University of Southern Queensland

Faculty of Health, Engineering and Sciences

Dissertation

Analysis of Road Safety Trends at Signalised Intersections in Toowoomba

A dissertation submitted by

Ross Milton

In fulfilment of the requirements of

ENG4111 and 4112 Research Project

towards the degree of

Bachelor of Engineering (Honours) (Civil)

Submitted October, 2016

Abstract

Road trauma is one of the most significant public health concerns of developed countries. Transportation is a risky activity as motion creates kinetic energy and if a road crash occurs the energy exchange can be harmful to both people and property. Previous Toowoomba Road Crash data indicates that 64% of all collisions occurred at intersections. Therefore the main aim of this research project was to identify intersection features which aid in the reduction of road crashes at signalised intersections in Toowoomba.

This aim has been achieved through the development of a signalised intersection classification system which was successful in classifying 50 out of 71 intersections into similar groups, based upon intersection geometry, signal phasing and traffic volume. Road crash trends were analysed at these 50 intersections and common crash types and contributing factors were identified.

A 33% reduction in road crashes was observed at intersections with four phase signal cycles, when compared to intersections with two and three phase cycles.
Similar crash reductions and reductions in crash severity were also observed at intersections with designated right turn lanes compared to intersections without any. Intersections with two phase signal cycles had an increased proportion of road crashes caused by drivers disobeying traffic signals, when compared to intersections with three and four phase cycles.

Engineering solutions to enhance road user safety within the region have been proposed for the intersections with the 10 highest crash rates. These crash reduction solutions have been based upon the findings of this research project. Significant crash rate reductions could be achieved by adding additional controls to these 10 intersections.

University of Southern Queensland

Faculty of Health, Engineering and Sciences

ENG4111 & ENG4112 Research Project

Limitations of Use

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Ross Milton

Student Number: 0050087947

Acknowledgments

I would like to take this opportunity to thank the following people for their assistance, guidance and support during the preparation and delivery of this dissertation:

Dr Soma Somasundaraswaran (Project Supervisor)
University of Southern Queensland

Etiene LaGrange
Toowoomba Regional Council

I would also like to thank my family and loving wife for their constant support and encouragement during the course of completing my studies.

Ross Milton

Table of Contents

List of Figures

List of Tables

Glossary of Terms

AADT	Average Annual Daily Traffic
CRF	Crash Reduction Factor
DCA	Definition for Coding Accidents
DTMR	Department of Transport and Main Roads
HV	Heavy Vehicle
km/h	Kilometres per Hour
RMEV	Rate per Million Entering Vehicles
RTA	Roads and Traffic Authority
TRC	Toowoomba Regional Council
WHO	World Health Organisation

1 Introduction

Due to road crashes each year over one million people die and 50 million people are injured worldwide (World Health Organisation, 2004). In Australia and New Zealand nearly two thousand people are killed and over twenty thousand are seriously injured in road crashes each year. The cost to New Zealand and Australia resulting from road crashes is estimated over twenty billion dollars per year. Transportation is a risky activity as motion creates kinetic energy and if a crash occurs the energy exchange can be harmful to both people and property. At walking speed the damage if any is minor, however at the speed of vehicle in motion the damage can be life-threatening. Road trauma is one of the most significant public health concerns of developed countries (Austroads 2009).

Transportation is an essential element in the economic development and growth of a society. A region or nation cannot achieve the maximum use of its natural resources or the maximum productivity of its people without an efficient and effective transportation system. In Australia automotive transportation on road networks is the predominant method of transportation. With greater transportation mobility and increasing use by the road user comes increased risk of collisions on the road network. The cost to society through deaths and injuries resulting from road crashes can be enormous. In 2014, 1186 fatalities occurred as a result of road crashes across Australia, with 223 fatalities occurring on Queensland roads (Department of Transport and Main Roads 2015).

Previous studies indicate that intersections are one of the most hazardous locations on the road network with potential for higher risk collisions, such as right angle crashes. To avoid collisions at intersections traffic must be separated in space, by the means of an overpass for example, or separation in time. A common way to separate traffic in ‘time’ is with traffic signals. Traffic signals are used extensively at intersections to control traffic movements, as cost and space limitations often make grade changes (separation in space) uneconomical to employ.

1.1 Study Location

The chosen location to carry out this research project is the South-East Queensland City of Toowoomba. Toowoomba is located 125 kilometres to the west of the state capital Brisbane on the crest of the Great Dividing Range, approximately 700 metres above sea level. The estimated population within the city was 113,625 in 2014 (Australian Bureau of Statistics 2016).

In Toowoomba, road transport is the most common and efficient method of transportation currently available. The City's transport system is dominated by the National and State highways that pass through it, with heavy North-South traffic movement via the New England Highway and East-West traffic movement via the Gore and Warrego Highways. These major traffic routes intersect near the city's centre and cause increased loading of the road network, particularly during peak travel times (Sharp 2006).

There is currently no highway bypass system around the city, although one has been in the planning stage for many years now. In recent times a contract to deliver such infrastructure has been awarded and work is likely to commence in 2016. It will however take a number of years to complete. The National and State highways that pass through Toowoomba are the responsibility of the Department of Transport & Main Roads (DTMR). All other local roads and streets within the city are the responsibility of the Toowoomba Regional Council (TRC), a local government organisation. The layout of Toowoomba's streets is generally of a grid type pattern with a road hierarchy not clearly defined. This produces increased connectivity while resulting in a mixing of different traffic types. There are over 2500 different intersections across the Toowoomba City road network, with 78 of these being signalised intersections.

1.2 Problem Statement

Since amalgamation in 2008, the Toowoomba Regional Council has recognised the need for embracing a more strategic engineering approach towards road safety across the region. In 2013, fatal crashes were higher than average within the Darling Downs region. Therefore this study aims to examine the crash statistics within the Toowoomba Region for developing innovative engineering approaches to enhance road safety within the region. A study conducted in 2006 of Toowoomba Road Crashes indicated that 64% of all collisions occurred at intersections (Sharp 2006).

With a significant proportion of road crashes occurring at intersections, this is where the study has focused. By creating an intersection classification system, similar intersections can be categorized together. These can then be studied and then a comparison of their crash statistics can be made to determine if one particular intersection is performing better or worse than other intersections of the same configuration. With this information known an investigation can be carried out to determine why an intersection might be performing well or poorly and remedial actions can be designed to improve road user safety.

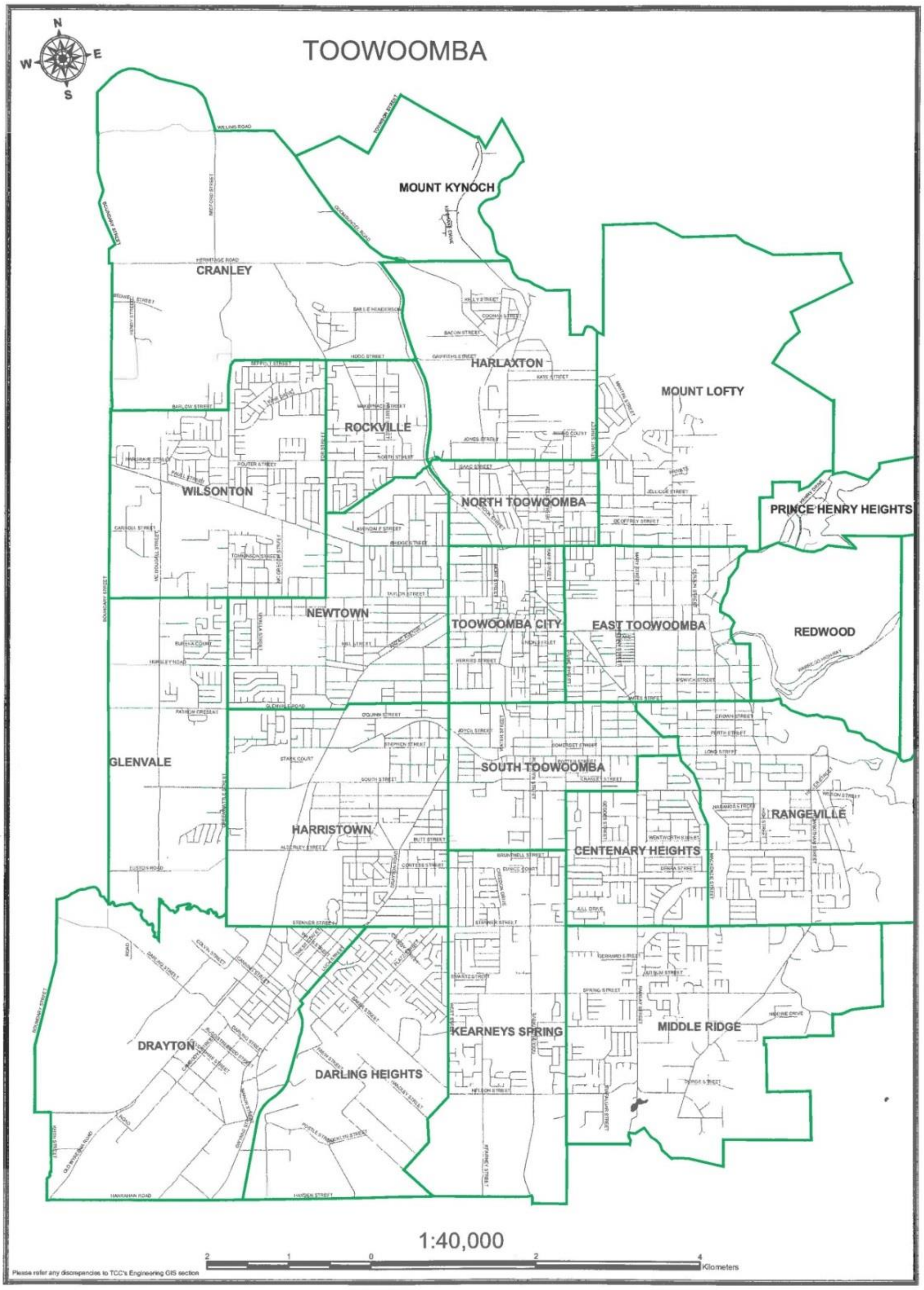


Figure 1 - Toowoomba Suburbs

(Toowoomba Regional Council)

1.3 Project Aim

The aim of this research project was to identify signalised intersections which are performing well or poorly in terms of Road User Safety and to identify intersection features which aid in the reduction of road crashes at signalised intersections in Toowoomba.

1.4 Project Objectives

1. Develop a signalised intersection classification system which will enable similar intersections to be categorized by their physical configuration.

2. Quantify, characterise and interpret trends in road crashes reported including identification of the common crash types and contributing factors.

3. Evaluate the effectiveness of the strategies that can be adapted to propose innovative engineering solutions to enhance Road User Safety in the Toowoomba Region.

4. Compare Toowoomba Regional Council safety initiatives and programs to other initiatives developed nationally and internationally.

2 Background Information

A Literature review has been carried out to gain further knowledge of the subject and to highlight significant research that has already been carried out. This literature review will discuss in detail the following topics specific to the project:

- The Road Crash
- Factors Contributing to Road Safety
- Crash Data Analysis
- Road Hierarchy
- Intersection Classification
- Road Crash Reduction Techniques
- Toowoomba Regional Council Safety Initiatives

2.1 The Road Crash

A road crash which is also referred to as an accident or collision, is an unintentional event which causes property damage and/or injury or death as a result of the movement of a vehicle on a road. A road crash may involve a single vehicle or many, and may result from a range of factors, including speed, inattention, drink driving, fatigue, road design and maintenance deficiencies and possibly vehicle defects (Austroads, 2009).

The following examples do not constitute a road crash:

- Vehicle crashes on a private property
- A crash that involves deliberate intent, such as suicide or murder.

Austroads (2009) have also stated that there are three elements which interact to cause a road crash. These elements are the Vehicle Factor, the Road Factor and the Human Factor. A road crash results from a failure in this system.

The Queensland Department of Transport and Main Roads (2012) defines a number of key terms which will be used throughout this research project.

- **Road Crash Fatality** – Is a person who dies within 30 days as a result of injuries sustained in a road traffic crash.
- **Crash Severity –** Is a measure of the seriousness of a road crash. The severity is determined by the most severe casualty resulting from the crash, or dollar value if there are no casualties. The severity levels range from a Fatal Crash to a Property Damage Only Crash.
- **Crash Frequency** – The number of crash occurrences per year.
- **Intersection Crash –** Is a crash which occurs as a result of interaction with an intersection.

2.2 Factors Influencing Road Safety

Most other cities in Australia of similar size to Toowoomba have a highway bypass system in place so freight and other through traffic can avoid travelling through the city centre. Toowoomba does not currently have such a bypass system in place. The city is part of the National Highway system and has heavy North-South traffic movement via the New England Highway and East-West traffic movement via the Gore and Warrego Highways. These major traffic routes intersect near the city's centre and cause increased loading of the road network, particularly during peak time (Sharp, 2006). A highway bypass for Toowoomba has been in the planning stage for many years now. In recent times a contract to deliver such infrastructure has been awarded and work will commence in 2016. It will however take a number of years to complete.

