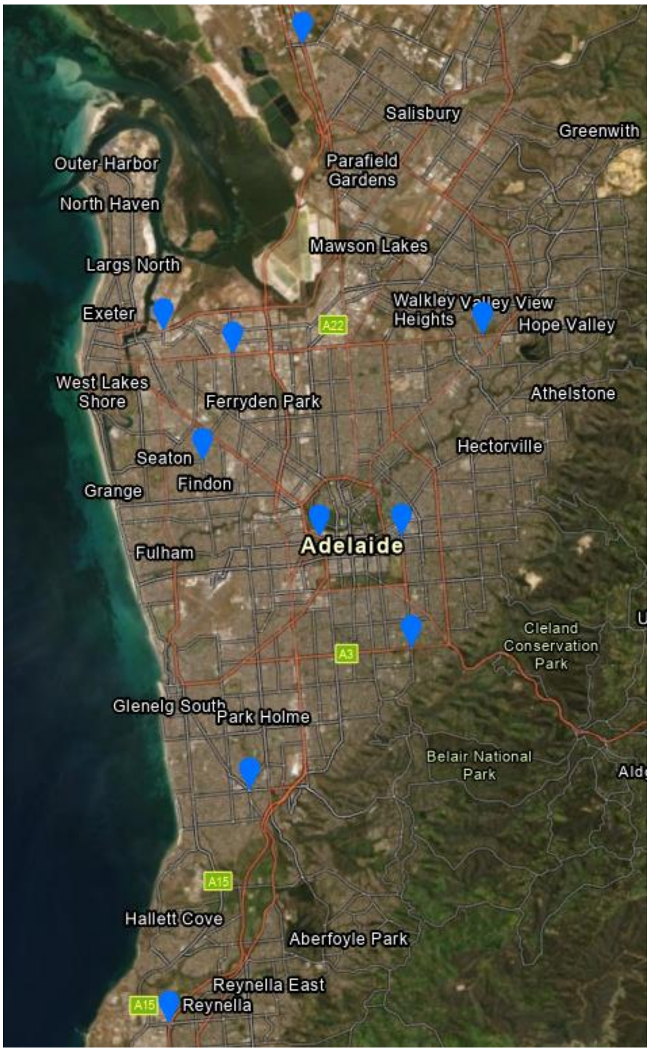


Figure 4.1 Selected intersections' location

Table 4.8 summarises the results from the SIDRA models after applying the mitigation measures. Mitigation measures were selected to tackle the major crash types in that intersection. It implies that not all fatal crashes could be avoided after applying the mitigation measures. The expected benefit was calculated by comparing operational and accident costs before and after applying mitigation measures. Expected reduced accidents are estimated based on the accidents occurring between 2018 and 2020, assuming target types of accidents could be fully avoided. Further comments on the results are included in the Discussion.

Table 4.8 Intersection Summary

SCATS ID	Major crash types	Number of Accidents (2018-2020)	Expected benefit(Loss) per year	Expected reduced accidents per year
10	Right Turn, Right Angle	32	$55,837	7
53	Rear End, Right Turn	28	$1,827,218	7
73	Rear End, Right Angle	14	$153,838	4
94	Rear End, Right Turn	11	$12,417,470	3
116	Rear End, Right Turn	27	$1,603,039	7
236	Rear End, Right Turn	8	$1,433,498	1
315	Rear End, Side Swipe	16	($24,857)	3
325	Right Turn, Rear End	14	$100,805	3
449	Right Turn, Right Angle	10	($8,222)	2
3166	Side Swipe, Right Turn	10	($63,130)	2

4.7 Case Studies Result – Fullarton Road – The Parade intersection

Fullarton Road – The Parade intersection had 14 crashes from 2018 to 2020. The major crash types were Right-turn and Right Angle accidents. Assumptions are that right turn accidents can be treated by removing filtered right turn, and the right-angle accidents can be avoided by increasing the red time.

The mitigation measures of this intersection include the abovementioned measures and optimising the cycle time. The annual operation costs and the accident costs before and after applying mitigation measures were compared. The benefit of the measures was $153,838 per year.

Table 4.9 Accident Occurrence by Crash Type

Crash Type	Occurrence
Total	14
Right Turn	7
Right Angle	4
Rear End	2
Side Swipe	1

Table 4.10 Expected Benefit per year

	Intersection Operation Cost	Accident Cost	Total Cost
Before	$1,875,517	$1,675,667	$3,551,184
After	$1,811,679	$1,585,667	$3,397,346
Total Benefit	$63,838	$90,000	$153,838

The same approach was applied to the other nine modelled intersections. The results are presented in the Appendix.

5 Discussion

This chapter comments on the intersection rankings and interprets the results. The choice of mitigation measures for each crash type is justified. As more familiar with the project, more limitations and opportunities to expand are identified and presented here. In addition, the impact of COVID on the road crash is discussed based on a late-included finding.

5.1 Comments on the Intersection Rankings

Five intersection rankings were compiled in this study. The rankings of modelled intersections in each list are shown in Table 5.1.

Table 5.1 Rankings of modelled intersections in various ranking lists

SCATS ID	Intersection Name	No. of Accidents	No. of Accidents with Casualties	Crash Index	Cost of Accident	Cost of Accident per 10 million Vehicles
325	Grand Junction Rd, Nelson Rd	147	61	96	5	1
53	Port Wakefield Rd, Waterloo Corner Rd	26	24	12	2	2
94	Cross Rd, Fullarton Rd	200	88	134	1	3
449	Brodie Rd North, Sherriffs Rd, Southern Expy	228	205	189	9	4
236	Fife St, Findon Rd, Trimmer Pde	280	342	261	11	5
73	Flinders St, Fullarton Rd, The Parade, The Parade W	147	261	174	8	6
315	Francis St, Perkins Dr	122	124	115	7	7
10	Grand Junction Rd, Hanson Rd	13	61	33	4	8
116	Diagonal Rd, Finniss St, Sturt Rd	32	32	22	3	9
3166	George St, Port Rd	228	342	226	10	10

*There were 570 intersections in each ranking list.

The 'Number of Accidents' list focuses on the occurrences of crashes. The list highlights the intersections that are prone to crashes. However, the crash severity is ignored. It implies that intersections with fewer crashes and more casualties are often overlooked. As shown in Table 5.1, most of the intersections ranked after 100.

The 'Number of Accidents with Casualties' list, which DIT is currently using in the annual report, focuses on the occurrences of casualty crashes. Although it highlights the intersections with more casualty crashes, the crash severity is still ignored. A minor injury and a fatality both count as one. This ranking fails to highlight the intersections with more fatalities. As shown in Table 5.1, no modelled intersections ranked top of the list. If DIT applies this ranking to prioritise the investments, intersection with higher casualties will not be treated in time.

The ‘Crash Index’ ranking emphasises the crash severity. The crash with more severe injuries (or fatalities) scores higher. However, it only counts the most severe casualty in the crash. For instance, crashes with any number of fatalities score the same. It fails to differentiate the crashes under the same category. Also, the crash index weighting is subjective. The literature review shows that different countries and jurisdictions have adopted their weighting for specific purposes, and it is not easy to justify which weighting is the best fit. For instance, in this study, a fatal accident weighs 9.5, and a property-damage-only accident weighs 1. It implies that an individual’s life is worth the repair fee for the properties damaged in 9.5 accidents, which is unreasonable. Intersections with more PDO accidents outweigh the intersections with just one or two fatalities. As a result, no modelled intersections made to the top of the ‘Crash Index’ list

The ‘Cost of Accidents’ list also emphasises the crash severity in monetary value. It is more objective compared to the ‘Crash Index’ ranking. The individual life’s value is evaluated based on the Willingness-to-pay approach, which is an approach supported by OBPR. It includes the human, vehicle, and other costs associated with the accident. However, there are no standards for evaluating the value of a statistical life. Different organisations could suggest their values for various crashes that may change the intersections’ rankings. Using the Australian Automobile Association’s method, nine out of ten modelled intersections topped the ‘Cost of Accidents’ ranking list.

The ‘Cost of Accidents per 10 million vehicles’ ranking list considers both cost and exposure. While the cost is a good representation of the crash severities, exposure shows how likely drivers are involved in these crashes. For example, two intersections have the same cost of accidents. The one with lower traffic volume is considered more dangerous as drivers in that intersection have a higher chance of being involved in the crashes. The study aims to improve intersection safety and ultimately save driver’s life. Therefore, the importance of drivers in intersection safety justifies the adoption of this ranking list to identify the worst performing intersections.

5.2 Comments on Selected Intersections

The result shows that not every mitigation measure applied to the intersection could save money. The following subsections describe the findings of the selected intersections.

Grand Junction Road, Nelson Road (325)

The major crash type is the right-turn accident. By removing the filtering right-turn and optimising cycle time, the benefit becomes $100,000 per year. The fatal accident in this intersection was a ‘Hit fixed object’ accident. More research is required to find out the actual cause of the accident and apply a suitable mitigation measure.

Port Wakefield Road, Waterloo Corner Road (53)

It was a T-junction before turning into a 4-leg intersection as part of the Northern Connector Project in 2020 (DIT 2022). The fatal accident occurred in March 2020. It was a right-angle accident, flagged as 'Drugs Involved' in the road crash data. The speed limit of Port Wakefield Road is 90 km/h, which causes a lot of rear-end accidents as drivers have less time to react when the front vehicle stops suddenly. Reducing the approaching speed of Port Wakefield Road, removing filtering right-turn, and increasing red time could save $1.8 million per year.

Cross Road, Fullarton Road (94)

DIT announced the $61 million upgrade to this intersection (DIT 2019). The alternative scenario was built based on the concept plan. The increase in yellow and red time and removing the filtering right-turn and the upgrade could save $12 million per year.

Diagonal Road, Sturt Road (116)

The major crash types were 'rear-end' and 'right-turn' accidents. The fatal accident was a right-angle accident, and it was also flagged as 'Drugs Involved' in the road crash data. Increasing red time and removing filtering right-turns could reduce the accidents above and save $1.6 million per year.

Brodie Road, Sherriffs Road, Southern Expressway Ramp (449)

The fatal accident in this intersection was identified as a 'Hit Fixed Object'. The news report for this accident reported a collision between a motorcycle and a truck (Mirage News 2019). Further research is required to examine the cause of the accident and suggest corresponding mitigation measures. Introducing measures would increase the operation cost of the intersection. In this case, it cannot cover the cost reduced due to reducing accidents. It is considered infeasible.

Fife Street, Findon Road, Trimmer Parade (236)

The fatal accident was a right-turn accident. Theoretically, it can be avoided by removing filtering right-turn.

Flinders St, Fullarton Road, The Parade (73)

As mentioned in the Results section, the applied mitigated measures aim to treat the two major crash types of the intersection. The fatal accident in this 5-leg intersection was a rear-end accident, and the abovementioned mitigating measures did not treat it.

Francis St, Perkins Dr (315)

This intersection locates in an industrial area. The percentage of commercial vehicles is higher than in other selected intersections. The two major crash types are 'rear-end' and 'side-swipe'. The fatal accident was a side-swipe accident, which occurred during merging lanes. The damage could be reduced by widening and extending the short lanes. It was not included in the mitigation measures applied in the model. More research is required on the cost of widening and extending lanes. In this study, the treatment of rear-end accidents costs more than the benefit of reducing accidents. It is considered infeasible.

Grand Junction Rd, Hanson Rd (10)

This T-Junction had more right-turn and rear-end accidents than other crash types. Removing filtering right turns and optimising cycle time help treat these accidents and save $55,837 per year.

George St, Port Rd (3166)

This T-junction connects the major road to the access to Royal Adelaide Hospital. Despite no filtering right-turn in the phase sequence, the fatal accident occurred when a private car collided with a right-turning ambulance that carried a Priority 3 (urgent but not life-threatening) patient (ABC News 2018). The patient sadly passed away the next day. It can only be safer for the ambulance to drive on a driveway above ground to deliver the patient to the hospital. The mitigation measures applied in this intersection increase the operating cost, which the benefit of reducing accidents cannot cover.

5.3 Comments on Mitigation Measures

The following table lists the major crash types and their corresponding mitigation measures.

Table 5.2 Mitigation measures of various crash types

Accident Type	Mitigation measures
Side-swipe	Increase lane width / Add median
Right-turn	Run protected right turn / Ban movement / Add inter-green time
Rear-end	Reduce speed limit, Increase Yellow Time
Right angle	Increase red time
Head-on	Increase median width / Add signs and markings
Bicycles	Increase bicycle lane width / Add median
Pedestrians	Delay red arrow drop / Two-stage crossing
Hitting Objects	Relocate objects

Side-swipe

Side-swipe accidents may occur when drivers swerve to the next lane to avoid obstacles, overtake vehicles, or merge lanes. Increasing lane widths can tolerate more mistakes from the above maneuvers and reduce the crash severity. Adding median is an alternative option when side-swipe accidents involve vehicles in the opposite lane.

Right-turn

Right-turn accidents may occur when drivers perform a right turn while misjudging the gap between opposing vehicles. Running a protected right turn can avoid opposing movement. Banning the right-turn movement is an alternative option. However, it just passes the risk to the other intersections. Adding inter-green time is a specific option for a leading right-turn phase sequence. A leading right turn means a filtering right turn follows a protected right turn in the phase sequence. Drivers are forced to stop by deliberately adding a few seconds of red time between two phases. This measure allows drivers more time to refocus and observe the opposite traffic before doing a filtering right turn.

Rear-end

Rear-end accidents may occur when drivers misjudge the intention of the front driver. It happens at the intersection where drivers are in the dilemma zone (Zhang, Fu & Hu 2014). Some drivers think they could pass the intersection, while others tend to stop when they see the yellow light. When the front car suddenly stops in front of the stop line, rear-end accident often occurs as the ensuing driver fails to apply the brake in time. The crash severity can be reduced by reducing the speed limit, as drivers have more time to react if the speed is lowered. Increasing yellow time allows the vehicles to pass through the intersection while the light is still yellow, reducing the chance of sudden stopping.

Another idea is to introduce Variable Message Signs (VMS) in the dilemma zone to tell the drivers to stop when the light is turning red soon. Drivers who see the sign turned on should stop. Drivers who drive past the sign can safely enter the intersection before the red lights. Further study is needed to analyse the cost and the feasibility of this measure.

Right-angle

Right angle accidents may occur when a vehicle collides with the vehicle in the intersection that comes from the adjacent movement. Increasing red time allows more time for the clearance of the intersection, thus reducing the chance of collision.

Head-On

Head-on accidents usually occur in mid-blocks where vehicles collide with the opposite traffic. It can be avoided by introducing a median between the opposing traffic lanes. In the case of ramps, some drivers carelessly drive in the lane of the opposite direction. Signs are installed to warn the driver to go back.

Bicycles

Bicycle accidents usually occur at intersections with a bicycle lane. It can be reduced by increasing the width of the bicycle lane or adding a median between the bicycle lane and normal lanes. It gives more room for cyclists to react and brake their bikes.

Pedestrians

Pedestrians are more vulnerable than other road users. Two-stage crossings can be installed at large intersections, allowing pedestrians to safely stay in the middle island and wait for the next green. Alternatively, applying 'delay red arrow drop' on the left turn lanes would also reduce the chance of hitting pedestrians. 'Delay red arrow drop' means the left turn vehicles give way to pedestrians for seconds before the red arrow drops (allow left-turn movement). This measure forces drivers to wait for the pedestrians to cross. Both measures can be applied in SIDRA models. As pedestrian volume was out of the scope of the study, they remained unchanged.

Hitting Objects

This accident type may have different causes. It needs to be studied case by case to apply the appropriate mitigating measures. Relocating the object is one of the methods. However, it cannot be reflected in SIDRA models.

Theoretically, the abovementioned mitigation measures can reduce the particular type of accidents. However, in this study, the measures are applied without considering other factors, such as intersection linkage and capacity. Further studies are required to see if the mitigating measures can be applied to the particular intersection.

5.4 Comments on Estimation of benefit

The benefit estimation used in this study is very simple. Only the first year return was assessed. The approach was adopted because most mitigation measures changed the phase sequences and timing. A more detailed benefit-cost analysis should be adopted whenever the initial investment is large (e.g. the $61-million Fullarton Road – Cross Road intersection upgrade). The benefit should aim for a longer period, i.e. ten years or more.

Furthermore, the operational cost in SIDRA Intersection relates to the emission and the traffic delay. The time 'wasted' in the intersection was evaluated using the average hourly salary of a person. The hourly rate, fuel cost and emission cost were SIDRA default values for 2020. Research is required to obtain a more accurate value for the current year.

5.5 COVID Impact on Traffic Volume and Accidents

COVID has changed our ways of living, including driving habits. Figure 5.1 shows the casualties and crashes numbers in recent years. It was shown that there was a rise in the number of accidents in 2019. It dropped in 2020 but remained higher than pre-COVID time in 2018.

Year	Fatalities	Fatal crashes	Serious injuries	Serious injury crashes
2022*	19	19	178	164
2021**	99	94	865	760
2020	93	85	715	624
2019	114	110	833	729
2018	80	75	576	485
2017	100	93	622	533
2016	86	77	692	574

* Year to date - report date as of midnight 31 March 2022 (SAPOL data)
** Preliminary Figures

Figure 5.1 Casualties and Crashes numbers in recent years

The AADT and the number of accidents in the West Adelaide region (selected intersections) were investigated. Pillips Street-Port Road intersection (in West Adelaide) was singled out for comparison. 7 intersections in the West Adelaide region were chosen in this study. The estimated AADT was determined by averaging the daily traffic every Friday of the year. As shown in Table 5.3, the traffic volume dropped by 10% in 2020, while the number of accidents dropped by about 4%. It implied that the crash rate increased during COVID times. The crash rate increased even more at the Phillips Street-Port Road Intersection.

It showed that the data could be interpreted differently depending on the research scope. Also, the police figures were misleading that the crash rate was better in 2020, which was worse. Since it was a late inclusion, further investigations are needed to refine the methodology and thus find the correlations between COVID, traffic volume and the number of accidents.

Table 5.3 AADT and Accidents number of the West Adelaide Region

WEST ADELAIDE	Before COVID		After
	2018	2019	2020
Estimated AADT	430428	426755	383937
Percentage Change	-	-0.85%	-10.03%
No. of Accidents	77	68	65
Percentage Change	-	-11.69%	-4.41%

Table 5.4 AADT and Accidents number of Phillips Street-Port Road Intersection

Philips St/ Port Rd	Before COVID		After
	2018	2019	2020
Estimated AADT	85182	82116	74247
Percentage Change	-	-3.60%	-9.58%
No. of Accidents	7	2	9
Percentage Change	-	-71.43%	350.00%

5.6 Limitations

There are no standards established for determining the social cost of accidents. Different organisations develop different methods to estimate the value of life. The difference could be in millions. It limits the reliability of the statistics when they are used as evidence for funding applications. The Government should assign a specific accredited organisation to evaluate the costs of the accidents. These values would be used in all assessments.

The traffic volume used in the study was estimated. Especially during COVID times, the traffic volume dropped due to lockdowns and work from home arrangements. They cannot be reflected using the extrapolation of one-week data. A better approach would be compiling the data into the Flinders SCAT Database, and the data would be retrievable and processed easily by Excel.

This study concerned the number, type and severity of accidents at intersections. An in-depth analysis of each accident in each accident is required to determine the best mitigation measure for that intersection. Each selected intersection should be studied individually such that other aspects such as intersection capacity, linkage and surroundings can be considered.

Despite the study aimed at improving intersection safety, the applied mitigation measures cannot guarantee avoiding all fatal accidents.

The traffic volume of the top 50 intersections was studied. Traffic volumes of more intersections should be determined to compile a more detailed ranking list. SIDRA Models should be calibrated by doing manual turning movement surveys on sites.

5.7 Future Work Recommendations

This study only focused on signalised intersections. The scope could be expanded to roundabouts and un-signalised intersections because accidents often happen in other types of intersections. Since SCATS data only provides traffic data at signalised intersections, methods should be developed for traffic counting in roundabouts and un-signalised intersections.

The Flinders SCATS database should be improved. The incorrect data should be fixed, and the newest data should be updated to the database. It would be beneficial for determining accurate traffic volumes.

Another research direction could be to develop models of alternative intersection designs. All movements occur at the same junction in the current intersection designs. It has a higher risk of accidents. The risk can be reduced by relocating some movements at some distance before or after the existing intersection. It could ensure uninterrupted movements at the intersection, and higher risk movement (e.g. filtering right turn) can be removed. It can be modelled in SIDRA to check the new design's performance. AIMSUN model helps visualise the innovative design and compare it with the existing design.

6 Conclusion

There is no justification for people losing their lives or being seriously injured by using the road network. The existing network was built for maximum capacity and mobility. Since Australia has adopted the Safe System Approach, it is necessary to improve the intersections to improve road safety.

This study analysed South Australia road crash data from 2018 to 2020. Then, it identified the worst-performing intersections based on the cost of accidents per 10 million vehicles. This new ranking system filled the knowledge gap that the current ranking system may lead to poor investment in intersections of less importance.

The top ten intersections on the list were modelled in SIDRA Intersection 9. By studying their crash types and occurrences, mitigation measures were suggested, and evaluated in their SIDRA models. Simple cost analyses were performed to estimate the benefits of the applied measures. The results showed that these measures could save over 10 million dollars and reduce almost 40 accidents per year.

These study results help the stakeholders, such as DIT and local councils, identify the intersection with the highest priority and develop their case studies for particular intersections. This study provides a simple framework to the stakeholders for intersection rankings and intersection improvements. In particular, the cost analysis results can show the economic benefits of the intersection upgrade, which is good evidence for applying for federal government funding such as the Black Spot Program.

In addition, the study could be extended to analyse accidents that occurred in roundabouts and un-signalised intersections. Because accidents often occur at roundabouts and un-signalised intersections. Studying them helps stakeholders get a bigger picture to prioritise their investments in intersection upgrades.

In conclusion, spend less and save more. The project is only a case study for metropolitan Adelaide. It could be applied to other cities. The benefits could be multiplied when other cities adopt a similar approach.

7 References

ABC News 2018, Patient dies after ambulance collides with car and rolls outside Royal Adelaide Hospital, ABC, Adelaide, viewed 19/4/2022, <https://www.abc.net.au/news/2018-09-12/car-and-ambulance-collide-in-adelaide/10235602>.

Afghari, AP, Haque, MM & Washington, S 2020, 'Applying a joint model of crash count and crash severity to identify road segments with high risk of fatal and serious injury crashes', Accident Analysis & Prevention, vol. 144, p. 105615.

Australian Taxation Office 2022, Consumer price index (CPI) rates, ATO, Australia, viewed 8/3/2022, <https://www.ato.gov.au/rates/consumer-price-index/>.

Australian Transport Council 2011, National Road Safety Strategy 2011–2020, ATC, Australian Government.

Austroads 2010, Road Safety Engineering Risk Assessment - Part 7: Crash Rates Database, Austroads, Sydney, NSW, Australia.

Austroads 2015, Road Crash Injuries Cost and Prevention, Austroads, Sydney, NSW, Australia.

Austroads 2016, Safe System Assessment Framework, Austroads, Sydney, NSW, Australia.

Bureau of Infrastructure and Transport Research Economics 2010, Cost of Road Crashes in Australia 2006, BITRE, Australian Government.

Bureau of Infrastructure and Transport Research Economics 2020, International Road Safety Comparisons 2018, BITRE, Australian Government.

Bureau of Transport and Communications Economics 1995, Evaluation of Black Spot Program, BTCE, Australian Government.

Candappa, N, Logan, D, Van Nes, N & Corben, B 2015, 'An exploration of alternative intersection designs in the context of Safe System', Accident Analysis & Prevention, vol. 74, pp. 314-23.

Department of Infrastructure and Transport 2019, Cross Road and Fullarton Road Intersection Upgrade, DIT, Adelaide, viewed 19/4/2022, <https://www.dit.sa.gov.au/infrastructure/road_projects/fullarton_road>.

Department of Infrastructure and Transport 2021a, ROAD CRASHES in South Australia - Statistical Summary of Road Crashes & Casualties in 2020, DIT, Government of South Australia.

Department of Infrastructure and Transport 2021b, South Australia's Road Safety Strategy to 2031 – Consultation Draft July 2021, DIT, Government of South Australia.

Department of Infrastructure and Transport 2021c, Traffic Modelling Guidelines: SIDRA Intersection, DIT, Government of South Australia.

Department of Infrastructure and Transport 2022, Northern Connector Project, DIT, Adelaide, viewed 19/4/2022, <https://dit.sa.gov.au/infrastructure/nsc/northern_connector>.

Department of Transport, Energy and Infrastructure 2011, Towards Zero Together - SOUTH AUSTRALIA'S ROAD SAFETY STRATEGY 2020, DTEI, Government of South Australia.

Economic Connections 2017, COST OF ROAD TRAUMA IN AUSTRALIA: Summary report - September 2017, Australia Automobile Association (AAA), Canberra, ACT, Australia.

Green, M, Muir, C, Oxley, J & Sobhani, A 2021, 'Safe System in road safety public policy: A case study from Victoria, Australia', IATSS Research.

Hauer, E 1995, 'On Exposure and Accident Rate', Traffic Engineering and Control, vol. 36, no. 3, pp. 134-8.

Hobday, M, Chow, K, Meuleners, L & Argus, F 2017, 'Identification of high risk metropolitan intersection sites in Perth, Australia', Accident Analysis & Prevention, vol. 106, pp. 336-40.

Job, RFS, Truong, J & Sakashita, C 2022, 'The Ultimate Safe System: Redefining the Safe System Approach for Road Safety', Sustainability, vol. 14, no. 5, p. 2978.

Kimber, R 2003, Traffic and accidents: are the risks too high?, Lecture delievered 11th June 2003, Imperial College London, TRL, Crowthorne, UK.

Larsson, P & Tingvall, C 2013, 'The Safe System Approach – A Road Safety Strategy Based on Human Factors Principles', in D Harris (ed.), Engineering Psychology and Cognitive Ergonomics. Applications and Services, Berlin, Heidelberg, pp. 19-28.

Mirage News 2019, Motorcyclist dies after crash at Lonsdale, South Australia, Mirage News, Adelaide, viewed 19/4/2022, <https://www.miragenews.com/motorcyclist-dies-after-crash-at-lonsdale-south-australia/>.

Mooren, L, Grzebieta, R & Job, S 2011, 'Safe System – Comparisons of this Approach in Australia', paper presented to Australasian College of Road Safety Conference, Melbourne, 1-2 September.

Morrison, S (Prime Minister of Australia), McCormack, M (Deputy Prime Minister) & Frydenberg, J (Treasurer) 2019, $2.2 Billion Boost To Road Safety, Australian Government, viewed 19/8/2021, <https://www.pm.gov.au/media/22-billion-boost-road-safety>.

Ogden, KW 1994, Traffic Engineering Road Safety: A Practitioner's Guide, Federal Office of Road Safety, Canberra, ACT, Australia.