As mentioned previously a study carried out by Sharp in 2006 found that 64% of all crashes occurring in Toowoomba over the five year study period, occurred at intersections (both signalised and unsignalised). Over the same period 38% of fatal road crashes occurred at intersections and 62% occurred midblock. This seems to indicate that lower speed environments produce less severe crashes.

In 2011 across Queensland 269 road crash fatalities were recorded from 227 fatal crashes. The contributing factors determined by the Department of Transport and Main Roads (2012) have been listed below:

- Alcohol contributed to 33% of all Fatalities
- Illegal manoeuvers contributed to 25% of all Fatalities
- Speeding contributed to 18% of all Fatalities
- Fatigue contributed to 15% of all Fatalities

The statistics presented here are all crashes where human factors are the primary contributing factor.

Ogden (1996) identified a number of principles for the safe design and operation of intersections. Austroads (2009) also refers to these same principles, which are listed below:

- Minimise the number of conflict points
- Give precedence to major traffic movements through alignment, delineation, and traffic control
- Separate conflict points in space and time
- Clearly define vehicle paths
- Ensure adequate sight distances
- Control approach speeds
- Minimise road side hazards
- Provide for all traffic likely to use the intersection, such as heavy vehicles, public transport and pedestrians
- Minimise the road user delay

Another study by Ogden (1994) identified factors affecting road crashes at signalised intersections. These factors are listed below:

- **Controlled Right Turns** – This removes the need for drivers to select a gap in which to cross.
- **Leading Right Turns** – The controlled right turn phase is introduced before the through movement phase to reduce the risk of a through vehicle running the red light and colliding with the vehicle turning right.

- **Advance Warning –** Providing advanced warning to motorists of signals when they are not visible until late in the approach.
- **Red Light Cameras** – The number of motorists running red lights can be reduced if they perceive that there is a risk of detection.
- **Over Head Mast Arms** – Provides motorists with advanced warning of the intersection and a more conspicuous display.
- **Skid Resistant Pavements –** On the approach to an intersection pavements providing higher skid resistance have positive safety benefits

2.3 Crash Data Analysis

There are many methods used by various organisations around the world to define road crashes by type. The method commonly used in Australia and recommended by Austroads is the Definition of Coding of Accidents (DCA). Road crashes are generally categorized by type to describe the nature of the crash and to assist future analysis and investigations.

The standard table for Australian DCA codes is shown in Figure 2, which Austroads source from Andreassen (1991). The crash type is determined by first looking to the columns of the coding system which reference the traffic movement leading up to the conflict situation from which the crash resulted. The rows of the coding system are referred to next, and relate to the road user intent and actual movement (Andreassen 1994). Therefore each road crash is defined by a three digit code. For example a crash involving a vehicle turning right and colliding with an oncoming vehicle would be given a code of 202.

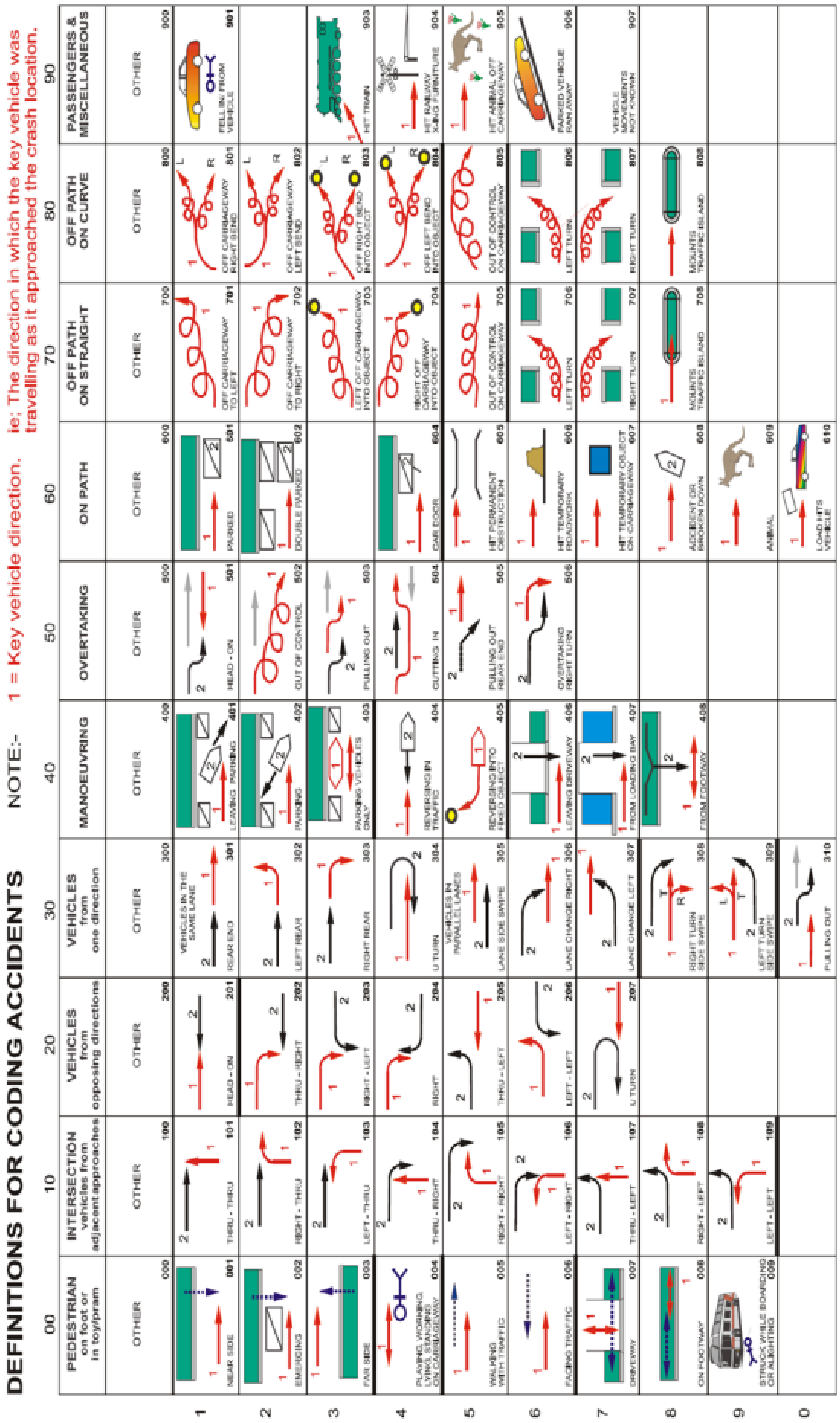


Figure 2 - Australian DCA Codes

(Modified from Andreassen 1991)

2.4 Road Hierarchy

A Road Hierarchy is a classification system where a particular road is categorised based on the function it is to perform or is already performing. If the function of the road is clear then suitable traffic management measures and design criteria can be implemented.

The function of a road is reflected in its classification through characteristics such as traffic speed, volume, level of access and the mix of vehicular and pedestrian movements. There are two essential functions of any road:

1. Traffic Mobility – Movement of people and goods
2. Traffic Access – Providing access to properties and land.

In its simplest form a road hierarchy will comprise of two basic road classifications, which have primarily different traffic and environmental goals:

1. Arterial Roads - The main function is to provide for the safe and efficient movement of people and freight.
2. Local Roads - Provide direct access to adjoining land uses and contribute to the overall operation of areas bounded by arterial roads, by providing a good environment in which to live or conduct a business.

Ideally a particular road would only perform one of these primary roles, but in practice most roads do both and are designed or managed to obtain an optimum balance between mobility and access (Austroads 2015).

The Toowoomba Planning Scheme sets out the criteria for all new and existing roads in the Toowoomba Region Local Government Area including reserve and carriageway widths, anticipated vehicle capacity, cross-falls, sight distances and design speeds. The Toowoomba Regional Council's objective under this scheme is to implement a functional hierarchy which enables an efficient street and road system that can provide for the movement of people and goods, while maintaining the amenity of the urban area (Toowoomba Regional Council 2016c).

The Toowoomba Regional Council states the following under its Planning Scheme regarding its road hierarchy:

- Higher order roads including state controlled roads, are preserved as through routes for inter-regional and intra-regional vehicle movements.
- The local street networks are designed to offer high levels of connectivity between higher order roads, while at the same time promoting slow traffic speeds where pedestrians and cyclists take precedence (Toowoomba Regional Council, 2016b).

The Toowoomba Regional Council classifies the roads within its network based on the following criteria.

Road Class	Desirable Speed	Urban Volume to Capacity Ratio	Lane Width
Highway	100 km/h	0.65	3.5 m
Region Arterial	80-100 km/h	0.65	3.5 m
Sub Arterial	60-80 km/h	0.70	3.5 m
Distributer	60 km/h	0.75	3.5 m
Collector / Local Access	40-50 km/h	0.85	3.5 m

Table 1 – TRC Road Classification 1

Road Class	Level of Access	Edge Treatment
Highway	-	Shoulders no kerbing
Region Arterial	Generally free flowing and controlled access	Shoulders
Sub Arterial	Controlled intersections and access limited to formal building addresses	Urban kerbing
Distributer	Access limited to formal building addresses and generally priority junctions	Barrier kerb with pedestrian and cycle paths
Collector / Local Access	Frontage access for developments and priority junctions with subordinate roads	Barrier kerb generally

Table 2 – TRC Road Classification 2

Road Class	Desirable Minimum Intersection Spacing	Preferred Intersection Form
Highway	5 km (3 km in urban areas)	Grade Separated
Region Arterial	1 km	Signals or Roundabouts
Sub Arterial	500 m	Signals or Roundabouts
Distributer	200 – 300 m	Priority Tee Intersection
Collector / Local Access	120 m	Priority Tee Intersection

Table 3 – TRC Road Classification 3

(Toowoomba Regional Council 2016a)

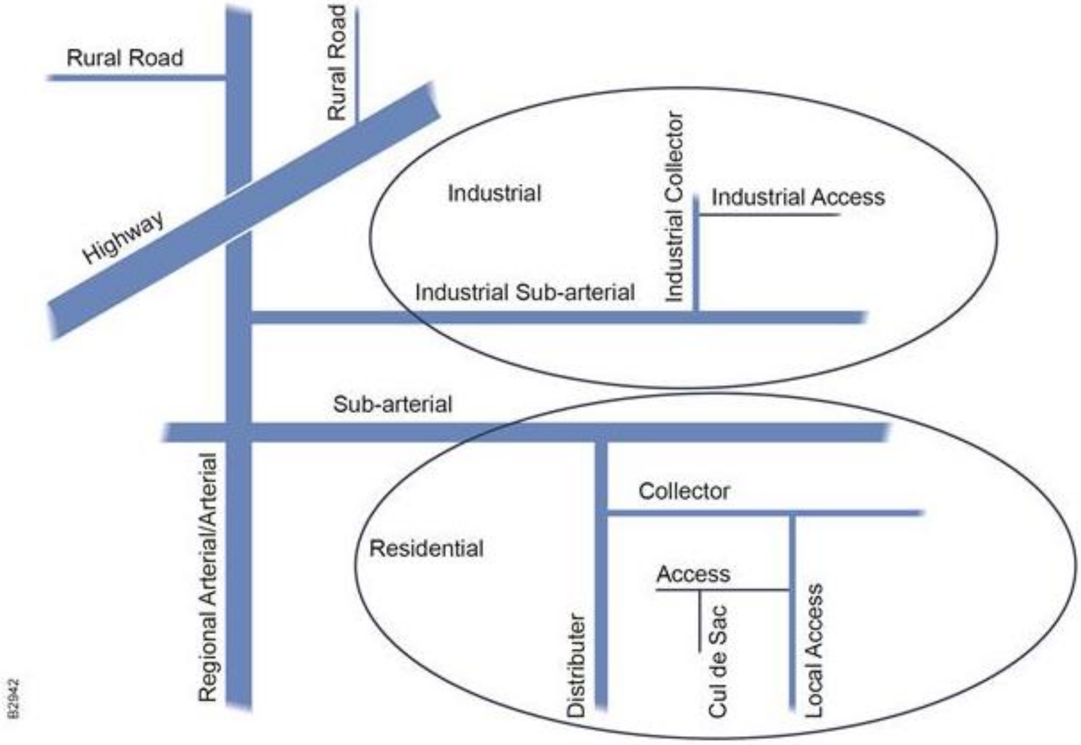


Figure 3 - TRC Functional Hierarchy of Roads

(Toowoomba Regional Council 2016c)

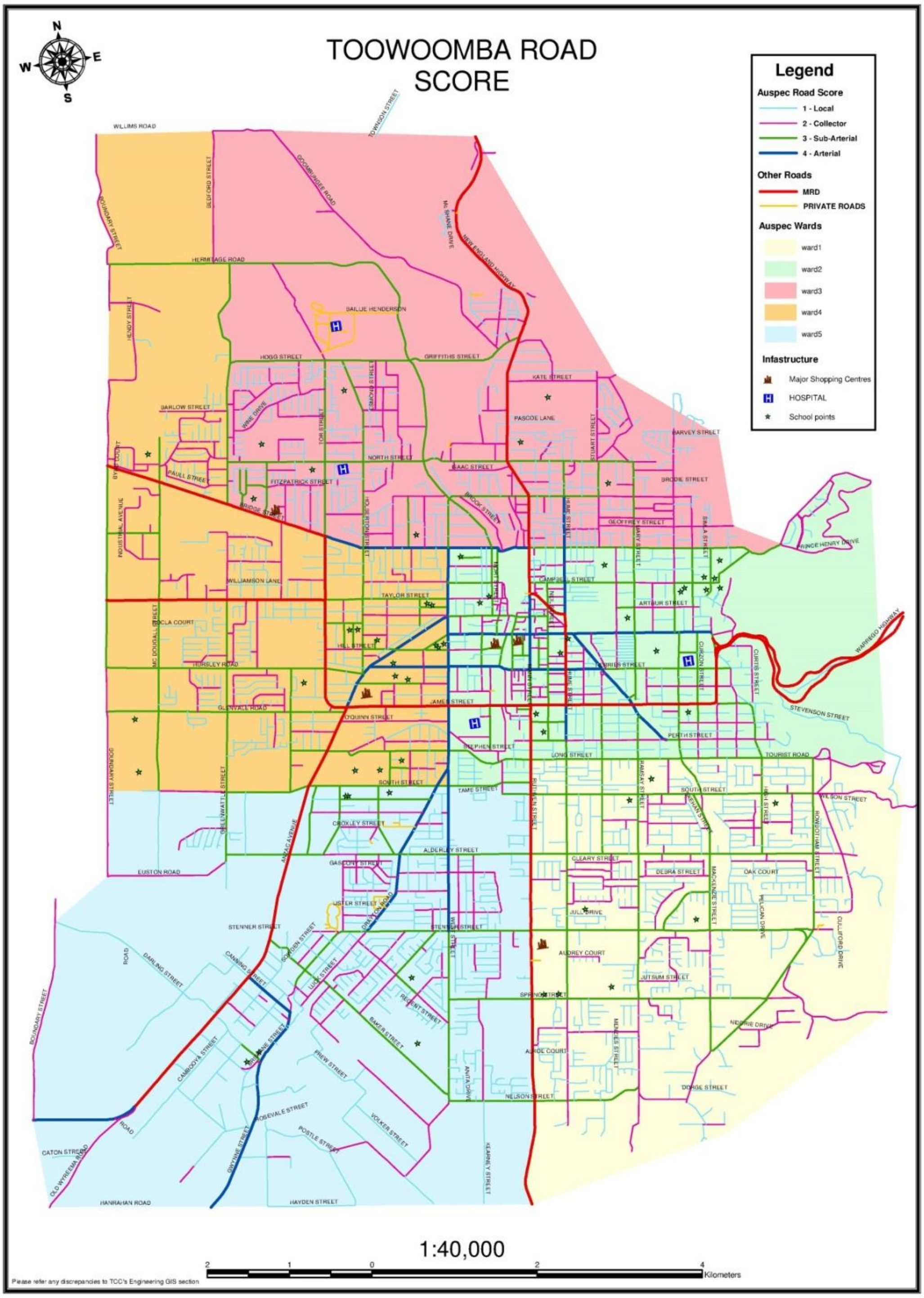


Figure 4 - Toowoomba Road Hierarchy

(Toowoomba Regional Council)

2.5 Intersection Classification

A search has been carried out to find other means or techniques to classify signalised intersections. However after studying the leading producers of literature in this area, it seems that only simple intersection classifications exist and little is discussed about linking the classifications to crash data.

Austroads' Guide to Traffic Management (2013) simply classifies intersections into the following groups:

- Signalised
- Unsignalised
- Roundabout
- Grade Separated

The New South Wales government department Roads and Traffic Authority (RTA) (2008) identifies signalised intersections based on the type of signal phasing. The main phasing alternatives described by the RTA are listed below:

- **Two Phase Design** – This is the simplest possible phasing for an intersection. One road, from both directions, is given access to the intersection. Traffic is then stopped so the other intersecting road can access the intersection. Traffic turning right must select their own gap to proceed.
- **Diamond Phasing** – Opposite right turns at an intersection are run simultaneously while through movements are stopped. The right turns are stopped to allow through traffic to proceed.
- **Split Approach Phasing** – Allows only one approach to access the intersection at any one time. This phasing is only used when signalised right turns are required but exclusive right turn lanes cannot be provided.
- **Repeated Right Turn -** The right turn phase is introduced for a second time within the same cycle.

Mannering (2005) in the text ‘Principles of Highway Engineering and Traffic Analysis’ differentiates signalised intersections by its signal phasing. The complete traffic signal cycle at an intersection is the sum of the individual phases. The simplest traffic signal cycle is made up of two phases, as shown below in Figure 5.

The first phase allows for North/South bound traffic to enter the intersection while stopping East/West bound traffic. The second phase is the opposite by allowing East/West traffic movements and stopping North/South bound traffic.

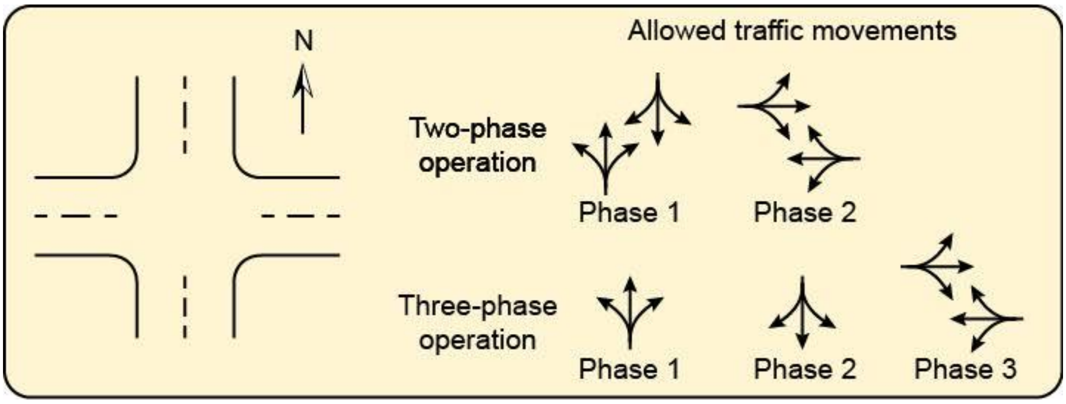


Figure 5 - Two Phase Signal Cycle
(Modified from Mannering 2005)

Two phase cycles can be inefficient or hazardous if one or more of the approaches includes a high volume of right turn movements. To alleviate this issue a separate phase could be given to each approach with high right turn movements. It should be noted that there is lost time with each added phase through ‘start-up and clearance’ times, therefore protected turn phases should only be added when warranted. Mannering provides a diagram illustrating typical signal cycles which is shown below in Figure 6.

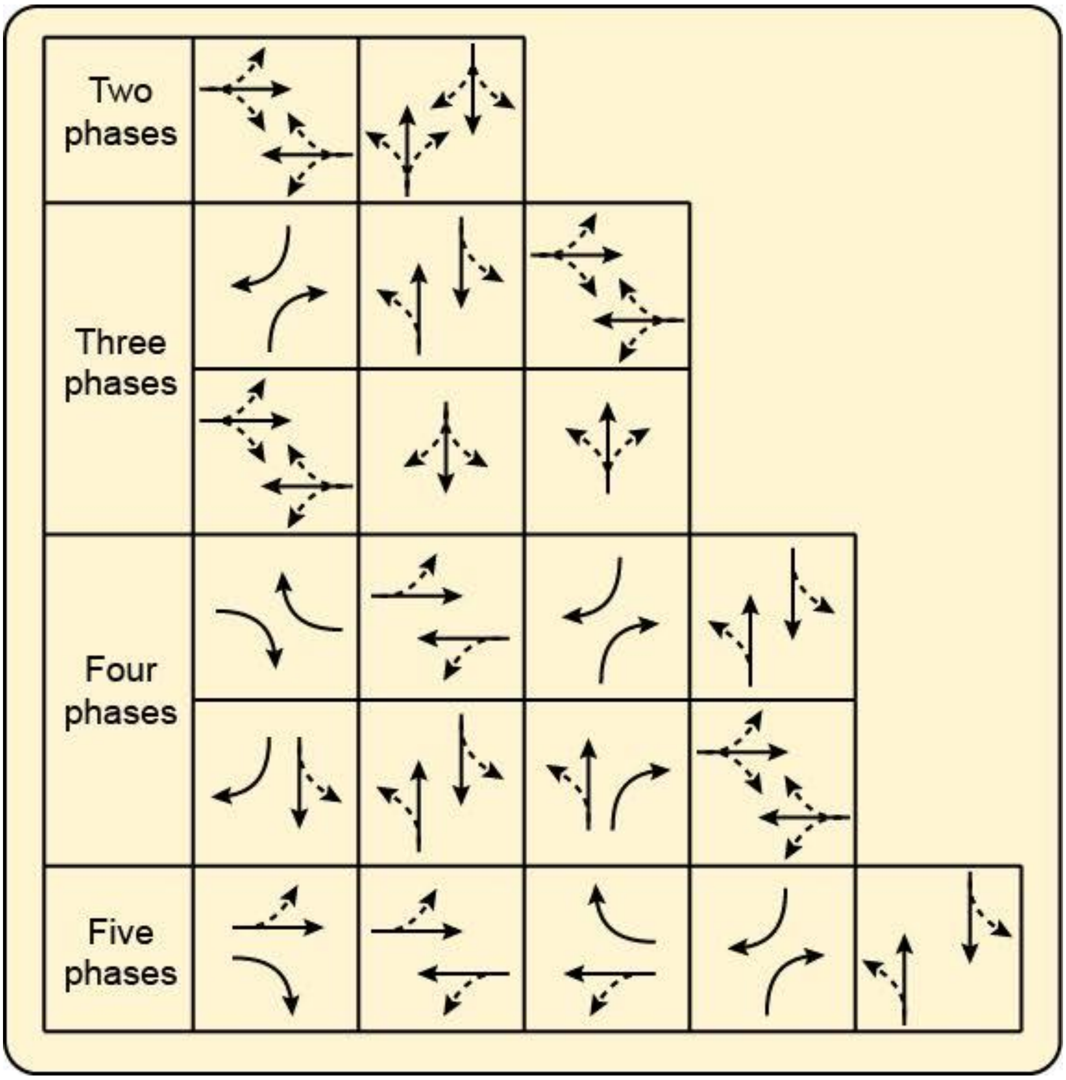


Figure 6 – Typical Signal Cycles

(Modified from Mannering 2005)

Morocoima-Black, Chavarría and Kang (2003) conducted an intersection crash study on behalf of the Champaign Country Regional Planning Commission, USA. In this study both signalised and unsignalised intersections were classified based on the volume of traffic entering the intersection.

- Class A: 20,000 daily vehicles or greater
- Class B: 10,000 to 19,999 daily vehicles
- Class C: 5,000 to 9,999 daily vehicles
- Class D: 2,000 to 4,999 daily vehicles
- Class E: 1,999 or less daily vehicles

A report into improving intersection safety, compiled by Rocchi (2003), produced an intersection classification system based on the hierarchy of the roads intersecting, traffic mix, traffic control type and the number of approach lanes. There are 36 possible intersection combinations. Each intersection is then assigned to one of six possible classifications. These classifications are shown below in Figure 8.