Ogden, KW, Newstead, SV, Ryan, PK & Gantzer, S 1994, FACTORS AFFECTING CRASHES AT SIGNALISED INTERSECTIONS, Monash University Accident Research Centre, Melbourne, VIC, Australia.

Risbey, T, Cregan, M & De Silva, H 2010, 'Social Cost of Road Crashes', paper presented to Australasian Transport Research Forum 2010, Canberra, Australia, 29 September - 1 October.

Selby, T 2013, City of Nedlands: West Coast Highway/North Street Intersection SIDRA Analysis, City of Nedlands, Perth, WA, Australia.

Stigson, H, Krafft, M & Tingvall, C 2008, 'Use of fatal real-life crashes to analyze a safe road transport system model, including the road user, the vehicle, and the road', Traffic Injury Prevention,, vol. 9, no. 5, pp. 463-71.

The Department of Infrastructure, Transport, Regional Development and Communications (DITRDC) 2021, 4. Crash Costs | Australian Transport Assessment and Planning Guidelines, DITRDC, Canberra, viewed 22/9/2021, <https://www.atap.gov.au/parameter-values/road-transport/4-crash-costs>.

The Office of Best Practice Regulation (OBPR) 2020, Best Practice Regulation Guidance Note, Department of the Prime Minister and Cabinet, Australian Government.

Western Australian Local Government Association 2019a, The Safe System Approach Fact Sheet, WALGA, Perth, WA, Australia.

Western Australian Local Government Association 2019b, Vision Zero Fact Sheet, WALGA, Perth, WA, Australia.

Wundersitz, LN & Hutchinson, TP 2008, Identifying and improving exposure measures, Centre for Automotive Safety Research, University of Adelaide, SA, Australia.

Zhang, Y, Fu, C & Hu, L 2014, 'Yellow light dilemma zone researches: a review', Journal of Traffic and Transportation Engineering (English Edition), vol. 1, no. 5, pp. 338-52.

Appendix A Site Visit Photos

Figure A1 TS449 Sherriffs Road, Southern Expressway

Figure A2 TS116 Diagonal Rd, Marion Road

Figure A3 TS053 Port Wakefield Road, Waterloo Corner Road

Figure A4 TS010 Grand Junction Road, Hanson Road

Figure A5 TS325 Grand Junction Road, Nelson Road

Figure A6 TS315 Francis Street, Perkins Drive

Figure A7 TS094 Cross Road, Fullarton Road

Figure A8 TS073 Fullarton Road, The Parade

Figure A9 TS3166 George Street, Port Road

Figure A10 TS236 Findon Road, Trimmer Parade

Appendix B Traffic Volumes Estimation

Table B1 2017 Traffic Volume and Accident Cost per 10 million vehicles

SCAT ID	Intersection Name	Year 2018	Year 2019	Year 2020	Average Accident Cost per 10 million vehicles	2017 1st Week of March	2017 Volume (From SCAT Database)	2017 Average Daily Traffic
325	Grand Junction Rd, Nelson Rd	0.259	6.488	0.218	2.322	143692	7349327	20135
53	Port Wakefield Rd, Waterloo Corner Rd	0.272	0.190	6.116	2.193	391709	19778205	54187
94	Cross Rd, Fullarton Rd	0.060	0.029	5.418	1.836	362328	18170969	49783
449	Brodie Rd North, Sherriffs Rd, Southern Expy	0.042	4.425	0.110	1.526	186229	9605253	26316
236	Fife St, Findon Rd, Trimmer Pde	3.850	0.000	0.144	1.331	229801	11748268	32187
73	Flinders St, Fullarton Rd, The Parade, The Parade W	0.084	0.063	3.421	1.190	274674	14035763	38454
315	Francis St, Perkins Dr	0.136	3.350	0.071	1.186	286911	14646254	40127
10	Grand Junction Rd, Hanson Rd	0.215	3.195	0.052	1.154	295131	14433443	39544
116	Diagonal Rd, Finniss St, Sturt Rd	0.274	0.110	2.861	1.081	346864	17450984	47811
3166	George St, Port Rd	3.053	0.031	0.032	1.038	267634	13823647	37873
252	Main North Rd, Saints Rd, The Grove Way	0.099	1.822	0.064	0.662	519245	26164302	71683
432	Curtis Rd, Peachey Rd	0.251	0.606	0.455	0.437	178508	9284297	25436
212	Belair Rd, Grange Rd, Newark Rd	0.176	0.847	0.122	0.382	202812	10305443	28234
526	Marion Rd, Southern Expy Ramp (SB)	0.514	0.478	0.125	0.373	232963	12066206	33058
496	McIntyre Rd, Montague Rd	0.074	0.883	0.150	0.369	254429	12952968	35488
16	Briens Rd, Grand Junction Rd, Hampstead Rd	0.247	0.310	0.546	0.368	339951	17402019	47677
65	Croydon Rd, Railway Ter, Richmond Rd	0.241	0.310	0.542	0.364	180174	8990987	24633
113	Marion Rd, Sturt Rd	0.356	0.359	0.267	0.328	427252	22006056	60291
55	Henley Beach Rd, Marion Rd	0.336	0.228	0.406	0.323	320389	16324960	44726
174	Bains Rd, Main South Rd, O'Sullivan Beach Rd	0.086	0.546	0.329	0.320	214552	10772809	29515
535	Main South Rd, Southern Expy	0.371	0.453	0.129	0.317	232144	11519533	31560
217	Furness Ave, South Rd	0.338	0.236	0.230	0.268	366576	18138712	49695
8	Elder Smith Rd, Salisbury Hwy	0.081	0.130	0.587	0.266	352593	17006268	46593
277	Main North Rd, Montague Rd	0.249	0.361	0.125	0.245	439408	22242805	60939
197	Main North Rd, Tolmer Rd, Womma Rd	0.103	0.533	0.076	0.238	338321	17286681	47361
15	Grand Junction Rd, Main North Rd, Port Wakefield Rd	0.200	0.244	0.252	0.232	584169	29632321	81184
100	Cross Rd, Marion Rd	0.304	0.227	0.152	0.228	352174	17920148	49096
25	Main North Rd, Regency Rd	0.189	0.220	0.274	0.227	496042	24792379	67924
250	Kings Rd, Salisbury Hwy	0.215	0.389	0.078	0.227	351896	16495539	45193
96	Cross Rd, Goodwood Rd	0.153	0.273	0.227	0.218	350462	17624103	48285
62	James Congdon Dr, Sir Donald Bradman Dr	0.340	0.088	0.201	0.210	331163	17114644	46889
238	Main North Rd, Park Ter, Smith Rd	0.032	0.215	0.376	0.208	380873	18987446	52020
77	Lower Portrush Rd, Payneham Rd, Portrush Rd	0.126	0.236	0.258	0.207	496864	24959127	68381
460	Hawker St, Park Ter, War Memorial Dr	0.114	0.285	0.213	0.204	405336	19785696	54207
282	Ascot Ave, North East Rd, Taunton Rd	0.176	0.085	0.336	0.199	421654	21035710	57632
41	Cheltenham Pde, Port Rd, West Lakes Blvd	0.236	0.299	0.061	0.198	364725	19057194	52211
78	Glynburn Rd, Lower North East Rd, Montacute Rd, Payneham Rd	0.120	0.138	0.335	0.198	392699	19918760	54572
40	Port Rd, Woodville Rd	0.124	0.191	0.242	0.186	360512	19137484	52431
195	Main North Rd, Philip Hwy, Yorktown Rd	0.192	0.279	0.083	0.185	364040	19620155	53754
134	Regency Rd, South Rd	0.118	0.346	0.083	0.182	477141	22854991	62616
108	Daws Rd, South Rd	0.110	0.301	0.127	0.179	526225	25950490	71097
54	Henley Beach Rd, South Rd	0.144	0.319	0.062	0.175	425418	21014721	57575
24	Churchill Rd, Regency Rd	0.111	0.351	0.060	0.174	369916	19047131	52184
130	Fitzroy Ter, Prospect Rd	0.137	0.242	0.127	0.169	397589	19668530	53886
29	North East Rd, Northcote Rd, Nottage Ter, Stephen Ter	0.087	0.250	0.133	0.157	408082	20753974	56860
74	Botanic Rd, Dequetteville Ter, North Ter	0.103	0.045	0.306	0.151	499679	24785997	67907
92	Cross Rd, Glen Osmond Rd, Portrush Rd, S Eastern Hwy	0.095	0.172	0.158	0.141	517408	25870136	70877
37	Adam St, Park Ter, Port Rd	0.069	0.144	0.199	0.138	556275	27664505	75793
262	Phillips St, Port Rd	0.072	0.023	0.303	0.133	495899	25432108	69677

Table B2 2018 Traffic Volume of selected intersections

SCAT ID	2018 First Week of March							Weekly Total	Percentage Change from 2017	Estimated 2018 Volume
	Mon	Tue	Wed	Thu	Fri	Sat	Sun			
325	22084	23000	22736	23476	22934	17339	15464	147033	2.33%	7520207
53	60599	60488	58777	64167	67644	46287	39668	397630	1.51%	20077169
94	52589	54517	55127	55069	56351	46344	41310	361307	-0.28%	18119765
449	31536	31445	31582	32149	31850	21581	17377	197520	6.06%	10187616
236	34056	34496	36011	35099	37865	30795	25765	234087	1.87%	11967384
73	41552	43103	45099	45732	46763	34162	28871	285282	3.86%	14577829
315	44042	45766	47275	47723	48619	30827	32312	296564	3.36%	15139021
10	48258	48407	48678	50481	51409	37153	32582	316968	7.40%	15501386
116	48688	49666	49953	55088	52357	46578	39963	342293	-1.32%	17221014
3166	43979	45506	48355	47355	48981	34596	29673	298445	11.51%	15415076
252	71359	76794	82445	81714	82534	60600	51029	506475	-2.46%	25520833
432	26650	27182	27740	29623	29132	25251	22376	187954	5.29%	9775589
212	30262	31703	32401	32596	32603	25845	22270	207680	2.40%	10552800
526	35274	35888	35937	37779	37665	29200	24792	236535	1.53%	12251216
496	40402	41213	40522	41986	41153	30730	25903	261909	2.94%	13333774
16	50096	54679	56218	55788	55958	41005	36864	350608	3.13%	17947549
65	28702	29376	29085	29009	30247	20457	17464	184340	2.31%	9198877
113	64554	66249	68060	70820	68179	52827	46127	436816	2.24%	22498660
55	45461	46545	48487	49020	50487	42280	36370	318650	-0.54%	16236352
174	32762	32749	32412	34006	34790	25790	20907	213416	-0.53%	10715770
535	32714	34151	34733	36324	37809	32762	27938	236431	1.85%	11732264
217	53954	57071	58955	59507	58790	46923	41010	376210	2.63%	18615416
8	54303	56253	58038	58791	59633	40711	36470	364199	3.29%	17566049
277	67701	69808	70903	72113	72352	50364	42773	446014	1.50%	22577200
197	48312	49809	50945	53420	53986	45061	37174	338707	0.11%	17306404
15	88287	89556	88457	95346	96731	75927	70176	604480	3.48%	30662609
100	52295	53380	53999	55257	56652	46645	41640	359868	2.18%	18311652
25	72505	69875	71990	77444	78152	65247	57021	492234	-0.77%	24602054
250	53082	55536	53960	53787	57902	44204	37014	355485	1.02%	16663778
96	50910	52352	53729	53900	55083	44839	39568	350381	-0.02%	17620030
62	51163	52211	50162	55276	57220	40984	37496	344512	4.03%	17804526
238	56556	58933	60440	61010	60835	44477	38110	380361	-0.13%	18961922
77	72434	74302	75790	77338	77779	64600	55738	497981	0.22%	25015238
460	61929	64009	65234	64131	68003	51655	42410	417371	2.97%	20373161
282	64802	66274	68614	68271	68357	53289	46680	436287	3.47%	21765729
41	54016	55185	56643	57142	58063	48687	40652	370388	1.55%	19353091
78	56435	58023	50416	60620	61277	53592	45787	386150	-1.67%	19586577
40	50968	54310	54667	55106	57382	44610	35786	352829	-2.13%	18729638
195	54591	59746	61417	62702	61678	46468	39805	386407	6.14%	20825638
134	76187	78417	80305	80841	80633	56056	48585	501024	5.01%	23998984
108	71949	75942	77552	77354	77645	61831	53853	496126	-5.72%	24466175
54	63752	65599	67838	68498	69763	53281	45943	434674	2.18%	21471947
24	57822	58187	59976	60371	60592	46901	39624	383473	3.66%	19745187
130	62416	65314	68350	66730	68514	54674	47110	433108	8.93%	21425637
29	62428	66342	69779	68231	69389	55594	48709	440472	7.94%	22401244
74	53660	59551	65435	64990	71029	59571	55654	429890	-13.97%	21324195
92	77418	78428	80266	81433	83230	65282	58990	525047	1.48%	26252082
37	88280	91624	95198	92646	96390	77283	66147	607568	9.22%	30215393
262	80822	83204	85878	84619	87323	62147	52577	536570	8.20%	27517914