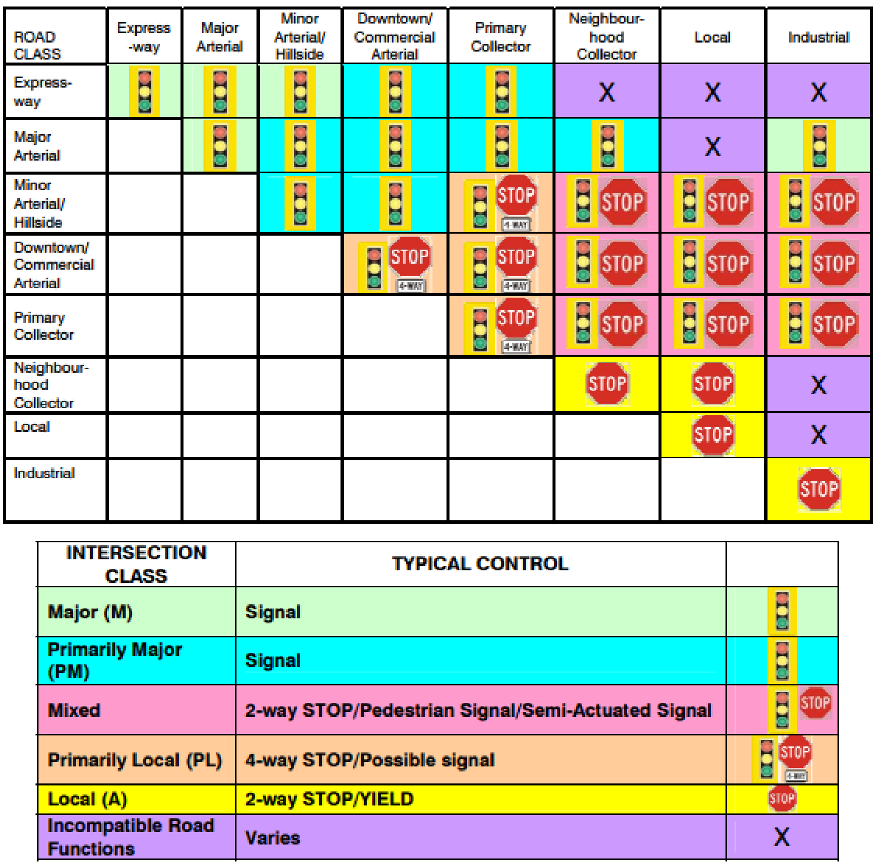


Figure 7 - Major Categories of Intersection Classification by Road Classification
(Rocchi 2003)

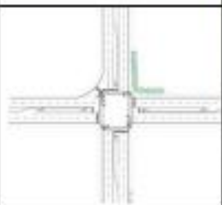
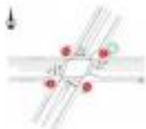
CLASS	DESCRIPTION	TYPICAL LAYOUT	EXAMPLE
MAJOR	An intersection between two major arterials and/or expressways. Movement of through traffic is most important. Access to adjacent properties and movement of pedestrians is a lower priority. Generally controlled by a multi-phase traffic signal.		
PRIMARILY MAJOR	An intersection between two roadways that have a strong proportion of through traffic, but which also allow some access to adjacent streets. Pedestrian volumes could be high. Fairly typical in downtown areas. Generally controlled by a traffic signal.		
MIXED	Occur where a local or industrial road crosses roadway of a much higher classification. Such intersections are common in traditional grid-style road networks. They usually have pedestrian or semi-actuated signals, or two-way STOP control.		
PRIMARILY LOCAL	At this intersection, traffic volumes are relatively balanced. Pedestrian volumes are likely high, and providing access to the adjoining properties is a priority. Such intersections usually have 4-way STOP control, or roundabouts, but a signal may be considered under certain situations.		
LOCAL	At this intersection, traffic volumes are relatively low. Access to adjacent properties and movement of bicycles and pedestrians is the priority. Generally has two-way STOP control		
Incompatible Functions	In a typical road hierarchy, intersections between expressways and local streets are not recommended. When they occur, they are frequently candidates for closure, turn restrictions or re-classification of one of the intersecting streets.	No diagram provided	No photo provided

Figure 8 - Intersection Classes

(Rocchi 2003)

The study conducted by Sharp (2006) developed the following classification system. In this system intersections are classed by road hierarchy, intersection type (cross, roundabout etc.) and method of control (signals, stop sign, give way etc.) This system produces forty possible intersection combinations. It was found that developing a system that incorporates every intersection feature creates too many possible combinations and makes comparison difficult.

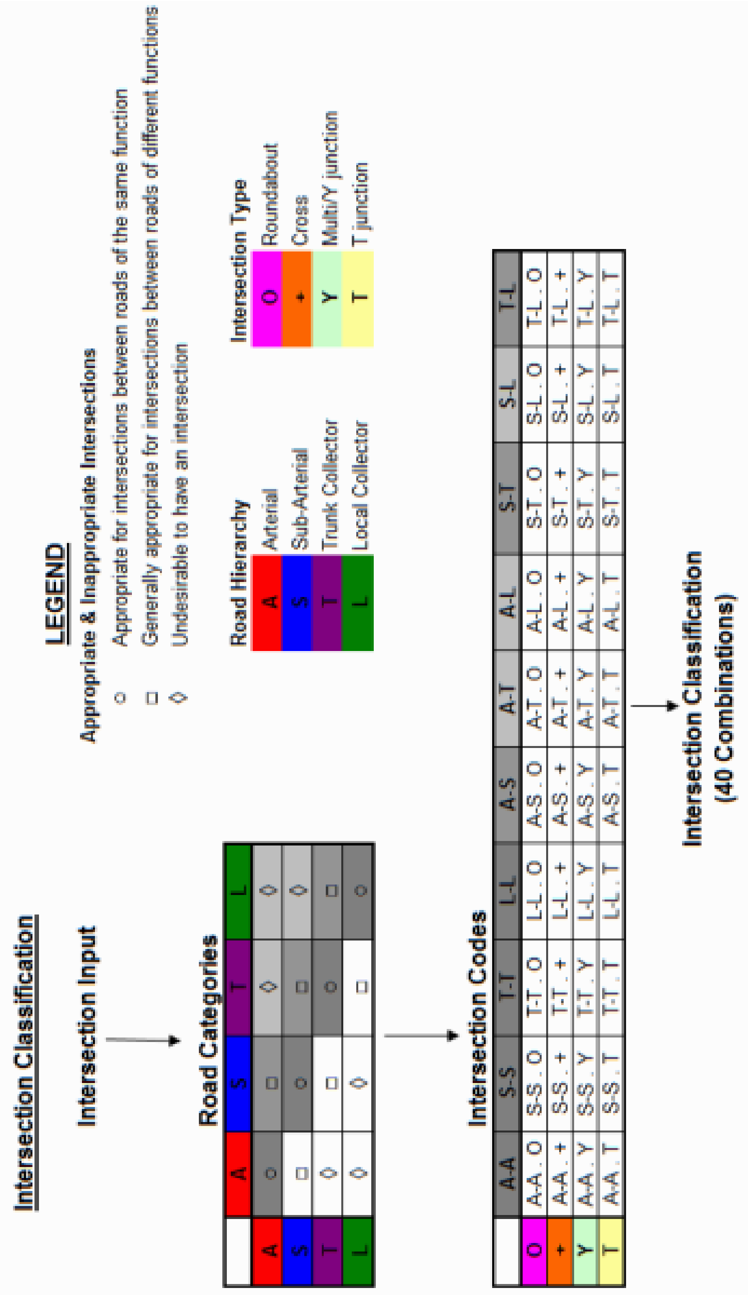


Figure 9 - Intersection Classification System Developed by Sharp (2006)
(Sharp 2006)

2.6 Crash Reduction Techniques

2.6.1 Suitable Travel Speed

The management of speeds selected by road users is an essential element of a safe road network. The likelihood of a road crash is reduced at lower speeds because the road user:

- Has more time for decision making
- Is better able to take evasive action
- Is less likely to lose control
- Is able to stop the motor vehicle sooner

When a collision does occur there is less crash impact energy at lower speeds, which will reduce injury severity to the vehicle occupants. At intersections, road users should not be exposed to traffic travelling perpendicular at speeds higher than 50 km/h. This can be achieved in urban areas by utilising some form of intersection control such as traffic signals or roundabouts (Austroads 2009).

The risk of an injury road crash doubles in urban areas when the travelled speed is 5km/h greater than the average travelled speed. Subsequently 1 - 2% decreases in the average speed travelled results in significant reductions in fatalities and serious injuries (Australian Transport Council 2006).

2.6.2 Improve Visibility

A driver's vision can be obscured or non-existent in certain directions without looking over their shoulder due to their position within the vehicle. The operator of a truck will usually have restricted vision to the side and rear of the vehicle. There is also no opportunity for a view over one shoulder. At intersections it is important that the roads that intersect do so at an angle of no more than 20 degrees off the right angle (Austroads 2009).

2.6.3 Crash Reduction Factors

Austroads (2012) conducted a study which assessed the effectiveness of engineering treatments used to improve road safety. As part of this study Austroads were able to produce a summary of various engineering treatments and each treatment's effectiveness, expressed as a Crash Reduction Factor (CRF). A CRF is the expected percentage reduction in road crashes. The purpose of the CRFs is to provide crash reduction information which can be used to allocate resources to the most cost effective project or the projects that will reduce crashes and casualties the most per dollar spent. The CRFs identified in the Austroads study relating to signalised intersections have been summarised below in Table 4.

Treatment	Environment Type	Crash Reduction Factor	Crash Modification Factor	Confidence	Year Assessed
Traffic Signals	Install Traffic Signals	30%	0.7	Medium	2011/12
	Provision of fully controlled right turns	35% (all casualty) 60% (right through) 45% (adjacent direction)	0.65 0.4 0.55	Medium Low Low	2011/12
	Provision of partially controlled right-turns	10%	0.9	Low	2011/12
	Change partial control to fully controlled right-turns	70%	0.3	Low	2011/12
Install Right-turn Lane	Install right-turn lane – signalised intersection	30%	0.7	Medium	2011/12
Install left-turn lane	All	20%	0.8	Low	2011/12
Add pedestrian phase at signals	All	50% (Pedestrians)	0.5 (Pedestrians)	Low	2010/11
Install red light Camera	Signalised Intersection	5%	0.95	High	2008/09
Road resurfacing to improve skid resistance	All	35%	0.65	High	2008/09

Table 4 – Road Crash Treatments

(Austroads 2012)

2.7 Toowoomba Regional Council Safety Initiatives

In October 2011 the Toowoomba Regional Council developed and adopted its first Regional Road Safety Strategy for the five year period of 2011 to 2015. The move towards a more strategic approach is supported by the international and nationally recognised ‘Safe System Framework’, from which the National Road Safety Strategy and Queensland Road Safety Strategy have been developed. The framework is aimed at reducing road traffic crashes within the region through the provision of a safer and more forgiving road environment, whilst also encouraging safer road user behaviour. The strategy guides decision making through the implementation of consistent strategies, policies and standards.

The ‘Safe System Framework’ recognises that humans, as road users, will make mistakes and therefore should not be penalised with death or serious injury when a road crash occurs.

In the five year period from 2003/04 to 2007/08, 24 fatalities were recorded on council controlled roads. Council’s Road Safety Strategy (2011-2015) was aimed at bringing about a 35% reduction of fatal crashes on the road network, which would result in a saving of nine lives on the regions roads over the five year life of the strategy. (Toowoomba Regional Council 2015)

Council developed and adopted the Strategy in October 2011. A review of the strategy was carried out in 2015 which assessed progress against each of the Strategic Priorities, Key Actions and Crash Reduction Targets, as outlined within the Strategic Plan. Some key actions which have been achieved since the strategy’s introduction have been listed below:

1. Incorporate the Strategy into Council’s Corporate Plan
2. Appoint a Road Safety Officer
3. Implement Road Safety Programs such as:
    - Blackspot treatments
    - Crash Database
    - School Working Group

4. Participate in active transport and safety events such as:
    - Fatal Free Friday
    - AustCycle Bike Skills and Bike Week
    - Toowoomba Road Safety Coalition
5. Introduce road safety audits of existing roads where serious crashes occur.
6. Monitor crash data to ensure potential infrastructure 'black spots', 'black links' and other hazards are addressed.
7. Support state agencies and other stakeholders at the local level in their efforts to reduce the incidence of people driving whilst under the influence of alcohol and/or drugs.
8. Review all school speed zones as part of any audit of the road network with a view to identifying and rectifying inconsistent times.
9. Investigate the introduction of speed management tools such as Speed Observation Trailers at excessive speed locations.
10. Review all curve advisory speed limits on the road network to identify and rectify inconsistences.

2.7.1 TRC Crash Reduction Initiatives

The Toowoomba Regional Council has been successful in securing targeted crash reduction funding through the Federal Black Spot funding program. Council has seen a total of 12 road safety engineering projects approved for funding between 2013 and 2015 with a total value of $5.6 million, these projects have been listed below in Table 5. Social Crash Costs have been estimated by Council using the value of statistical 'Productive' Life which assigns a value of $2.7 million per fatal crash and $266,000 per crash resulting in a hospitalised injury. Council has estimated that the Toowoomba Region suffers a Social Crash Cost loss of approximately $73 million each year. It is predicted that the 12 blackspot projects will bring about an average crash reduction of 73% at those sites, with an average crash reduction value $3.7 million per annum. A saving of $3.7 million per annum equates to 5% of the current total Social Crash Costs for Toowoomba (Toowoomba Regional Council 2015).

#	Projects	Year	$ TRC	$ Fed	Total	Estimated % Crash Reduction
1	**Gowrie-Lilyvale** Road upgrade	2013/14	$0	$375,000	$375,000	50%
2	**Woolmer Road**, Highfields, Queensland (Toowoomba Regional Council)	2014/15	$0	$300,576	$300,576	70%
3	**Goombungee-Meringandan** Road, Goombungee (Toowoomba Regional Council)	2014/15	$303,280	$303,280	$606,560	65%
4	Intersection of **Hursley Road and Boundary** Street, Toowoomba, Queensland.	2014/15	$397,830	$397,830	$795,660	70%
5	**Long Street,** 600m curvilinear section between intersection of Ruthven and West Streets, Toowoomba	2014/15	$0	$300,000	$300,000	80%
6	Intersection of **South and Rowbotham Streets,** Toowoomba, Queensland	2014/15	$350,000	$350,000	$700,000	85%
7	**Anzac Avenue Roundabout** at intersection of Hursley Road, Toowoomba City, Queensland	2014/15	$0	$300,000	$300,000	65%
8	**Old Goombungee Road** (Rural - north of Cawdor Drive)	2015/16	$0	$450,000	$450,000	65%
9	**Oakey-Kelvinhaugh Road** (Oakey)	2015/16	$0	$100,000	$100,000	65%
10	**Margaret Street / Dawnie Street**, Toowoomba	2015/16	$0	$600,000	$600,000	85%
11	**Hampton Street / Glenvale Road** Intersection	2015/16	$0	$550,000	$550,000	85%
12	**Fitzpatrick-Erin St Intersection,** Toowoomba	2015/16	$0	$550,000	$550,000	85%

Table 5 – TRC Blackspot Projects 2013-2015

(Toowoomba Regional Council 2015)

2.8 National & International Safety Initiatives

At present both the National and State Road Safety Strategies are based firmly on the Safe System approach to road safety. Internationally, the Safe System has been recognised by the World Health Organisation (WHO) as current best practice.

The United Nations Road Safety Strategy has been documented in its 'Global Plan for the Decade of Action for Road Safety 2011-2020' while the Federal Government and Queensland State Government strategies are defined in the National Road Safety Strategy and Queensland Road Safety Strategy. There are some differences between each of the strategies, but they all are based upon the Safe System Framework and the Four Pillars of Road Safety (The United Nation lists Five Pillars) which include:

- Safe Roads and Roadsides
- Safe Speeds
- Safe People
- Safe Vehicles

2.8.1 QLD State Government – Safe System Framework

- **Safe Roads and Roadsides** – improve roads and the surrounding environment to minimise the likelihood and severity of crashes.
- **Safe Speeds** – encourage travel speeds that are suitable to the environment and limit the physical impact forces of crashes to survivable levels.
- **Safe Road Users** – influence alert and compliant road user behaviour through public education, enforcement and licensing.
- **Safe Vehicles -** increase the adoption of safety features in vehicles that prevent crashes and minimise the danger to vehicle occupants

2.8.2 Australian National Road Safety Strategy

- **Safe Roads –** Roads and roadsides designed and maintained to reduce the risk of crashes occurring and to lessen the severity of injury if a crash does occur.
- **Safe Speeds** – Speed limits complementing the road environment to manage crash impact forces to within human tolerance; and compliance with speed limits.
- **Safe People -** Encourage safe, consistent and compliant behaviour through well-informed and educated road users. Licensing, education, road rules, enforcement and sanctions are all part of the safe system.
- **Safe Vehicles** – Vehicles which lessen the likelihood of a crash and protect occupants.

2.8.3 United Nations - Decade of Action for Road Safety 2011-2020

- **Pillar 1 – Road Safety Management -** Strengthen institutional and operational capacity to achieve National Road Safety Objectives.
- **Pillar 2 – Safer Roads and Mobility** – Improve the planning, design, construction and operation of road networks to ensure safety for all users.
- **Pillar 3 – Safer Vehicles** – Promote crashworthiness and empower consumers with safety information.
- **Pillar 4 – Safe Road Users –** Place vulnerable road users first in policy. Promote seat belts and crash helmets, address drink driving, set and enforce effective speed limits and improve driver training.
- **Pillar 5 – Post Crash Response** – Improve emergency response and trauma care as well as rehabilitation and care of road injury victims.

3 Data & Information

This section discusses the types of data that have been analysed in this project, the importance of this data and how it has been sourced. To successfully carry out this road crash study, key data and information was obtained. The following data and information was sourced before any analysis was undertaken:

- Crash Data for Signalised Intersections
- Traffic Volumes for Intersecting Streets
- Intersection Features, Lane Configurations and Signal Types.

3.1 Crash Data

Initially Crash Data can only originate from a few possible sources such as hospitals, insurance companies, the Police Service and some road authorities. The primary producer of road crash information within the Toowoomba Regional Council local government area is the Queensland Police Service. The Queensland Police are an obvious organisation to initially collect crash data as they are often the first responders to most crashes depending on the crash severity. Since 2011 the Queensland Police Service are only required to attend road crashes where:

- death or an injury requiring medical attention occurs
- confirmed involvement of drugs and/or alcohol in the crash
- a driver fails, or is refusing to provide the required details, such as identification (Queensland Police Service, 2015).

Since the introduction of this policy many ‘Property Damage Only’ crashes or other incidents which fall outside these criteria may go unrecorded. Despite this, data recorded by the Police is of high integrity and many government agencies obtain their crash data from this source.

The Department of Transport and Main Roads (DTMR) collects this crash data from the Queensland Police and organises it into a usable format. From here DTMR then distributes it to approved users via the 'Webcrash' platform. The crash data used for this research project has been obtained from the Toowoomba Regional Council, which in turn acquired this data from DTMR through their Webcrash platform. A problem which became apparent at the time of acquiring crash data was the currency of the data. Unfortunately due to the extensive vetting of data applied by DTMR before crash data is released to Local Authorities, the current reporting periods for crash data are as follows:

- Fatal crashes to 31 December 2014
- Hospitalisation crashes to 31 December 2013
- Medical Treatment and Minor Injury crashes to 31 December 2011
- Property Damage Only crashes to 31 December 2010

Due to this staggered release of data by DTMR it was decided that the analysis of signalised intersections would be carried out over a period in time where the data was complete. The most complete and current crash data available at the time was from the period 2007 – 2011.

While the availability of complete data has limited the analysis to pre 2011, it should be noted as to why a five year study period was selected. The length of the time period chosen to study was very important. To provide statistical reliability, five years of crash data is typically used. A period longer than five years can be used, but significant changes to road features is more likely to have occurred, which may affect crash causes. A three year assessment period may be suitable but any period shorter may not produce enough crash data to identify any accurate trends (Austroads, 2009).

The data for the 2007 – 2011 assessment period was obtained through the Toowoomba Regional Council via the 'Webcrash' platform and it is this data that has been used to conduct the analysis of signalised intersections from the same time period.

The crash data obtained from the TRC contained the following information:

- Crash Severity (Hospitalisation, Medical Treatment etc.)
- Date and time when the crash occurred
- The crash location stated as a longitude and latitude
- The Street and intersecting Street where the crash occurred
- The Suburb where the crash occurred
- The Crash Type (Multi-Vehicle, Single-Vehicle, Hit Pedestrian)
- The Crash Nature (Angle, Head-on, Rear-end etc.)
- Road Surface Conditions (Wet / Dry, Sealed / Unsealed)
- The specific DCA Code relating to the road crash

3.2 Traffic Volume Data

Traffic volume data was extremely important as it was needed to determine the frequency at which crashes were occurring at the various intersections. Simply comparing the total number of crashes which occur at two intersections is not necessarily a fair comparison of the intersection's performance without knowing the traffic volume entering each intersection. A more accurate comparison was to compare intersection crash rates, which is usually presented as the number of crashes per million entering vehicles. Traffic volume data is commonly collected using pneumatic tube counters, however a number of different methods can be employed.

TRC periodically collects traffic volume data across its network using pneumatic loops. The loops are set up in a location and left to record the number of vehicles passing over them for a period of seven days before they are collected and moved to another location. In addition to counting the traffic passing over the loops, the counters can determine what type of traffic is passing by (eg. trucks, semi-trailers, cars etc.) and the speed they are travelling. This data once collected is scrutinized for errors then made available to Council staff through a GIS software package called 'Dekho'. TRC will only collect data on its own road network, therefore traffic volume data for state and federally controlled roads, such as the Warrego Highway, the Gore Highway and the New England Highway had to be obtained separately. This information is made available on the DTMR website.

3.3 Intersection Features

To develop a useful Intersection Classification System, key intersection features were needed to be determined. These key features include:

1. Junction Type – 'Cross' or 'T-Junction'
2. Number of Traffic Lanes Entering the Intersection
3. Number of Traffic Lanes Exiting the Intersection
4. Type of Signal Phasing – Two Phase, Three Phase, Four Phase
5. Dedicated Right Turn Lanes Provided
6. Dedicated Left Turn Lanes Provided
7. Number of Slip Lanes Provided
8. Traffic Volume Entering the Intersection
9. Traffic Speed Limit

Many of these intersection features can only be determined by viewing the site. This can be achieved by physically visiting the site or viewing aerial mapping. For the majority of signalised intersections viewing aerial mapping was the preferred method to determine this information. Given the analysis period was from 2007 – 2011 it was important to ensure that the intersections features observed were from this period in time. This was easily achieved using aerial mapping software 'Nearmap', 'Google Earth' and Council's GIS software 'Dekho'. Through a combination of historical imagery and Google's 'Street View' footage all the required intersection features from that time period could be viewed and recorded.

Using historical imagery all intersections were also checked if changes occurred within the study period. Changes such as alterations to traffic lanes, signal phasing and line marking could all affect the intersection's interaction with traffic and therefore the analysis and results.

4 Methodology

4.1 Intersection Classification System

As previously mentioned roads and streets are classified by their hierarchy and road crashes are classified by the traffic moment leading up to the collision. Therefore it would seem appropriate that intersections should also be classified as part of this road crash study. This classification system must be able to identify and group intersections whose configuration and characteristics are similar. A method of classifying similar intersections has been developed after reviewing the different systems identified in the literature review. It was therefore proposed to classify the intersections based on their geometry, signal phasing and traffic volume as these are the intersection features which the road user interacts with directly.

Therefore the following intersection features will be used to identify and group similar intersections as part of this classification system:

1. Junction Type – ‘Cross’ or ‘T-Junction’
2. Number of Traffic Lanes Entering the intersection
3. Number of Traffic Lanes Exiting the intersection
4. Type of Signal Phasing – Two Phase, Three Phase, Four Phase
5. Dedicated Right turn lanes provided
6. Dedicated Left turn lanes provided
7. Number of Slip Lanes provided
8. Traffic Volume entering the intersection
9. Traffic Speed Limit

These key features were chosen because they will allow intersections to be clearly identified based on their geometry and signal phasing. There are many other features which could have been used to classify intersections, however one of the goals of this study was to observe the relationship between intersection geometry, signal design and road crashes. A problem with having a large number of features with which to classify the intersections, was that each intersection becomes unique and would be difficult to group with other similar intersections.

To assist with data collection the following table was developed to record and display the necessary information on which the intersections would be classified. This information was collected for each signalised intersection within the Toowoomba Region and a sample is displayed in Appendix B – Example Intersection Profile

	Major Road	**Minor Road**
No. of Lanes Entering		
No. of Lanes Exiting		
No. Right turn lanes		
No. Left turn lanes		
No. of Slip lanes		
No. of Signal Phases		

Figure 10 – Intersection Profile

The major and minor roads were determined by the traffic volume of the two intersecting streets. The road with the larger traffic volume was designated the 'major' road. The number of lanes entering was determined as the number of through lanes entering the intersection in both directions for each major and minor road. The number of lanes exiting was determined in the same fashion. Right and left turn lanes were recorded separately and not counted as through lanes.

The signal phasing was described as One Phase, Two Phases or Three Phases depending on how many signal phases occurred on the road before phasing changes to the other intersecting street. This intersection profile was completed for each intersection of interest in the study area. Additional information recorded on each intersection profile was the posted speed limit and traffic volume of the major and minor roads. An aerial image of the intersection was also captured and included in the profile.

4.1.1 Classification Criteria

Using the intersection profile data shown in Figure 10 a classification criterion was developed. It was this criterion which was used to assess and classify each intersection into groups with other similar intersections. The criterion is simply a table of various lane and signal combinations for the major and minor roads. Each combination was assigned an identifying number. All possible combinations have not been listed in the Table as it became obvious that not all possible signal and lane combinations exist within the intersections on the Toowoomba road network. A slightly different criterion was written for the major and minor roads because it was found that different geometric traits often existed between the two. The criterion used for intersection classification is shown below in Table 6 for Major Roads and Table 7 for Minor Roads.