Table B3 2019 Traffic Volume of selected intersections

SCAT ID	2019 First Week of March							Total	Percentage Change from 2018	Estimated 2019 Volume
	Mon	Tue	Wed	Thu	Fri	Sat	Sun			
325	22471	22953	23147	23954	23892	18284	15668	150369	2.27%	7690831
53	34023	34345	34980	36795	37842	29505	28050	235540	-40.76%	11892906
94	52891	54387	55511	55947	54436	46408	40726	360306	-0.28%	18069564
449	33475	33483	34327	33736	33285	22295	17828	208429	5.52%	10750277
236	32514	33069	33893	34106	34818	28949	23378	220727	-5.71%	11284372
73	42660	43037	44657	44460	45173	34820	23723	278530	-2.37%	14232803
315	42338	43181	43200	43990	47388	30735	28318	279150	-5.87%	14250070
10	48517	49667	50394	50971	51853	37376	31148	319926	0.93%	15646048
116	47565	48698	49090	54189	51111	45342	39139	335134	-2.09%	16860839
3166	47041	47979	49346	49717	51954	37983	33271	317291	6.31%	16388496
252	79449	82925	83037	84944	85534	63414	52238	531541	4.95%	26783887
432	28078	28955	29411	30405	30680	26622	22791	196942	4.78%	10243059
212	30638	31483	32848	32979	32969	26683	22533	210133	1.18%	10677443
526	30892	37054	38465	36346	37464	28501	24516	233238	-1.39%	12080449
496	39983	41177	41555	43251	41803	31487	26526	265782	1.48%	13530949
16	52979	54648	55134	56935	56318	42704	37675	356393	1.65%	18243681
65	28410	29856	29755	30073	30183	20379	17692	186348	1.09%	9299080
113	78303	79400	89561	89491	76670	71619	62311	547355	25.31%	28192085
55	45992	46749	47329	49824	50377	40456	34961	315688	-0.93%	16085427
174	32445	32703	33467	34819	33996	25633	20362	213425	0.00%	10716222
535	33555	33056	33892	32215	36138	29581	28986	227423	-3.81%	11285266
217	56578	49021	54189	53663	57299	46952	41435	359137	-4.54%	17770619
8	56559	57810	58701	58530	60932	40836	35955	369323	1.41%	17813189
277	68095	70491	70863	69617	73638	49877	42622	445203	-0.18%	22536148
197	50609	52869	53990	56148	56795	43643	37050	351104	3.66%	17939835
15	86305	88557	89550	89594	94255	73050	67317	588628	-2.62%	29858506
100	53670	55314	57802	57182	57534	47338	41304	370144	2.86%	18834540
25	72099	73889	74862	72130	77815	63495	56478	490768	-0.30%	24528782
250	52963	54986	56007	56542	58425	42385	36034	357342	0.52%	16750827
96	50888	53009	55247	54381	55064	44554	39146	352289	0.54%	17715980
62	50341	50536	50540	52586	54119	40007	35622	333751	-3.12%	17248393
238	57518	60112	60280	61065	62017	46469	39003	386464	1.60%	19266171
77	72821	74693	76696	78037	78035	66800	48382	495464	-0.51%	24888800
460	60981	62110	61941	63083	65014	49760	41352	404241	-3.15%	19732246
282	65246	65864	66913	68325	67993	53079	46061	433481	-0.64%	21625742
41	56927	58640	59504	60555	61275	51363	41293	389557	5.18%	20354687
78	56783	58659	60058	61626	61730	54797	40654	394307	2.11%	20000322
40	53438	54915	56331	56821	57902	44753	35949	360109	2.06%	19116091
195	58972	61455	62356	64451	64728	49022	41087	402071	4.05%	21669859
134	88101	89039	89793	90818	92845	70853	60794	582243	16.21%	27889363
108	76435	72333	74592	74017	76944	61282	53829	489432	-1.35%	24136064
54	70602	68197	71807	73703	74923	62080	53992	475304	9.35%	23478981
24	56389	57309	58307	59646	59854	46214	39254	376973	-1.70%	19410499
130	61321	63852	64152	66138	67355	53328	44889	421035	-2.79%	20828392
29	62931	66532	67524	68532	70421	56435	49476	441851	0.31%	22471376
74	59963	67716	70677	72587	78347	66882	47002	463174	7.74%	22975209
92	77263	78379	79309	81760	84284	66312	59576	526883	0.35%	26343881
37	85568	88080	88503	89720	93573	68890	57642	571976	-5.86%	28445343
262	78164	77210	80808	82241	85910	61396	51619	517348	-3.58%	26532117

Table B4 2020 Traffic Volume of selected intersections

SCAT ID	2020 First Week of March							Total	Percentage change from 2019	Estimated 2020 Volume
	Mon	Tue	Wed	Thu	Fri	Sat	Sun			
325	23428	24276	24545	25000	24628	18732	16189	156798	4.28%	8019652
53	22114	27728	29240	30434	33976	19478	14963	177933	-24.46%	8984209
94	51581	53656	55735	55811	57006	46156	41822	361767	0.41%	18142835
449	31279	31183	31967	32505	33272	21422	17090	198718	-4.66%	10249406
236	33007	34160	34614	35099	35181	28721	24591	225373	2.10%	11521892
73	40494	42267	42969	43992	45166	33286	27191	275365	-1.14%	14071073
315	40676	40979	42951	43383	43534	30327	30521	272371	-2.43%	13904015
10	48591	49732	49196	49867	50632	34686	31803	314507	-1.69%	15381030
116	49695	50834	51573	56108	52743	44323	38664	343940	2.63%	17303875
3166	44872	46281	46648	47206	49506	37798	32686	304997	-3.87%	15753495
252	83084	84170	81163	86636	87993	62823	52064	537933	1.20%	27105974
432	27904	28337	29275	30245	30788	27209	24938	198696	0.89%	10334286
212	30520	30716	32004	31496	32201	25259	21083	203279	-3.26%	10329173
526	31475	35237	35773	37069	37186	27969	24672	229381	-1.65%	11880678
496	36092	37496	37395	40069	38128	31520	26117	246817	-7.14%	12565441
16	53423	54796	56070	56773	56654	42333	37973	358022	0.46%	18327070
65	27898	28951	28981	29579	30376	20538	17534	183857	-1.34%	9174775
113	73733	72932	77217	77492	73535	58431	52075	485415	-11.32%	25001801
55	44210	44591	45765	46659	48126	39488	34440	303279	-3.93%	15453145
174	32001	32569	33708	33683	34510	25258	20541	212270	-0.54%	10658228
535	34036	34306	35124	36272	38257	31549	29673	239217	5.19%	11870512
217	56874	57464	58137	59026	60172	50436	44722	386831	7.71%	19140959
8	56234	56965	58294	59803	59970	37316	32504	361086	-2.23%	17415902
277	70677	72144	72869	74426	75006	49807	41090	456019	2.43%	23083653
197	52980	54340	54900	57593	58008	43225	35658	356704	1.59%	18225970
15	85983	87993	89333	90527	94269	70570	63889	582564	-1.03%	29550906
100	51532	53038	54105	55134	56670	45676	41086	357241	-3.49%	18177979
25	72846	74559	73522	76300	78575	60170	54107	490079	-0.14%	24494346
250	56069	58699	60041	61721	61853	42535	37003	377921	5.76%	17715491
96	50303	51686	53802	53931	55872	43988	38428	348010	-1.21%	17500796
62	49684	51103	51523	54120	54897	39453	34928	335708	0.59%	17349532
238	59527	60572	60827	62153	62663	44996	37533	388271	0.47%	19356254
77	69437	70560	72292	73277	73913	63660	54580	477719	-3.58%	23997410
460	60622	61741	63089	63535	66312	51220	42235	408754	1.12%	19952539
282	64092	65650	67604	68258	68908	53983	46821	435316	0.42%	21717287
41	55552	57479	57462	52075	51942	49855	42528	366893	-5.82%	19170474
78	56860	57423	58595	60248	59949	53268	45470	391813	-0.63%	19873820
40	52907	55267	55821	57085	57389	46061	38413	362943	0.79%	19266532
195	56776	58251	59064	61244	61382	45033	37408	379158	-5.70%	20434949
134	87151	90074	90426	91872	93169	76250	66633	595575	2.29%	28527964
108	74248	76461	77113	77712	78593	64079	56426	504632	3.11%	24885643
54	69172	70207	71853	72882	74826	64028	55820	478788	0.73%	23651083
24	55285	56291	57406	58412	58086	43678	38341	367499	-2.51%	18922679
130	62022	63930	63542	65295	68007	48545	34694	406035	-3.56%	20086349
29	64672	67032	67932	68320	70972	56215	48275	443418	0.35%	22551070
74	65852	71230	72302	73189	77212	64160	56882	480827	3.81%	23850865
92	61648	64309	67359	69775	72950	55643	51116	442800	-15.96%	22139774
37	82708	85508	87002	88799	92757	62878	57855	557507	-2.53%	27725774
262	77758	79217	80933	81798	85476	62517	52148	519847	0.48%	26660278

Table B5 2018 West Adelaide Region Average Traffic Volume

Week/SCAT ID	37	54	55	62	65	100	262	
5/01/2018	73594	57966	43033	46454	24118	48361	80578	
2/02/2018	92723	67988	49765	55118	29797	55946	86344	
2/03/2018	95684	69081	49547	54287	31382	56532	89126	
6/04/2018	94332	68821	48915	55081	28828	55245	85268	
4/05/2018	93937	66121	47563	55678	26792	55198	86343	
1/06/2018	94363	66465	47431	54623	29386	#N/A	85985	
6/07/2018	91829	65002	45923	54676	28573	55540	84406	
3/08/2018	92827	65714	46606	53375	28605	57542	84579	
7/09/2018	94287	65435	47816	58382	28498	57084	88667	
5/10/2018	92634	68503	47380	53833	25810	55766	80165	
2/11/2018	91749	72304	48966	54628	28295	57136	84077	
7/12/2018	95578	73999	49482	55770	28663	58850	86640	
Total	1103537	807399	572427	651905	338747	613200	1022178	
No. of Data	12	12	12	12	12	11	12	
Estimated AADT	91961.42	67283.25	47702.25	54325.42	28228.92	55745.45	85181.5	430428.2

#N/A – Data Not Available

Table B6 2019 West Adelaide Region Annual Average Traffic Volume

Week/SCAT ID	37	54	55	62	65	100	262	
4/01/2019	68369	63361	41738	43873	23182	48389	74667	
1/02/2019	89626	73371	49003	53181	29350	56271	81827	
1/03/2019	91187	75058	48982	51467	29945	55512	83063	
5/04/2019	89363	72467	48699	53175	28983	55224	82307	
3/05/2019	90442	72216	47923	52337	28824	54984	83164	
7/06/2019	90074	72750	47950	52723	28604	55092	83220	
5/07/2019	89490	72837	48025	52218	29463	56368	80098	
2/08/2019	88093	71769	47072	51383	28516	55188	80724	
6/09/2019	84874	71770	46399	53361	28186	55092	82542	
4/10/2019	93933	73877	48059	52884	27998	55795	81250	
1/11/2019	93049	72121	47430	51738	29925	56997	85528	
6/12/2019	97386	75623	50048	55290	31015	58696	87007	
Total	1065886	867220	571328	623630	343991	663608	985397	
No. of Data	12	12	12	12	12	12	12	
Estimated AADT	88823.83	72268.33	47610.67	51969.17	28665.92	55300.67	82116.42	426755

Table B7 2020 West Adelaide Region Annual Average Traffic Volume

Week/ID	37	54	55	62	65	100	262	
3/01/2020	62053	53414	37607	40315	20141	41553	56803	
7/02/2020	95244	72915	46636	53277	29753	55542	84362	
6/03/2020	92757	74826	48126	54897	30376	56670	85476	
3/04/2020	24109	54397	32547	29583	18594	38282	51921	
1/05/2020	61588	61236	35283	32111	21525	41578	56251	
5/06/2020	#N/A	67902	42820	40011	25708	49724	71146	
3/07/2020	#N/A	69637	43874	42098	26237	49990	76293	
7/08/2020	85245	68825	43679	43483	27229	#N/A	78243	
4/09/2020	89756	72346	46501	44935	28381	#N/A	82114	
2/10/2020	87639	73650	49649	46764	28107	#N/A	80010	
6/11/2020	92880	73123	47815	48883	29687	55536	84346	
4/12/2020	93384	74005	48573	48710	28964	57777	84001	
Total	784655	816276	523110	525067	314702	446652	890966	
No. of Data	10	12	12	12	12	9	12	
Estimated AADT	78465.5	68023	43592.5	43755.58	26225.17	49628	74247.17	383936.9