	Major Roads					
	No. of Lanes Entering	No. of Lanes Exiting	Designated Right turn	Designated Left turn lane	No. of Slip lanes	Signal Phasing
Type A	4	4	2	Any	Any	Two Phase
Type B	4	4	2	0	0	Two Phase
Type C	4	4	2	Any	Any	One Phase
Type D	4	4	0	Any	Any	One Phase
Type E	4	2	0	Any	Any	One Phase

Table 6 – Major Road Classification

	Minor Roads					
	No. of Lanes Entering	No. of Lanes Exiting	Designated Right turn	Designated Left turn lane	No. of Slip lanes	Signal Phasing
Type 1	4	4	2	Any	Any	Two Phase
Type 2	4	4	2	0	0	Two Phase
Type 3	4	4	0	0	0	One Phase
Type 4	4	2	0	0	0	One Phase

Table 7 – Minor Roads Classification

To use the criterion, firstly the major and minor roads are identified by traffic volume. The road with the greatest traffic volume was designated as the major road. Then using Table 6 the major road was assigned a Type (A, B, C, D or E) depending on which row it fits into. For example a Type B Major Road has four lanes entering and exiting the intersection and in addition to these it also offers two designated right turn lanes (one in each direction). This type provides no specific left turn or slip lanes and operates a two signal phase before changing to the minor road. The minor road was assigned a Type (1, 2, 3, or 4) in much the same fashion but uses Table 7 instead. For example a Type 4 Minor Road has four lanes entering the intersection but only two lanes exiting and offers no designated right or left turn facilities or slip lanes. This type only operates a single signal phase before changing to the major road.

Intersections are then simply classified by combining the two classifications given to the major and minor roads which intersect. For example an intersection which contains a Type A Major Road and a Type 2 Minor Road was simply classified as a Type A2 Intersection.

This classification system was applied to each signalised intersection. During this process it was found that there were a number of unique intersections in Toowoomba which did not fit the criteria. Many of these unique intersections were signalised T-Junctions. It had been proposed to develop a separate criterion to classify these types of intersections, however it was found that many of these had unique configurations or there were too few similar T-Junctions to classify together. Therefore it was decided that signalised T-Junctions would not be assessed as part of this project. There were also a number of intersections which had major alterations or works carried out on them during the study period. Major alterations include changes to traffic lanes, signal phasing and major line marking changes. These altered intersections were also removed from assessment as the alterations may have affected the road user’s interaction with the intersection and therefore the crash data collected on these intersections. Of the 71 signalised intersections operating in Toowoomba between 2007-2011 only 50 were classified using this proposed system.

These 50 intersections were classified into 14 different classes. Some of the classes only contained one intersection and many possible classifications didn't contain any intersections. Of the 14 classes only five contained four or more similar intersections. A breakdown of the number of intersections contained within each class has been produced below in Table 8. It was decided that Intersection Classes containing fewer than four intersections would not be used to compare with other classes due to the limited amount of data. A complete list of the 50 intersections assessed and their classification has been provided in Appendix D – Intersection Classifications.

Intersection Class	No. of Matching Intersections
A1	7
A3	2
A4	5
B1	1
B2	3
B3	1
B4	3
C3	2
C4	1
D2	1
D3	4
D4	6
E4	14
Total	**50**

Table 8 - Classification Breakdown

The intersection profile data collected in conjunction with the road and intersection classifications were used to produce a spreadsheet which the relevant crash data could be added to. This spreadsheet was the primary tool used to analyse the crash data in conjunction with the intersection profile data.

4.2 Road Crash Trends

The road crash data for the 2007 – 2011 assessment period was obtained through the Toowoomba Regional Council via the 'Webcrash' platform. This crash data was provided in the form of an Excel spreadsheet and could be filtered by a number of different categories, some of which have been listed below:

- Crash Severity (Hospitalisation, Medical Treatment etc.)
- Date and time when the crash occurred
- The crash location stated as a longitude and latitude
- The Street and intersecting Street where the crash occurred
- The Suburb where the crash occurred
- The Crash Type (Multi-Vehicle, Single-Vehicle, Hit Pedestrian)
- The Crash Nature (Angle, Head-on, Rear-end etc.)
- Road Surface Conditions (Wet / Dry, Sealed / Unsealed)
- The specific DCA Code relating to the road crash

Firstly this data was filtered to show only crashes occurring at signalised intersections. This removed all crashes which occurred at mid-block locations and unsignalised intersections such as roundabouts and other signage controlled intersections. With the 50 intersections of interest already known it was a simple process to next filter the crash data spreadsheet by intersecting streets and record the total number of road crashes occurring at each intersection during the assessment period. Other information which was also recorded included:

- The Severity of each Crash
- The Crash Type
- The Crash Nature
- The Crash DCA Code

This information was entered into the primary spreadsheet with the intersection classification data to allow correlations to be made between the crash data and the intersection classifications.

With the total number of crashes occurring at each intersection known, crash rates were then able to be determined for each intersection. As mentioned previously simply comparing the total number of crashes which occur at two intersections is not necessarily a fair comparison of each intersection's performance without knowing the traffic volume entering each intersection. It was decided that a more accurate comparison was to compare intersection crash rates. Intersection crash rates are often expressed as the Rate per Million Entering Vehicles (RMEV). The RMEV was determined by:

$$\mathbf{REMV} = \frac{\mathbf{A} \times \mathbf{1,000,000}}{\mathbf{V}}$$

A = total number of road crashes occurring at the intersection during the study period
V = Average Daily Traffic entering the intersection × No. Years in Study Period × 365
(Garber 1999, p.138).

For example an intersection which had 13 crashes over a five year period and a combined average daily traffic of 13,000 vehicles would have the following crash rate:

$$\mathbf{REMV} = \frac{\mathbf{13} \times \mathbf{1,000,000}}{\mathbf{13,000} \times \mathbf{5} \times \mathbf{365}}$$

$$\mathbf{REMV} = \mathbf{0.55\ crashes\ per\ million\ vehicles\ entering}$$

Crash rates were determined for each intersection using this method. For the purpose of this project a small change was made to this formula. Crash rates were determined for ten million vehicles entering instead of a million vehicles entering. This was done simply for the ease of display of the crash rates. Intersections with low numbers of crashes had small decimal values. Each intersection crash rate was determined in the primary spreadsheet and can be seen in Appendix D – Intersection Classifications.

The second objective listed for this project was to interpret trends in road crashes at signalised intersections. With the primary spreadsheet now containing all 50 intersections of interest, their classifications and associated crash rates, road crash trends could now be investigated. To aid in the identification of intersections which are performing well in terms of Road User Safety and to identify intersection features which aid in the reduction of road crashes, key road crash trends were identified. These trends were used to assess intersection performance and have been listed below:

1. **Intersection Crash Rates** – This information was used to identify which intersections are producing the most road crashes per number of vehicles entering the intersection.
2. **Percentage Hospitalisation** – The percentage of road crashes which result in a hospitalisation causality. This will give an indication of the severity of crashes occurring at an intersection.
3. **DCA Code Percentage** – The common crash DCA codes which are occurring at intersections. This will identify the nature or types of crashes which are occurring more often.

The first instance where these trends were applied was to assess the impact of signal phasing on intersection crash rates. In the primary spreadsheet all intersections were filtered by the number of signal phases which occur within their cycle. All the intersections were separated into three groups consisting of two, three and four phase signal cycles. The crash rates for each group (two, three or four phases) were compared to assess if crash rates were affected by the number of signal phases occurring within a cycle.

Next the intersection classes identified through the process discussed in Section 4.1.1 were also assessed by comparing crash rates to determine if a particular class of intersection was performing better or worse than another class of intersection. Finally crash rates were also used to compare the performance of intersections which had dedicated right turn lanes and others which did not.

Similarly the percentage of crashes resulting in a hospitalisation at intersections with two, three and four signal phases were compared to determine if the number of signal phases affected the severity of road crashes. This assessment was also carried out on the different classes of intersections identified under the intersection classification system, to determine which intersections were producing the higher proportion of greater severity crashes.

Finally the DCA codes were sorted for each intersection to determine the nature of each crash that had occurred. Again this was carried out on intersections with two, three and four signal phases to determine if the number of signal phases affected the nature of road crashes which had occurred. The results for all these assessments have been represented in a number of charts and are shown in Section 5.2.

4.3 Enhancing Road User Safety

The third key objective of this project was to develop engineering solutions to improve Road User Safety within the Toowoomba Region. To achieve this objective it was decided to identify the intersections with the 10 highest crash rates. These 10 intersections have been individually analysed to ascertain the nature and severity of the crashes which had occurred previously. Through this process common road crash occurrences were identified which enabled suitable solutions and treatments to be proposed to reduce the overall crash rate. Suitable Crash Reduction Factors, as discussed in Section 2.6.3, were used as treatments to lower crash rates at these intersections. Intersection features which were identified in Section 4.2 to reduce road crashes in the local area were also recommended to be incorporated as treatments for the higher risk intersections. If the proposed crash treatments were to be applied, the potential reduction in road crashes was estimated for each of the 10 intersections. Refer to Section 5.3 for the results.

4.4 TRC Road Safety Strategy

The final objective of the project was to compare Toowoomba Regional Council safety initiatives and programs to other initiatives developed nationally and internationally. To achieve this it was proposed to review the recently adopted TRC Road Safety Strategy and compare it to current strategies utilised by other road authorities. The strategies were evaluated by reviewing the core elements and objectives that make up each of the safety strategies. The United Nations, the Australian Federal Government and the Queensland State Government are organisations which all have developed Road Safety Strategies. It was these strategies that will be compared to the TRC safety initiatives.

It had been hoped to assess the effectiveness of the TRC Road Safety Strategy in detail during the period of its operation, by comparing crash data prior to the introduction of the strategy and after its introduction. However as previously mentioned the availability of current road crash data has been a problem during this project. Currently fatal crashes are only reported up to 31 December 2014 on the 'Webcrash' platform with other crash severity data less current.

5 Results & Discussion

This section is dedicated to the presentation and discussion of results derived from the methods and steps outlined in the previous sections.

5.1 Intersection Classification

A key objective of this project was to develop an intersection classification system which enabled similar intersections to be categorized by their physical configuration. A classification model has been developed after reviewing a number of alternative methods. The model developed has been designed to classify intersections based on geometry, traffic volume and signal phasing. Between 2007 and 2011, 71 signalised intersections were identified to be operating in Toowoomba. While collecting profile information on each intersection it was discovered that there were a number of unique intersections, particularly T-Junctions, and other intersections which had undergone major alterations during the study period. These intersections were removed from the classification process leaving 50 intersections to be classified under the proposed system described in Section 4.1. These 50 intersections were classified into 14 different groups, of which only five groups contained more than four intersections. This classification system has enabled 50 intersections to be successfully classified by intersection geometry, traffic volume and signal phasing. This initial step has been successful and has allowed further analysis to be carried out.

5.2 Road Crash Trends

5.2.1 Crash Data Summary

The total number of recorded road crashes which occurred at Toowoomba signalised intersections has been summarised below in Table 9. During the study period from 2007 to 2011, 701 road crashes have been recorded. In reviewing the crash statistics, specifically regarding Injury Crashes and Property Damage Only Crashes, it was evident that Injury Crashes account for approximately 50.1% (351 crashes) and Property Damage Only Crashes account for approximately 49.9% (350 crashes) of all crashes that occurred at the region's signalised intersections.

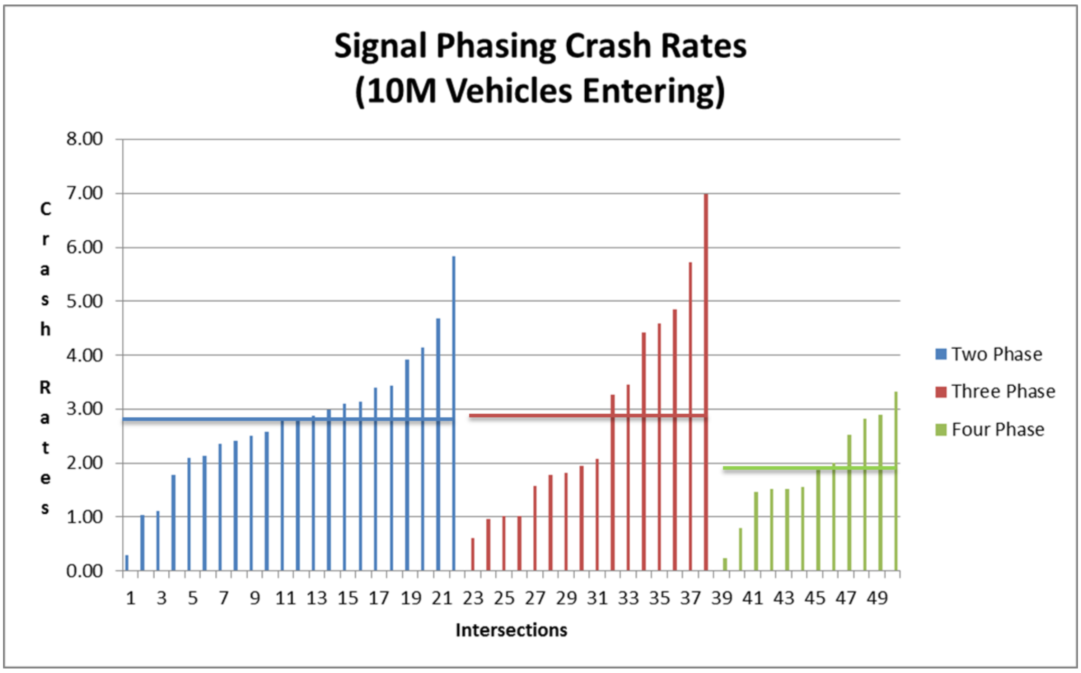
Year	Fatal	Hospitalisation	Medical Treatment	Minor Injury	Property Damage Only	Total
2007	0	13	26	21	85	**145**
2008	1	23	46	30	71	**171**
2009	0	28	26	11	102	**167**
2010	0	24	21	14	92	**151**
2011	1	20	35	11	*	**67**
Total	**2**	**108**	**154**	**87**	**350**	**701**
%	**0.3%**	**15.4%**	**22.0%**	**12.4%**	**49.9%**	

Table 9 – Road Crashes by Severity

* Property Damage Only Crash Data was not available from 2011.