#N/A – Data Not Available

Appendix C Road Crash Data

Table C1 TS010 Grand Junction Road - Hanson Road 2018-20 Road Crash Data

REPORT_ID	Total Units	Total Cas	Total Fats	Total SI	Total MI	Year	Crash Type	Crash Type	Crash Index	Total Cost ($ mil)
2018-121-27/05/2021	3	0	0	0	0	2018	Rear End	PDO	1	0.03
2018-235-27/05/2021	3	0	0	0	0	2018	Rear End	PDO	1	0.03
2018-491-27/05/2021	2	0	0	0	0	2018	Side Swipe	PDO	1	0.02
2018-1134-27/05/2021	2	1	0	0	1	2018	Right Angle	MI	3.5	0.033
2018-1354-27/05/2021	2	0	0	0	0	2018	Hit Pedestrian	PDO	1	0.02
2018-2639-27/05/2021	2	0	0	0	0	2018	Rear End	PDO	1	0.02
2018-3438-27/05/2021	2	0	0	0	0	2018	Rear End	PDO	1	0.02
2018-3933-27/05/2021	2	0	0	0	0	2018	Side Swipe	PDO	1	0.02
2018-4016-27/05/2021	2	0	0	0	0	2018	Right Turn	PDO	1	0.02
2018-5187-27/05/2021	2	0	0	0	0	2018	Right Angle	PDO	1	0.02
2018-7279-27/05/2021	2	0	0	0	0	2018	Right Turn	PDO	1	0.02
2018-8795-27/05/2021	2	0	0	0	0	2018	Right Turn	PDO	1	0.02
2018-10725-27/05/2021	2	0	0	0	0	2018	Rear End	PDO	1	0.02
2018-11928-27/05/2021	2	0	0	0	0	2018	Rear End	PDO	1	0.02
2018-12686-27/05/2021	2	0	0	0	0	2018	Right Turn	PDO	1	0.02
2019-410-27/05/2021	2	0	0	0	0	2019	Side Swipe	PDO	1	0.02
2019-417-27/05/2021	2	1	1	0	0	2019	Hit Pedestrian	F	9.5	4.671
2019-1073-27/05/2021	2	1	0	0	1	2019	Rear End	MI	3.5	0.033
2019-1147-27/05/2021	2	0	0	0	0	2019	Side Swipe	PDO	1	0.02
2019-2641-27/05/2021	2	0	0	0	0	2019	Right Turn	PDO	1	0.02
2019-2946-27/05/2021	2	0	0	0	0	2019	Hit Fixed Object	PDO	1	0.02
2019-3116-27/05/2021	2	0	0	0	0	2019	Rear End	PDO	1	0.02
2019-4133-27/05/2021	2	1	0	0	1	2019	Rear End	MI	3.5	0.033
2019-4455-27/05/2021	2	0	0	0	0	2019	Right Turn	PDO	1	0.02
2019-6187-27/05/2021	2	1	0	0	1	2019	Right Turn	MI	3.5	0.033
2019-7144-27/05/2021	2	0	0	0	0	2019	Right Angle	PDO	1	0.02
2019-9138-27/05/2021	1	1	0	0	1	2019	Roll Over	MI	3.5	0.023
2019-9571-27/05/2021	2	1	0	0	1	2019	Rear End	MI	3.5	0.033
2019-9783-27/05/2021	2	1	0	0	1	2019	Right Turn	MI	3.5	0.033
2020-1220-27/05/2021	2	0	0	0	0	2020	Right Turn	PDO	1	0.020
2020-2844-27/05/2021	2	0	0	0	0	2020	Rear End	PDO	1	0.020
2020-6829-27/05/2021	2	0	0	0	0	2020	Rear End	PDO	1	0.020
2020-10855-27/05/2021	2	0	0	0	0	2020	Side Swipe	PDO	1	0.020

Table C2 TS053 Port Wakefield Road - Waterloo Corner Road 2018-20 Road Crash Data

REPORT_ID	Total Units	Total Cas	Total Fats	Total SI	Total MI	Year	Crash Type	Crash Type	Crash Index	Total Cost
2018-87-27/05/2021	2	1	0	0	1	2018	Side Swipe	MI	3.5	0.033
2018-1532-27/05/2021	2	1	0	0	1	2018	Rear End	MI	3.5	0.033
2018-1827-27/05/2021	4	0	0	0	0	2018	Rear End	PDO	1	0.04
2018-2265-27/05/2021	3	2	0	0	2	2018	Rear End	MI	3.5	0.056
2018-5476-27/05/2021	2	0	0	0	0	2018	Rear End	PDO	1	0.02
2018-6142-27/05/2021	2	2	0	1	1	2018	Right Angle	SI	9.5	0.285
2018-6636-27/05/2021	2	0	0	0	0	2018	Rear End	PDO	1	0.02
2018-9165-27/05/2021	2	0	0	0	0	2018	Rear End	PDO	1	0.02
2018-10801-27/05/2021	2	0	0	0	0	2018	Rear End	PDO	1	0.02
2018-11032-27/05/2021	2	0	0	0	0	2018	Rear End	PDO	1	0.02
2019-2325-27/05/2021	3	0	0	0	0	2019	Rear End	PDO	1	0.03
2019-3350-27/05/2021	4	0	0	0	0	2019	Rear End	PDO	1	0.04
2019-4314-27/05/2021	2	1	0	0	1	2019	Right Angle	MI	3.5	0.033
2019-5438-27/05/2021	2	1	0	0	1	2019	Rear End	MI	3.5	0.033
2019-7971-27/05/2021	2	0	0	0	0	2019	Rear End	PDO	1	0.02
2019-8352-27/05/2021	1	0	0	0	0	2019	Other	PDO	1	0.01
2019-8428-27/05/2021	2	0	0	0	0	2019	Side Swipe	PDO	1	0.02
2019-9303-27/05/2021	2	0	0	0	0	2019	Hit Fixed Object	PDO	1	0.02
2019-12006-27/05/2021	2	0	0	0	0	2019	Rear End	PDO	1	0.02
2020-102-27/05/2021	3	0	0	0	0	2020	Rear End	PDO	1	0.030
2020-916-27/05/2021	2	0	0	0	0	2020	Rear End	PDO	1	0.020
2020-1650-27/05/2021	2	0	0	0	0	2020	Side Swipe	PDO	1	0.020
2020-2739-27/05/2021	2	3	1	1	1	2020	Right Angle	F	9.5	4.982
2020-5158-27/05/2021	2	1	0	0	1	2020	Right Turn	MI	3.5	0.033
2020-5900-27/05/2021	2	1	0	0	1	2020	Right Angle	MI	3.5	0.033
2020-8253-27/05/2021	3	3	0	1	2	2020	Right Turn	SI	9.5	0.314
2020-9234-27/05/2021	3	0	0	0	0	2020	Rear End	PDO	1	0.030
2020-9984-27/05/2021	2	1	0	0	1	2020	Rear End	MI	3.5	0.033

Table C3 TS073 Fullarton Road - The Parade 2018-20 Road Crash Data

REPORT_ID	Total Units	Total Cas	Total Fats	Total SI	Total MI	Year	Crash Type	Crash Type	Crash Index	Total Cost
2018-2204-27/05/2021	2	0	0	0	0	2018	Side Swipe	PDO	1	0.02
2018-2971-27/05/2021	2	0	0	0	0	2018	Right Turn	PDO	1	0.02
2018-5511-27/05/2021	2	0	0	0	0	2018	Right Turn	PDO	1	0.02
2018-7971-27/05/2021	3	0	0	0	0	2018	Right Angle	PDO	1	0.03
2018-799-27/05/2021	2	1	0	0	1	2018	Right Turn	MI	3.5	0.033
2019-170-27/05/2021	2	0	0	0	0	2019	Right Angle	PDO	1	0.02
2019-5025-27/05/2021	2	0	0	0	0	2019	Right Angle	PDO	1	0.02
2019-7434-27/05/2021	2	0	0	0	0	2019	Rear End	PDO	1	0.02
2019-7934-27/05/2021	3	0	0	0	0	2019	Right Angle	PDO	1	0.03
2020-11428-27/05/2021	2	1	1	0	0	2020	Rear End	F	9.5	4.711
2020-1695-27/05/2021	3	0	0	0	0	2020	Right Turn	PDO	1	0.030
2020-179-27/05/2021	2	0	0	0	0	2020	Right Turn	PDO	1	0.020
2020-2099-27/05/2021	2	1	0	0	1	2020	Right Turn	MI	3.5	0.033
2020-8080-27/05/2021	2	0	0	0	0	2020	Right Turn	PDO	1	0.020

Table C4 TS094 Cross Road - Fullarton Road 2018-20 Road Crash Data

REPORT_ID	Total Units	Total Cas	Total Fats	Total SI	Total MI	Year	Crash Type	Crash Type	Crash Index	Total Cost
2018-518-27/05/2021	2	1	0	0	1	2018	Side Swipe	MI	3.5	0.033
2018-5013-27/05/2021	2	0	0	0	0	2018	Rear End	PDO	1	0.02
2018-9365-27/05/2021	1	1	0	0	1	2018	Roll Over	MI	3.5	0.023
2018-9548-27/05/2021	2	1	0	0	1	2018	Hit Pedestrian	MI	3.5	0.033
2019-5251-27/05/2021	2	1	0	0	1	2019	Rear End	MI	3.5	0.033
2019-10391-27/05/2021	2	0	0	0	0	2019	Right Turn	PDO	1	0.02
2020-854-27/05/2021	2	0	0	0	0	2020	Rear End	PDO	1	0.020
2020-3503-27/05/2021	6	4	2	1	1	2020	Right Angle	F	9.5	9.713
2020-5825-27/05/2021	3	0	0	0	0	2020	Right Turn	PDO	1	0.030
2020-7804-27/05/2021	2	1	0	0	1	2020	Rear End	MI	3.5	0.033
2020-8784-27/05/2021	2	1	0	0	1	2020	Rear End	MI	3.5	0.033

Table C5 TS116 Diagonal Road - Sturt Road 2018-20 Road Crash Data

REPORT_ID	Total Units	Total Cas	Total Fats	Total SI	Total MI	Year	Crash Type	Crash Type	Crash Index	Total Cost
2018-481-27/05/2021	2	1	0	0	1	2018	Right Turn	MI	3.5	0.033
2018-1683-27/05/2021	3	1	0	0	1	2018	Rear End	MI	3.5	0.043
2018-2741-27/05/2021	1	1	0	0	1	2018	Other	MI	3.5	0.023
2018-3434-27/05/2021	2	0	0	0	0	2018	Right Turn	PDO	1	0.02
2018-7036-27/05/2021	2	0	0	0	0	2018	Right Turn	PDO	1	0.02
2018-8711-27/05/2021	2	0	0	0	0	2018	Right Turn	PDO	1	0.02
2018-8843-27/05/2021	2	1	0	1	0	2018	Right Turn	SI	9.5	0.272
2018-9336-27/05/2021	2	0	0	0	0	2018	Right Angle	PDO	1	0.02
2018-11889-27/05/2021	2	0	0	0	0	2018	Side Swipe	PDO	1	0.02
2019-901-27/05/2021	2	0	0	0	0	2019	Rear End	PDO	1	0.02
2019-4181-27/05/2021	2	0	0	0	0	2019	Rear End	PDO	1	0.02
2019-4489-27/05/2021	2	0	0	0	0	2019	Right Turn	PDO	1	0.02
2019-4837-27/05/2021	2	0	0	0	0	2019	Right Turn	PDO	1	0.02
2019-5600-27/05/2021	2	0	0	0	0	2019	Rear End	PDO	1	0.02
2019-9554-27/05/2021	2	1	0	0	1	2019	Rear End	MI	3.5	0.033
2019-10832-27/05/2021	2	0	0	0	0	2019	Right Turn	PDO	1	0.02
2019-11999-27/05/2021	2	1	0	0	1	2019	Rear End	MI	3.5	0.033
2020-3310-27/05/2021	3	0	0	0	0	2020	Rear End	PDO	1	0.030
2020-4685-27/05/2021	2	0	0	0	0	2020	Right Turn	PDO	1	0.020
2020-4842-27/05/2021	3	1	0	0	1	2020	Rear End	MI	3.5	0.043
2020-5300-27/05/2021	2	1	0	0	1	2020	Right Turn	MI	3.5	0.033
2020-6796-27/05/2021	2	0	0	0	0	2020	Side Swipe	PDO	1	0.020
2020-7151-27/05/2021	2	0	0	0	0	2020	Rear End	PDO	1	0.020
2020-8308-27/05/2021	2	0	0	0	0	2020	Side Swipe	PDO	1	0.020
2020-9571-27/05/2021	2	0	0	0	0	2020	Side Swipe	PDO	1	0.020
2020-10196-27/05/2021	2	1	1	0	0	2020	Right Angle	F	9.5	4.711
2020-11504-27/05/2021	2	1	0	0	1	2020	Rear End	MI	3.5	0.033

Table C6 TS236 Findon Road - Trimmer Parade 2018-20 Road Crash Data

REPORT_ID	Total Units	Total Cas	Total Fats	Total SI	Total MI	Year	Crash Type	Crash Type	Crash Index	Total cost
2020-2818-27/05/2021	2	0	0	0	0	2020	Right Angle	PDO	1	0.020
2020-4418-27/05/2021	2	0	0	0	0	2020	Side Swipe	PDO	1	0.020
2020-5490-27/05/2021	2	0	0	0	0	2020	Rear End	PDO	1	0.020
2020-5705-27/05/2021	2	0	0	0	0	2020	Hit Fixed Object	PDO	1	0.020
2020-10128-27/05/2021	2	0	0	0	0	2020	Rear End	PDO	1	0.020
2020-11496-27/05/2021	4	2	0	0	2	2020	Rear End	MI	3.5	0.066
2018-7207-27/05/2021	2	1	1	0	0	2018	Right Turn	F	9.5	4.587
2018-7702-27/05/2021	2	0	0	0	0	2018	Rear End	PDO	1	0.02

Table C7 TS315 Francis Street - Perkins Drive 2018-20 Road Crash Data

REPORT_ID	Total Units	Total Cas	Total Fats	Total SI	Total MI	Year	Crash Type	Crash Type	Crash Index	Total Cost
2018-511-27/05/2021	2	0	0	0	0	2018	Rear End	PDO	1	0.02
2018-3812-27/05/2021	3	0	0	0	0	2018	Rear End	PDO	1	0.03
2018-4243-27/05/2021	2	0	0	0	0	2018	Side Swipe	PDO	1	0.02
2018-5251-27/05/2021	2	0	0	0	0	2018	Rear End	PDO	1	0.02
2018-5527-27/05/2021	3	0	0	0	0	2018	Side Swipe	PDO	1	0.03
2018-8998-27/05/2021	2	1	0	0	1	2018	Rear End	MI	3.5	0.033
2018-11062-27/05/2021	2	0	0	0	0	2018	Rear End	PDO	1	0.02
2018-11937-27/05/2021	2	1	0	0	1	2018	Rear End	MI	3.5	0.033
2019-1026-27/05/2021	3	0	0	0	0	2019	Other	PDO	1	0.03
2019-1922-27/05/2021	2	1	0	0	1	2019	Rear End	MI	3.5	0.033
2019-3725-27/05/2021	2	0	0	0	0	2019	Rear End	PDO	1	0.02
2019-7441-27/05/2021	2	0	0	0	0	2019	Side Swipe	PDO	1	0.02
2019-12629-27/05/2021	2	1	1	0	0	2019	Side Swipe	F	9.5	4.671
2020-3480-27/05/2021	2	2	0	0	2	2020	Rear End	MI	3.5	0.046
2020-4694-27/05/2021	2	1	0	0	1	2020	Rear End	MI	3.5	0.033
2020-10785-27/05/2021	2	0	0	0	0	2020	Right Angle	PDO	1	0.020

Table C8 TS325 Grand Junction Road - Nelson Road 2018-20 Road Crash Data

REPORT_ID	Total Units	Total Cas	Total Fats	Total SI	Total MI	Year	Crash Type	Crash Type	Crash Index	Total Cost
2018-12039-27/05/2021	3	2	0	0	2	2018	Rear End	MI	3.5	0.056
2018-13190-27/05/2021	2	0	0	0	0	2018	Right Turn	PDO	1	0.02
2018-2173-27/05/2021	2	0	0	0	0	2018	Right Angle	PDO	1	0.02
2018-2890-27/05/2021	2	1	0	0	1	2018	Right Angle	MI	3.5	0.033
2018-2901-27/05/2021	2	0	0	0	0	2018	Side Swipe	PDO	1	0.02
2018-3552-27/05/2021	2	2	0	0	2	2018	Right Turn	MI	3.5	0.046
2019-11081-27/05/2021	3	2	1	1	0	2019	Hit Fixed Object	F	9.5	4.937
2019-1478-27/05/2021	2	1	0	0	1	2019	Right Turn	MI	3.5	0.033
2019-6572-27/05/2021	2	0	0	0	0	2019	Right Turn	PDO	1	0.02
2020-10061-27/05/2021	2	0	0	0	0	2020	Rear End	PDO	1	0.020
2020-8527-27/05/2021	2	3	0	0	3	2020	Right Turn	MI	3.5	0.059
2020-9314-27/05/2021	2	1	0	0	1	2020	Hit Fixed Object	MI	3.5	0.033
2020-9573-27/05/2021	3	0	0	0	0	2020	Right Turn	PDO	1	0.030
2020-9585-27/05/2021	2	1	0	0	1	2020	Right Turn	MI	3.5	0.033

Table C9 TS449 Grand Junction Road - Hanson Road 2018-20 Road Crash Data

REPORT_ID	Total Units	Total Cas	Total Fats	Total SI	Total MI	Year	Crash Type	Crash Type	Crash Index	Total Cost
2018-2614-27/05/2021	1	0	0	0	0	2018	Roll Over	PDO	1	0.01
2018-7223-27/05/2021	2	1	0	0	1	2018	Right Turn	MI	3.5	0.033
2019-4286-27/05/2021	3	2	0	0	2	2019	Right Angle	MI	3.5	0.056
2019-8063-27/05/2021	3	1	1	0	0	2019	Hit Fixed Object	F	9.5	4.681
2019-9230-27/05/2021	2	0	0	0	0	2019	Right Turn	PDO	1	0.02
2020-10019-27/05/2021	2	0	0	0	0	2020	Rear End	PDO	1	0.020
2020-10404-27/05/2021	2	0	0	0	0	2020	Right Angle	PDO	1	0.020
2020-11272-27/05/2021	1	0	0	0	0	2020	Other	PDO	1	0.010
2020-183-27/05/2021	3	0	0	0	0	2020	Right Turn	PDO	1	0.030
2020-4498-27/05/2021	2	1	0	0	1	2020	Rear End	MI	3.5	0.033

Table C 10 TS3166 George Street - Port Road 2018-20 Road Crash Data

REPORT_ID	Total Units	Total Cas	Total Fats	Total SI	Total MI	Year	Crash Type	Crash Type	Crash Index	Total Cost
2018-873-27/05/2021	2	2	0	0	2	2018	Right Angle	MI	3.5	0.046
2018-5414-27/05/2021	2	0	0	0	0	2018	Side Swipe	PDO	1	0.02
2018-7342-27/05/2021	2	0	0	0	0	2018	Side Swipe	PDO	1	0.02
2018-9454-27/05/2021	2	2	1	0	1	2018	Right Turn	F	9.5	4.6
2018-13170-27/05/2021	2	0	0	0	0	2018	Side Swipe	PDO	1	0.02
2019-4156-27/05/2021	2	0	0	0	0	2019	Hit Fixed Object	PDO	1	0.02
2019-9754-27/05/2021	2	0	0	0	0	2019	Rear End	PDO	1	0.02
2019-11205-27/05/2021	1	0	0	0	0	2019	Left Road - Out of Control	PDO	1	0.01
2020-937-27/05/2021	3	0	0	0	0	2020	Rear End	PDO	1	0.030
2020-11346-27/05/2021	2	0	0	0	0	2020	Right Turn	PDO	1	0.020

Appendix D SIDRA Outputs

TS010 Grand Junction Road – Hanson Road

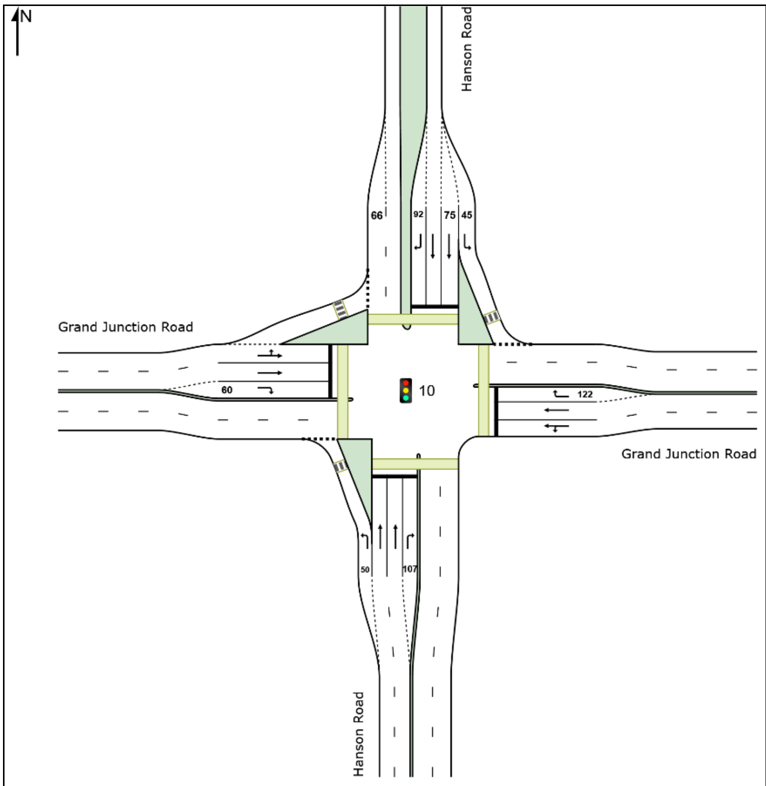


Figure D1 TS010 Grand Junction Road – Hanson Road Site Layout

TableD1 TS010 Accident Occurrence by Crash Type

Crash Type	Occurrence
Total	32
Rear End	12
Right Turn	9
Side Swipe	5
Right Angle	3
Hit Pedestrian	2
Hit Object	1
Roll Over	1

Proposed Changes:

- Remove filtering right turn
- Optimize cycle time

Table D2 TS010 Yearly Cost Comparison

TS010	Intersection Operation Cost	Accident Cost	Total Cost
Before	$2,746,686	$1,804,000	$4,550,686
After	$2,859,182	$1,635,667	$4,494,849
Total Benefit	-$112,496	$168,333	$55,837

Table D3 TS010 Performance Summary Before Mitigating Measures

Intersection Performance - Annual Values	
Performance Measure	**Vehicles**
Demand Flows (Total)	1,760,337 veh/y
Delay	18,150 veh-h/y
Effective Stops	1,434,124 veh/y
Travel Distance	2,386,581 veh-km/y
Travel Time	60,866 veh-h/y
Cost	2,746,686 $/y
Fuel Consumption	324,806 L/y
Carbon Dioxide	786,521 kg/y
Hydrocarbons	65 kg/y
Carbon Monoxide	754 kg/y
NOx	3,017 kg/y

Table D4 TS010 Performance Summary After Mitigating Measures

Intersection Performance - Annual Values	
Performance Measure	**Vehicles**
Demand Flows (Total)	1,760,337 veh/y
Delay	21,189 veh-h/y
Effective Stops	1,476,128 veh/y
Travel Distance	2,386,581 veh-km/y
Travel Time	63,904 veh-h/y
Cost	2,859,182 $/y
Fuel Consumption	330,076 L/y
Carbon Dioxide	799,136 kg/y
Hydrocarbons	68 kg/y
Carbon Monoxide	772 kg/y
NOx	3,055 kg/y

TS053 Port Wakefield Road – Waterloo Corner Road

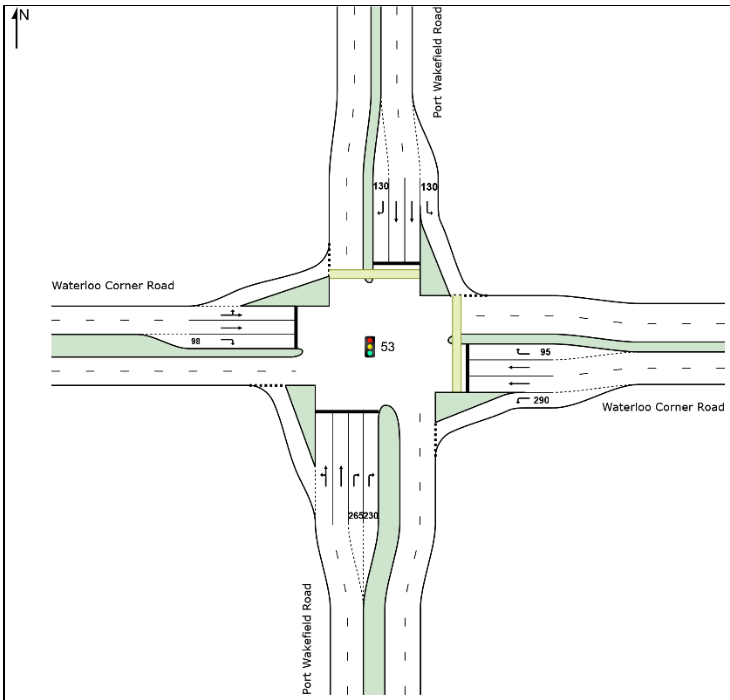


Figure D2 TS010 Grand Junction Road – Hanson Road Site Layout

Table D5 TS053 Accident Occurrence by Crash Type

Crash Type	Occurrence
Total	28
Rear End	17
Right Angle	4
Side Swipe	3
Right Turn	2
Hit Object	1
Other	1

Proposed Changes:

- Remove filtering right turn
- Reduce approaching speed
- Increase red time
- Optimise cycle time

Table D6 TS053 Yearly Cost Comparison

TS053	Intersection Operation Cost	Accident Cost	Total Cost
Before	$1,832,801	$2,089,333	$3,922,134
After	$1,944,916	$150,000	$2,094,916
Total Benefit	-$112,115	$1,939,333	$1,827,218

Table D7 TS053 Performance Summary Before Mitigating Measures

Intersection Performance - Annual Values		
Performance Measure	**Vehicles**	
Demand Flows (Total)	1,152,000	veh/y
Delay	11,744	veh-h/y
Effective Stops	856,049	veh/y
Travel Distance	1,843,664	veh-km/y
Travel Time	35,528	veh-h/y
Cost	1,832,801	$/y
Fuel Consumption	291,611	L/y
Carbon Dioxide	705,202	kg/y
Hydrocarbons	63	kg/y
Carbon Monoxide	937	kg/y
NOx	2,868	kg/y

Table D8 TS053 Performance Summary After Mitigating Measures

Intersection Performance - Annual Values		
Performance Measure	**Vehicles**	
Demand Flows (Total)	1,152,000	veh/y
Delay	11,395	veh-h/y
Effective Stops	988,787	veh/y
Travel Distance	1,843,664	veh-km/y
Travel Time	38,490	veh-h/y
Cost	1,944,916	$/y
Fuel Consumption	297,829	L/y
Carbon Dioxide	720,050	kg/y
Hydrocarbons	61	kg/y
Carbon Monoxide	841	kg/y
NOx	2,965	kg/y

TS073 Fullarton Road – The Parade

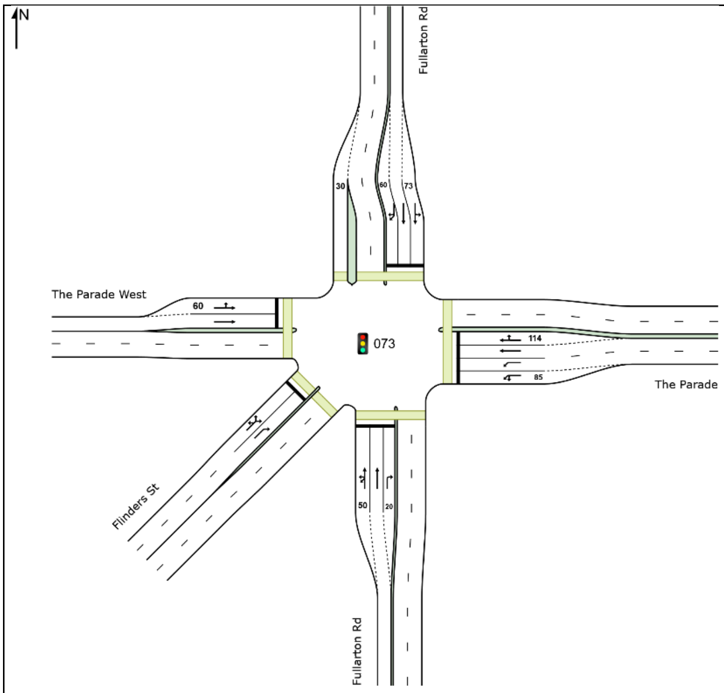


Figure D3 TS073 Grand Junction Road – Hanson Road Site Layout

Table D9 TS073 Accident Occurrence by Crash Type

TS073	Occurrence
Total	14
Right Turn	7
Right Angle	4
Rear End	2
Side Swipe	1

Proposed Changes:

- Remove filtering right turn
- Increase red time
- Optimise cycle time

Table D10 TS073 Yearly Cost Comparison

TS073	Intersection Operation Cost	Accident Cost	Total Cost
Before	$1,875,517	$1,675,667	$3,551,184
After	$1,811,679	$1,585,667	$3,397,346
Total Benefit	$63,838	$90,000	$153,838

Table D11 TS073 Performance Summary Before Mitigating Measures

Intersection Performance - Annual Values		
Performance Measure	**Vehicles**	
Demand Flows (Total)	1,337,937	veh/y
Delay	16,954	veh-h/y
Effective Stops	1,127,131	veh/y
Travel Distance	1,717,536	veh-km/y
Travel Time	45,698	veh-h/y
Cost	1,875,517	$/y
Fuel Consumption	160,884	L/y
Carbon Dioxide	380,031	kg/y
Hydrocarbons	33	kg/y
Carbon Monoxide	423	kg/y
NOx	392	kg/y

Table D12 TS073 Performance Summary After Mitigating Measures

Intersection Performance - Annual Values		
Performance Measure	**Vehicles**	
Demand Flows (Total)	1,337,937	veh/y
Delay	15,118	veh-h/y
Effective Stops	1,164,134	veh/y
Travel Distance	1,717,535	veh-km/y
Travel Time	43,863	veh-h/y
Cost	1,811,679	$/y
Fuel Consumption	159,531	L/y
Carbon Dioxide	376,843	kg/y
Hydrocarbons	33	kg/y
Carbon Monoxide	421	kg/y
NOx	394	kg/y

TS094 Cross Road – Fullarton Road

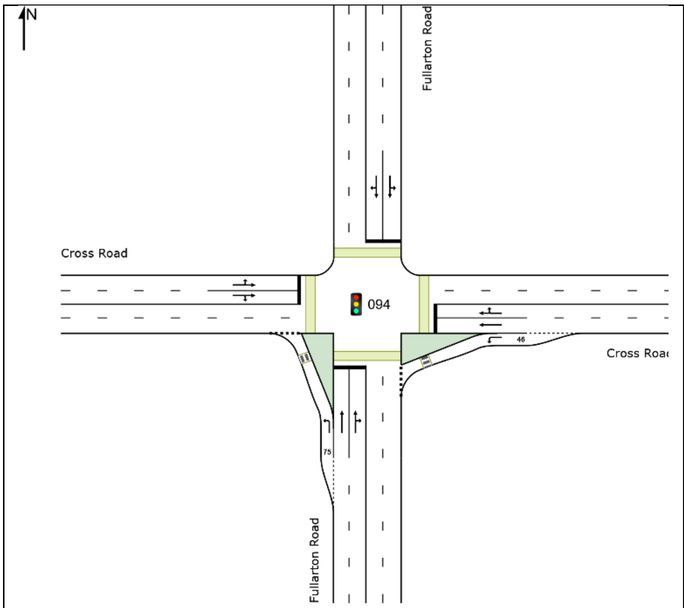


Figure D4 TS094 Grand Junction Road – Hanson Road Site Layout (Before Upgrade)

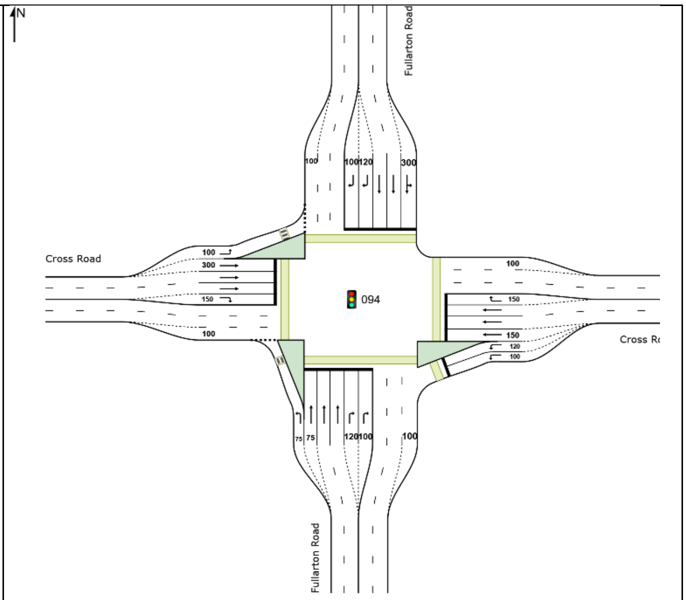


Figure D5 TS094 Grand Junction Road – Hanson Road Site Layout (After Upgrade)

Table D13 TS094 Accident Occurrence by Crash Type

Crash Type	Occurrence
Total	11
Rear End	5
Right Turn	2
Right Angle	1
Side Swipe	1
Roll Over	1
Hit Pedestrian	1

Proposed Changes:

- Intersection upgrade according to DIT proposal
- Remove filtering right turn
- Optimise Phasing
- Optimise cycle time

Table D14 TS073 Yearly Cost Comparison

TS094	Intersection Operation Cost	Accident Cost	Total Cost
Before	$14,226,760	$3,330,333	$17,557,093
After	$5,109,957	$29,667	$5,139,624
Total Benefit	$9,116,803	$3,300,667	$12,417,470

Table D15 TS094 Performance Summary Before Mitigating Measures

Intersection Performance - Annual Values	
Performance Measure	**Vehicles**
Demand Flows (Total)	2,284,801 veh/y
Delay	320,797 veh-h/y
Effective Stops	3,425,453 veh/y
Travel Distance	3,195,086 veh-km/y
Travel Time	381,466 veh-h/y
Cost	14,226,760 $/y
Fuel Consumption	707,824 L/y
Carbon Dioxide	1,673,838 kg/y
Hydrocarbons	205 kg/y
Carbon Monoxide	1,612 kg/y
NOx	1,961 kg/y

Table D16 TS094 Performance Summary After Mitigating Measures

Intersection Performance - Annual Values	
Performance Measure	**Vehicles**
Demand Flows (Total)	2,284,800 veh/y
Delay	72,795 veh-h/y
Effective Stops	2,543,030 veh/y
Travel Distance	3,219,890 veh-km/y
Travel Time	128,181 veh-h/y
Cost	5,109,957 $/y
Fuel Consumption	384,263 L/y
Carbon Dioxide	909,506 kg/y
Hydrocarbons	88 kg/y
Carbon Monoxide	944 kg/y
NOx	1,329 kg/y

TS116 Diagonal Road – Sturt Road

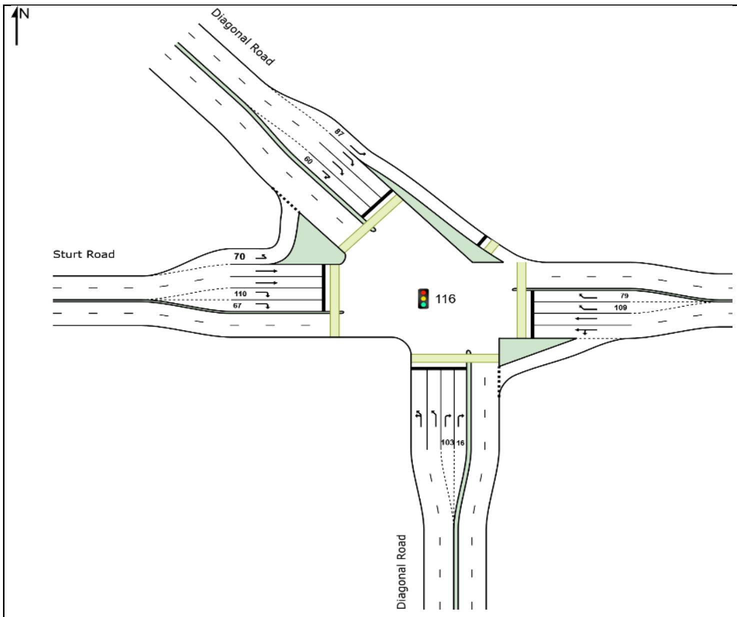


Figure D6 TS116 Diagonal Road – Sturt Road Site Layout

Table D17 TS116 Accident Occurrence by Crash Type

Crash Type	Occurrence
Total	27
Rear End	10
Right Turn	10
Side Swipe	4
Right Angle	2
Other	1

Proposed Changes:

- Remove filtering right turn
- Increase red and yellow time

Table D18 TS116 Yearly Cost Comparison

TS116	Intersection Operation Cost	Accident Cost	Total Cost
Before	$2,834,676	$1,869,000	$4,703,676
After	$3,066,304	$34,333	$3,100,637
Total Benefit	-$231,628	$1,834,667	$1,603,039

Table D19 TS116 Performance Summary Before Mitigating Measures

Intersection Performance - Annual Values	
Performance Measure	**Vehicles**
Demand Flows (Total)	1,866,442 veh/y
Delay	34,453 veh-h/y
Effective Stops	1,794,138 veh/y
Travel Distance	2,084,531 veh-km/y
Travel Time	69,931 veh-h/y
Cost	2,834,676 $/y
Fuel Consumption	230,473 L/y
Carbon Dioxide	545,465 kg/y
Hydrocarbons	51 kg/y
Carbon Monoxide	581 kg/y
NOx	739 kg/y

Table D20 TS116 Performance Summary After Mitigating Measures

Intersection Performance - Annual Values	
Performance Measure	**Vehicles**
Demand Flows (Total)	1,866,442 veh/y
Delay	40,586 veh-h/y
Effective Stops	1,899,713 veh/y
Travel Distance	2,084,531 veh-km/y
Travel Time	76,296 veh-h/y
Cost	3,066,304 $/y
Fuel Consumption	239,721 L/y
Carbon Dioxide	567,277 kg/y
Hydrocarbons	54 kg/y
Carbon Monoxide	598 kg/y
NOx	759 kg/y

TS236 Findon Road – Trimmer Parade

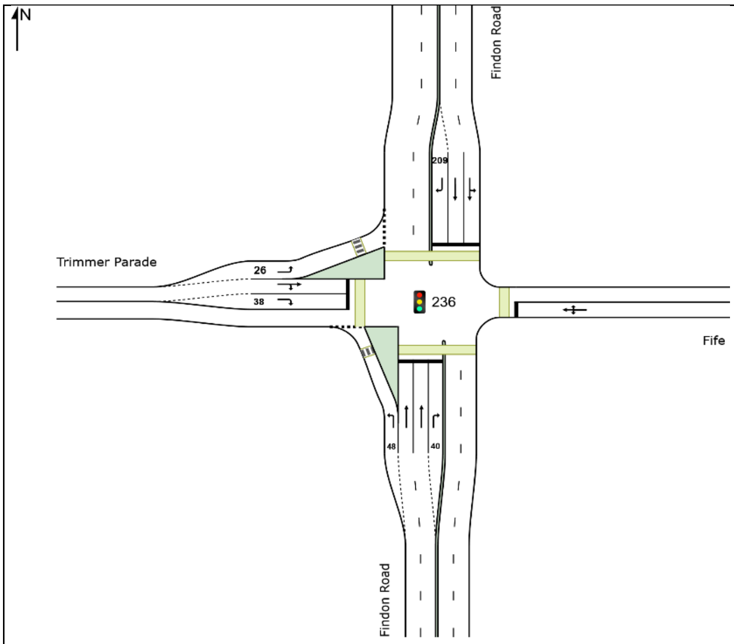


Figure D7 TS236 Findon Road – Trimmer Parade Site Layout

Table D21 TS236 Accident Occurrence by Crash Type

Crash Type	Occurrence
Total	8
Rear End	4
Right Turn	1
Side Swipe	1
Hit Object	1
Right Angle	1

Proposed Changes:

- Remove filtering right turn
- Increase red time

Table D22 TS236 Yearly Cost Comparison

TS236	Intersection Operation Cost	Accident Cost	Total Cost
Before	$1,586,505	$1,591,000	$3,177,505
After	$1,702,007	$42,000	$1,744,007
Total Benefit	-$115,502	$1,549,000	$1,433,498

Table D23 TS236 Performance Summary Before Mitigating Measures

Intersection Performance - Annual Values		
Performance Measure	**Vehicles**	
Demand Flows (Total)	1,496,084	veh/y
Delay	15,087	veh-h/y
Effective Stops	1,167,057	veh/y
Travel Distance	1,339,455	veh-km/y
Travel Time	37,860	veh-h/y
Cost	1,586,505	$/y
Fuel Consumption	147,818	L/y
Carbon Dioxide	350,685	kg/y
Hydrocarbons	32	kg/y
Carbon Monoxide	377	kg/y
NOx	584	kg/y

Table D24 TS236 Performance Summary After Mitigating Measures

Intersection Performance - Annual Values		
Performance Measure	**Vehicles**	
Demand Flows (Total)	1,496,084	veh/y
Delay	18,140	veh-h/y
Effective Stops	1,211,509	veh/y
Travel Distance	1,339,455	veh-km/y
Travel Time	41,036	veh-h/y
Cost	1,702,007	$/y
Fuel Consumption	152,397	L/y
Carbon Dioxide	361,497	kg/y
Hydrocarbons	33	kg/y
Carbon Monoxide	387	kg/y
NOx	595	kg/y

TS315 Francis Street, Perkins Drive

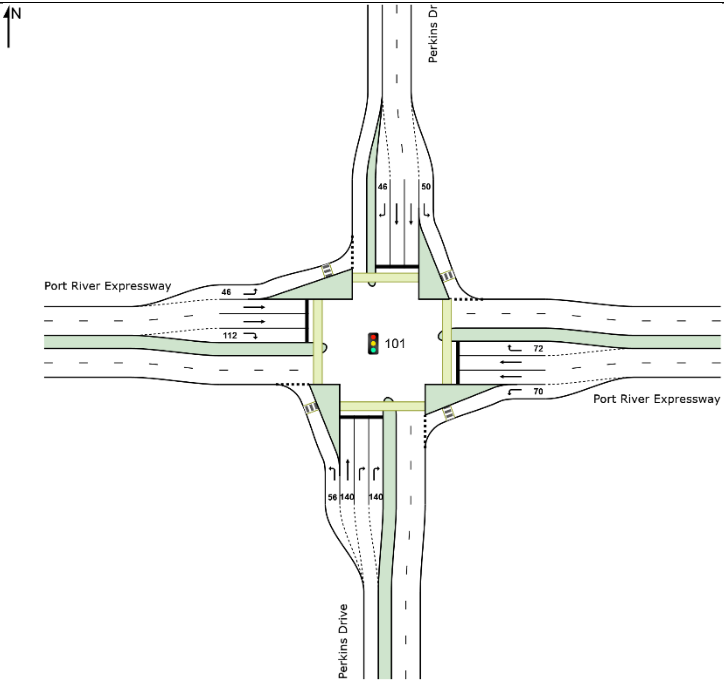


Figure D8 TS315 Francis Street – Perkins Drive Site Layout

Table D25 TS315 Accident Occurrence by Crash Type

Crash Type	Occurrence
Total	16
Rear End	10
Side Swipe	4
Right Turn	1
Other	1

Proposed Changes:

- Increase ted and yellow time

Table D26 TS315 Yearly Cost Comparison

TS315	Intersection Operation Cost	Accident Cost	Total Cost
Before	$3,362,960	$1,693,000	$5,055,960
After	$3,490,484	$1,590,333	$5,080,817
Total Benefit	-$127,524	$102,667	-$24,857

Table D27 TS315 Performance Summary Before Mitigating Measures

Intersection Performance - Annual Values		
Performance Measure	**Vehicles**	
Demand Flows (Total)	2,028,126	veh/y
Delay	19,160	veh-h/y
Effective Stops	1,722,424	veh/y
Travel Distance	3,323,683	veh-km/y
Travel Time	74,924	veh-h/y
Cost	3,362,960	$/y
Fuel Consumption	391,762	L/y
Carbon Dioxide	946,798	kg/y
Hydrocarbons	77	kg/y
Carbon Monoxide	968	kg/y
NOx	3,145	kg/y

Table D28 TS315 Performance Summary After Mitigating Measures

Intersection Performance - Annual Values		
Performance Measure	**Vehicles**	
Demand Flows (Total)	2,028,126	veh/y
Delay	22,476	veh-h/y
Effective Stops	1,845,153	veh/y
Travel Distance	3,323,683	veh-km/y
Travel Time	78,240	veh-h/y
Cost	3,490,484	$/y
Fuel Consumption	399,636	L/y
Carbon Dioxide	965,565	kg/y
Hydrocarbons	80	kg/y
Carbon Monoxide	988	kg/y
NOx	3,209	kg/y

TS325 Grand Junction Road – Nelson Road

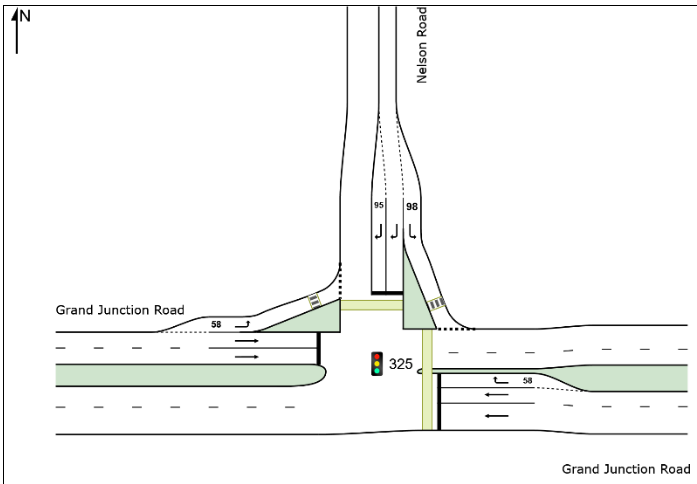


Figure D9 TS325 Grand Junction Road – Nelson Road Site Layout

Table D29 TS325 Accident Occurrence by Crash Type

TS325	Occurrence
Total	14
Right Turn	7
Rear End	2
Right Angle	2
Hit Fixed Object	2
Side Swipe	1

Proposed Changes:

- Remove filtering right turn
- Optimise cycle time

Table D30 TS325 Yearly Cost Comparison

TS325	Intersection Operation Cost	Accident Cost	Total Cost
Before	$1,117,980	$1,786,667	$2,904,647
After	$1,097,508	$1,706,333	$2,803,841
Total Benefit	$20,472	$80,333	$100,805

Table D31 TS325 Performance Summary Before Mitigating Measures

Intersection Performance - Annual Values	
Performance Measure	**Vehicles**
Demand Flows (Total)	1,013,053 veh/y
Delay	5,441 veh-h/y
Effective Stops	531,320 veh/y
Travel Distance	1,242,458 veh-km/y
Travel Time	26,278 veh-h/y
Cost	1,117,980 $/y
Fuel Consumption	110,071 L/y
Carbon Dioxide	262,101 kg/y
Hydrocarbons	24 kg/y
Carbon Monoxide	291 kg/y
NOx	482 kg/y

Table D32 TS325 Performance Summary After Mitigating Measures

Intersection Performance - Annual Values	
Performance Measure	**Vehicles**
Demand Flows (Total)	1,013,053 veh/y
Delay	4,312 veh-h/y
Effective Stops	759,110 veh/y
Travel Distance	1,242,458 veh-km/y
Travel Time	25,155 veh-h/y
Cost	1,097,508 $/y
Fuel Consumption	117,496 L/y
Carbon Dioxide	279,634 kg/y
Hydrocarbons	26 kg/y
Carbon Monoxide	307 kg/y
NOx	548 kg/y

TS449 Sherriffs Road – Southern Expressway Ramp

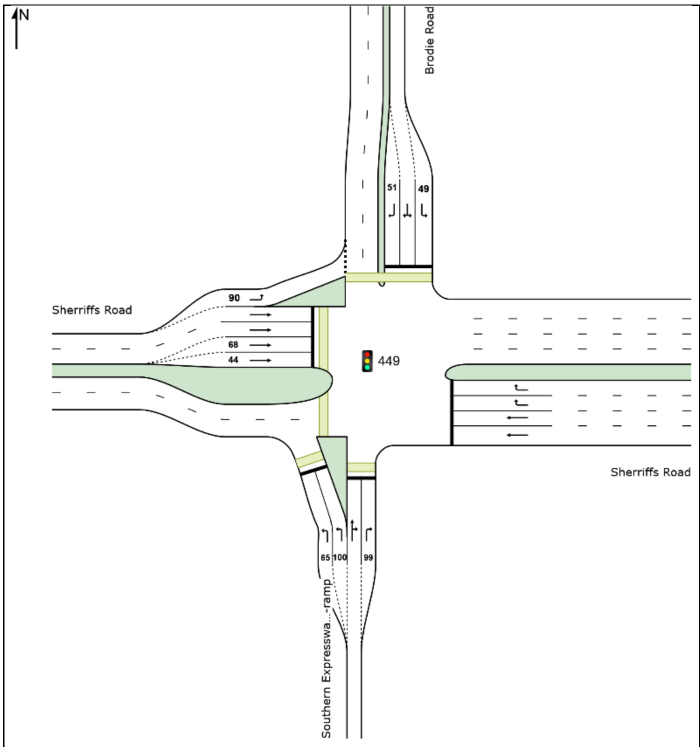


Figure D10 TS449 Sherriffs Road – Southern Expressway Ramp Site Layout

Table D33 TS449 Accident Occurrence by Crash Type

Crash Type	Occurrence
Total	10
Right Turn	3
Right Angle	2
Rear End	2
Rollover	1
Fixed Object	1
Other	1

Proposed Changes:

- Increase red and yellow time
- Reduce approaching speed

Table D34 TS449 Yearly Cost Comparison

TS449	Intersection Operation Cost	Accident Cost	Total Cost
Before	$1,500,659	$1,637,667	$3,138,326
After	$1,579,548	$1,567,000	$3,146,548
Total Benefit	-$78,889	$70,667	-$8,222

Table D35 TS449 Performance Summary Before Mitigating Measures

Intersection Performance - Annual Values	
Performance Measure	**Vehicles**
Demand Flows (Total)	1,483,453 veh/y
Delay	11,605 veh-h/y
Effective Stops	1,050,702 veh/y
Travel Distance	1,490,929 veh-km/y
Travel Time	36,701 veh-h/y
Cost	1,579,548 $/y
Fuel Consumption	161,778 L/y
Carbon Dioxide	385,961 kg/y
Hydrocarbons	34 kg/y
Carbon Monoxide	411 kg/y
NOx	938 kg/y

Table D36 TS449 Performance Summary After Mitigating Measures

Intersection Performance - Annual Values	
Performance Measure	**Vehicles**
Demand Flows (Total)	1,483,453 veh/y
Delay	11,208 veh-h/y
Effective Stops	1,033,168 veh/y
Travel Distance	1,490,929 veh-km/y
Travel Time	33,471 veh-h/y
Cost	1,500,659 $/y
Fuel Consumption	174,272 L/y
Carbon Dioxide	415,504 kg/y
Hydrocarbons	39 kg/y
Carbon Monoxide	525 kg/y
NOx	1,035 kg/y

TS3166 George Street – Port Road

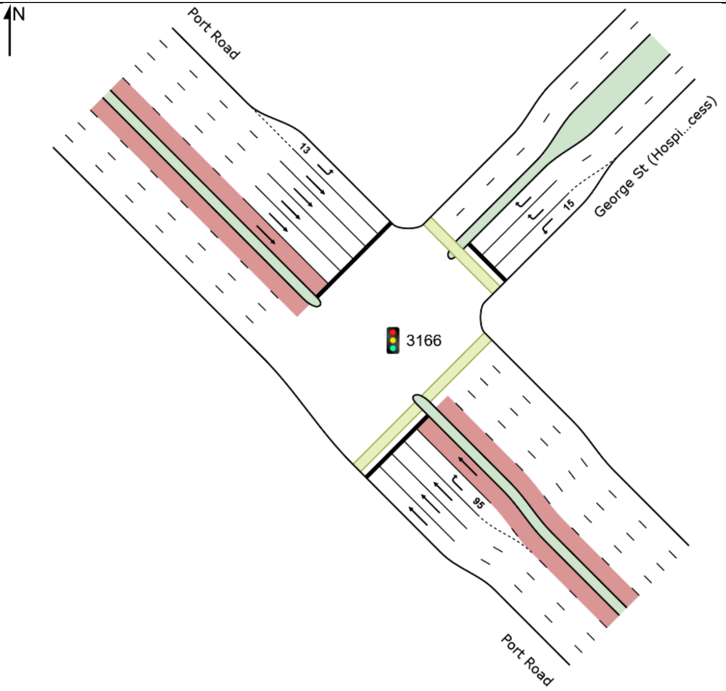


Figure D11 TS3166 George Street – Port Road Site Layout

Table D37 TS449 Accident Occurrence by Crash Type

TS3166	Occurrence
Total	10
Side Swipe	3
Right Turn	2
Rear End	2
Right Angle	1
Left Road - Out of Control	1
Hit Fixed Object	1

Proposed Changes:

- Increase red and yellow time

Table D38 TS3166 Yearly Cost Comparison

TS3166	Intersection Operation Cost	Accident Cost	Total Cost
Before	$1,787,878	$1,602,000	$3,389,878
After	$1,886,008	$1,567,000	$3,453,008
Total Benefit	-$98,130	$35,000	-$63,130

Table D39 TS3166 Performance Summary Before Mitigating Measures

Intersection Performance - Annual Values		
Performance Measure	**Vehicles**	
Demand Flows (Total)	2,003,368	veh/y
Delay	34,477	veh-h/y
Effective Stops	1,264,334	veh/y
Travel Distance	443,305	veh-km/y
Travel Time	42,927	veh-h/y
Cost	1,787,878	$/y
Fuel Consumption	116,288	L/y
Carbon Dioxide	276,159	kg/y
Hydrocarbons	28	kg/y
Carbon Monoxide	243	kg/y
NOx	523	kg/y

Table D40 TS3166 Performance Summary After Mitigating Measures

Intersection Performance - Annual Values		
Performance Measure	**Vehicles**	
Demand Flows (Total)	2,003,368	veh/y
Delay	36,986	veh-h/y
Effective Stops	1,304,594	veh/y
Travel Distance	443,305	veh-km/y
Travel Time	45,491	veh-h/y
Cost	1,886,008	$/y
Fuel Consumption	120,458	L/y
Carbon Dioxide	286,000	kg/y
Hydrocarbons	29	kg/y
Carbon Monoxide	250	kg/y
NOx	536	kg/y