5.2.2 Intersection Signal Phasing and Crash Rates

All the intersections of interest were separated into three groups consisting of intersections with two, three and four phase signal cycles. The crash rates for each group (two, three or four phases) were compared to determine if they were affected by the number of signal phases occurring within a cycle. The results have been graphed and are displayed below:



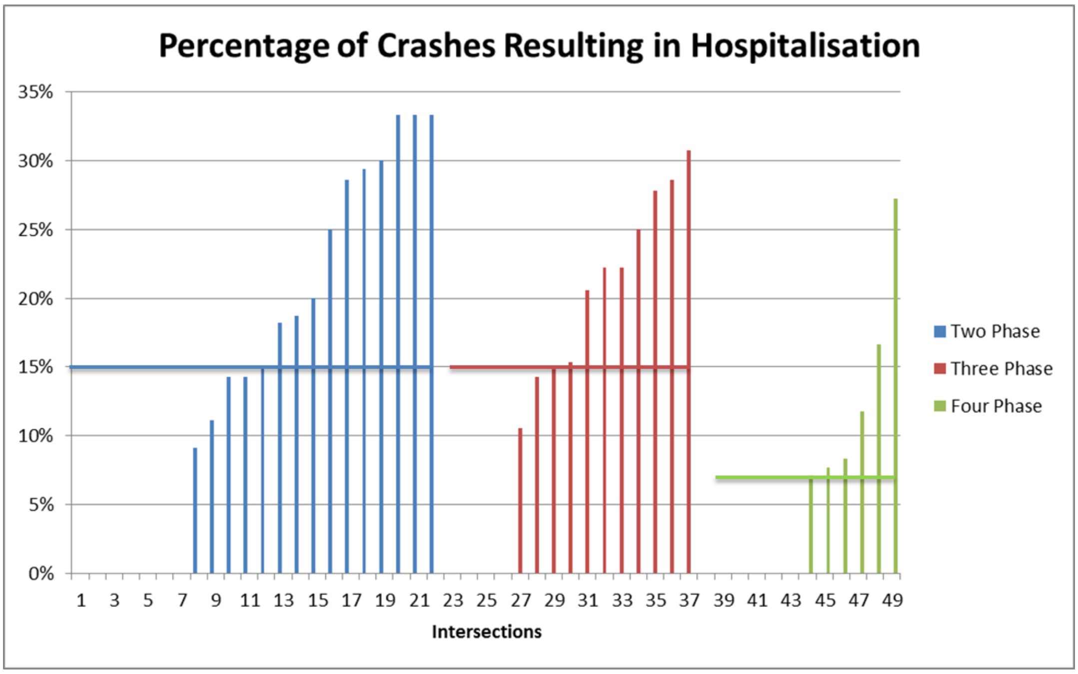
	Two Phase	Three Phase	Four Phase
Average Crash Rate	2.79	2.88	1.88

Figure 11 – Crash Rates for Different Signal Phase Cycles

In the chart above each bar represents an intersection and its crash rate. The intersections in each phasing group are displayed in ascending order of crashes per 10 million vehicles entering. There was little difference in the average crash rates between the two phase intersections and the three phase intersections. However the four phase intersections' average crash rate was significantly lower at 1.88 compared to 2.79 and 2.88 crashes per 10 million vehicles entering. Therefore the results indicate that there was on average a 33% reduction in road crashes at Toowoomba intersections with four phase signal cycles compared to intersections with two and three phase signal cycles.

5.2.3 Intersection Signal Phasing and Crash Severity

The percentage of crashes resulting in a hospitalisation causality were compared amongst the intersections with two, three and four phase signal cycles to determine if the number of signal phases affected the severity of crashes occurring at these intersections. The results have been graphed and are displayed below:



	Two Phase	Three Phase	Four Phase
Average %	15%	15%	7%

Figure 12 – Percentage Hospitalisations for Different Signal Phase Cycles

In the chart above each bar represents an intersection and the percentage of its crashes which resulted in a hospitalisation causality. The intersections in each phasing group are displayed in ascending order of the percentage of hospitalisations. The gaps seen in the chart are intersections where none of the recorded crashes resulted in a hospitalisation causality.

There was no difference in the average percentage of crashes which resulted in a hospitalisation causality at the two phase intersections and the three phase intersections, both equalled to 15%. However at four phase intersections only 7% of crashes result in a hospitalisation causality.

Therefore the results indicate that there was on average a 53% reduction in road crashes resulting in a hospitalisation causality at Toowoomba intersections with four phase signal cycles compared to intersections with two and three phase signal cycles.

5.2.4 Intersection Signal Phasing and DCA Codes

The breakdown of the common crash types (DCA) that have occurred at intersections with two, three and four phase signal cycles have been assessed and are displayed below in the following pie charts:

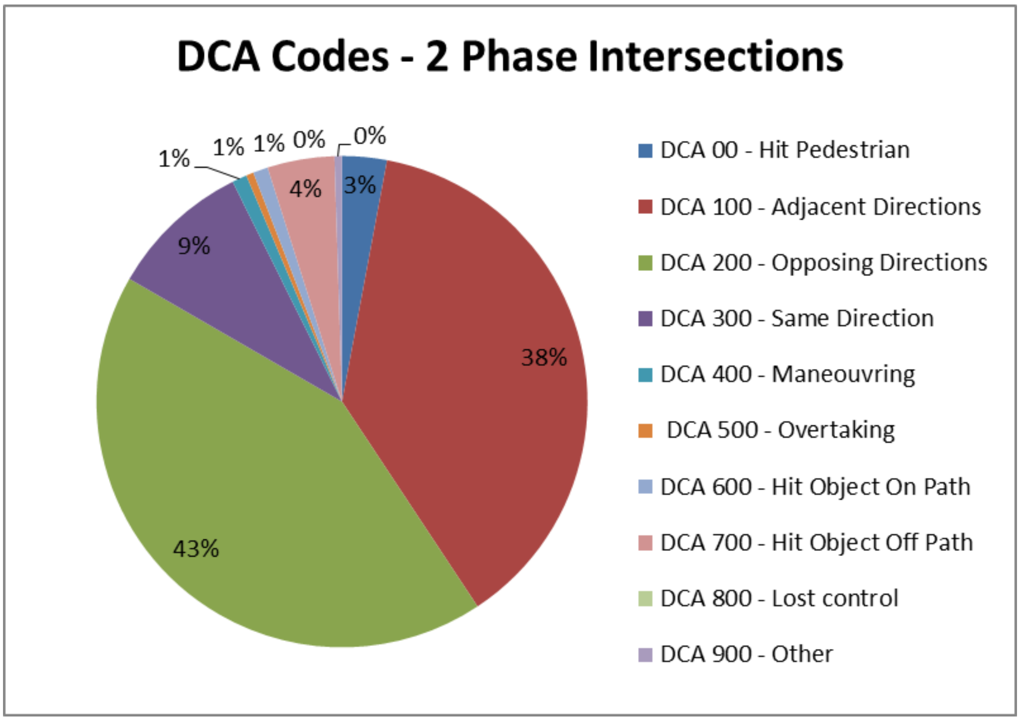


Figure 13 – DCA Codes at Two Phase Intersections

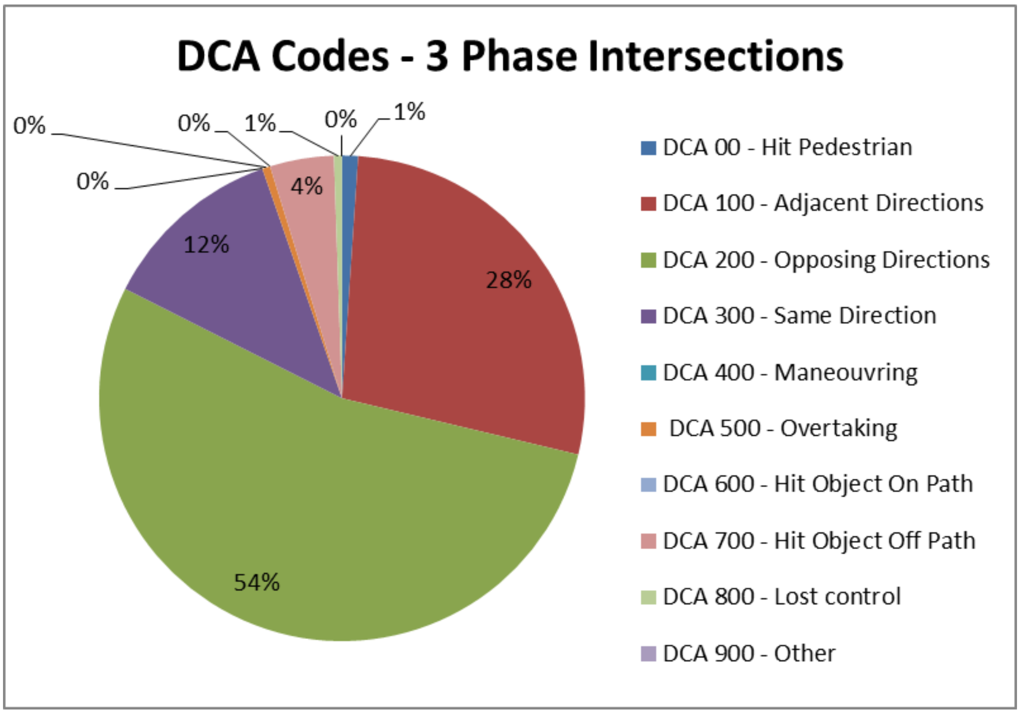


Figure 14 - DCA Codes at Three Phase Intersections

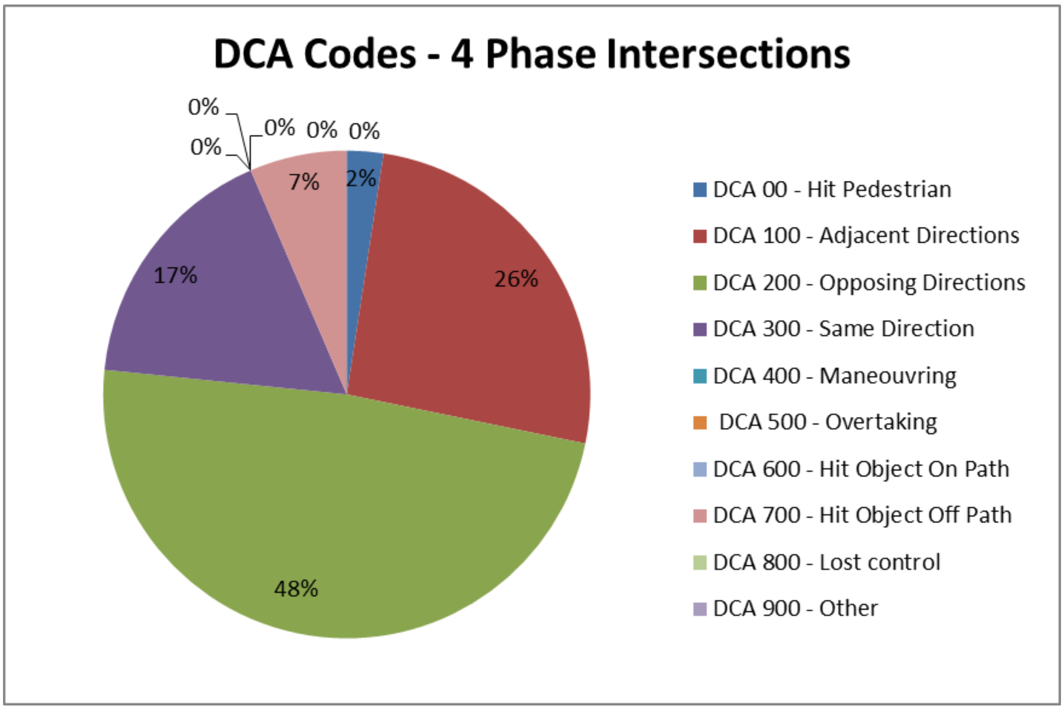


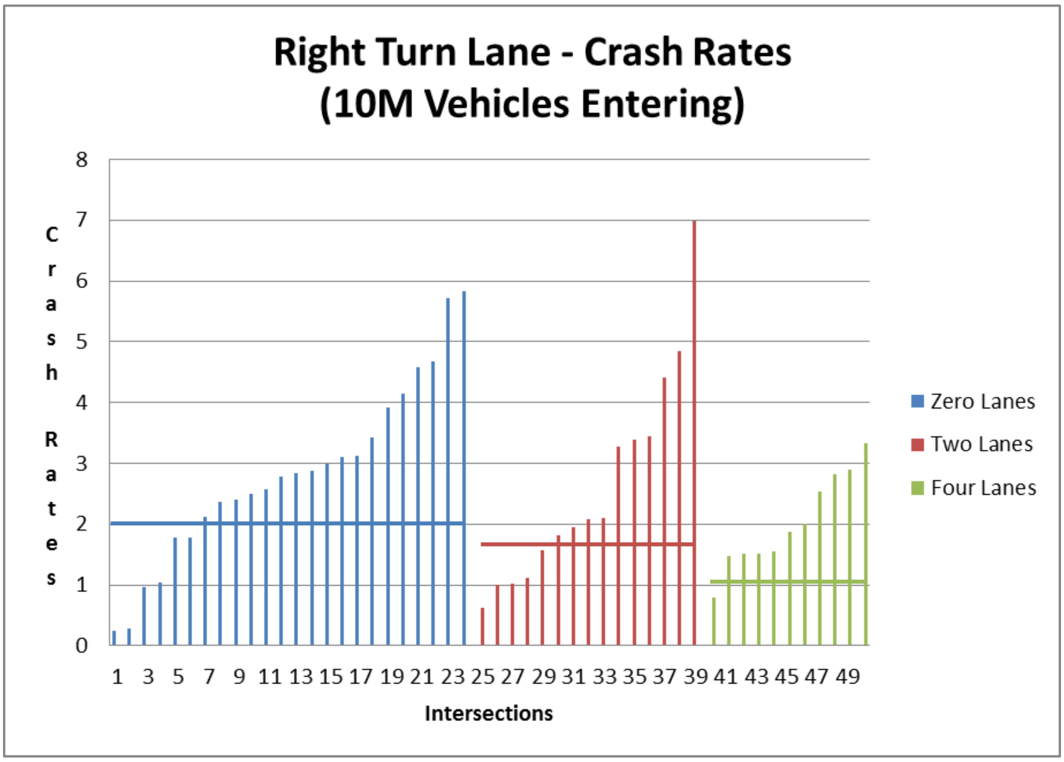
Figure 15 - DCA Codes at Four Phase Intersections

The key observations to note here are that the most common type of crashes which occurred at all Toowoomba signalised intersections were the DCA 200, 100 and 300 classifications. The intersections with three and four phase signal cycles both have a similar percentage of the DCA 100 and 200 classifications. While the four phase intersections have a slightly higher percentage of DCA 300 type crashes, which involves vehicles travelling in the same direction (usually a ‘Rear End’ collision). This could be attributed to increased vehicle queuing which is more likely to occur at four phase intersections due to the traffic inefficiencies which may occur with additional signal phases.

Another key observation was that the intersections with two phase signal cycles have a significantly higher percentage of DCA 100 type crashes at 38% compared to 27% for three and four phase intersections. The DCA 100 classification, involves vehicles travelling in adjacent directions. Generally, for this type of collision to occur one of the vehicles would need to travel through a red signal. Therefore the data indicates that increased signal phases reduces the number of road crashes caused by drivers disobeying traffic signals.

5.2.5 Right Turn Lanes and Crash Rates

All the intersections of interest were separated into three groups consisting of intersections with zero, two and four right turn lanes. Four right turn lanes means there is a designated right turn lane at each of the four intersection approaches. The crash rates for each group (zero, two and four right turn lanes) were compared to determine if they were affected by the number of designated right turn lanes provided at an intersection. The results have been graphed and are displayed below:



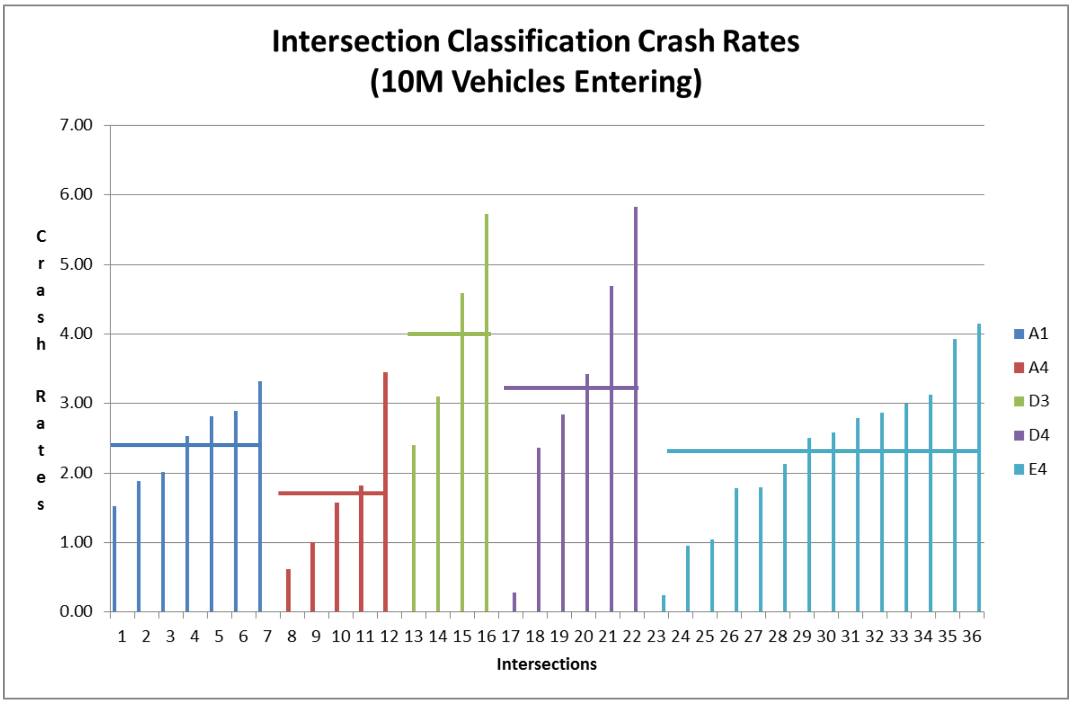
Right Turn Lanes	Zero	Two	Four
Average Intersection Crash Rate	2.84	2.64	2.03

Figure 16 - Crash Rates for Different No. of Intersections Right Turn Lanes

In the chart above each bar represents an intersection and its crash rate. The intersections in each group (zero, two and four right turn lanes) are displayed in ascending order of crashes per 10 million vehicles entering. A noticeable reduction in road crashes can be seen at intersections with additional right turn lanes. Intersections which provide no designated right turn lanes have an average crash rate of 2.84 crashes per 10 million vehicles, while intersections which provide two and four right turn lanes have crash rates of 2.64 and 2.03 per 10 million vehicles respectively. Therefore the results indicate that there was on average a 28% reduction in road crashes at Toowoomba intersections with four right turn lanes compared to intersections with zero designated right turn lanes. It should be noted that the majority of intersections with designated right turn lanes also have additional signal phases which may account for some of the safety benefits or vice versa.

5.2.6 Intersection Configurations and Crash Rates

As discussed previously the 50 intersections of interest were classified into 14 different intersection configurations, which are shown in Table 8 under Section 4.1.1. Of these 14 different intersection configurations only five configuration groups contained more than four individual intersections. These five intersection configurations are A1, A4, D3, D4 and E4. The crash rates for all the intersections which fall under these configurations were compared to determine if a particular intersection configuration performed better in terms of Road User Safety. The results have been graphed and are displayed below:



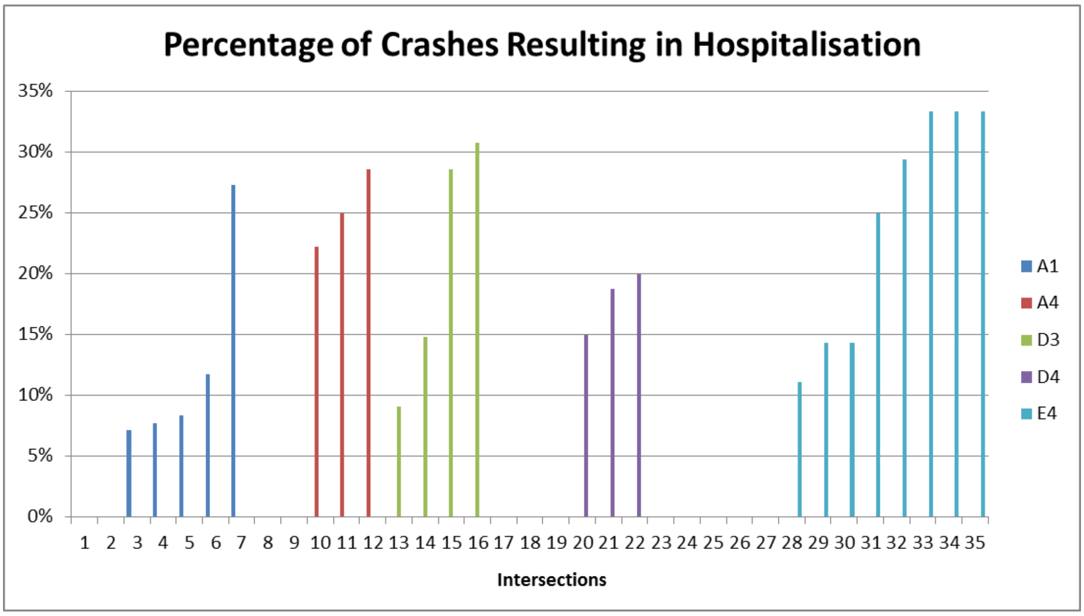
Intersections	A1	A4	D3	D4	E4
Average Crash Rate	2.4	1.7	4.0	3.2	2.3

Figure 17 - Crash Rates for Different Intersection Configurations

In the chart above, each bar represents an intersection and its crash rate. The intersections in each configuration group are displayed in ascending order of crashes per 10 million vehicles entering. The results show that the intersection configuration ‘A4’ produced the lowest average crash rate at 1.7 crashes per 10 million vehicles, while the intersection configuration ‘D3’ produced the highest average crash rate at 4.0 crashes per 10 million vehicles. Possible reasons for this are that the ‘D3’ configuration is a two signal phase intersection but both intersecting street have four lanes entering with no specific right turn lanes. These intersections have considerable traffic access with limited signal control. The ‘A4’ configuration has the highest level of signal control and lane provisions in the major direction of traffic flow, yet in the minor direction of traffic flow has the least control as outlined in the classification criteria. This intersection configuration seems to provide the ideal combination of signal control and intersection access from a road user safety stand point.

5.2.7 Intersection Configurations and Crash Severity

The percentage of crashes resulting in a hospitalisation causality were compared amongst the five intersections configurations A1, A4, D3, D4 & E4 to determine if a particular intersection configuration produced more or less severe crashes. The results have been graphed and are displayed below:



Intersections	A1	A4	D3	D4	E4
Average %	9%	15%	21%	9%	15%

Figure 18 - Percentage Hospitalisations for Different Intersection Configurations

In the chart above each bar represents an intersection and the percentage of its crashes which resulted in a hospitalisation causality. The intersections in each configuration group are displayed in ascending order based on the percentage of crashes which resulted in a hospitalisation. The gaps seen in the chart are intersections where none of the recorded crashes resulted in a hospitalisation causality.

The results show that the intersection configuration ‘A1’ and ‘D4’ produced the lowest percentage of hospitalisations at 9%, while the intersection configuration ‘D3’ produced the highest at 21% on average. It should be noted that these percentages should be reviewed in conjunction with the number of crashes which occurred at an intersection. For example an intersection which only produced two crashes but one resulted in a hospitalisation would be shown as producing crashes where 50% resulted in hospitalisation causalities.

5.3 Enhancing Road User Safety

A key objective of this project was to develop engineering solutions to improve Road User Safety within the Toowoomba Region. This objective has been achieved by identifying the intersections with the 10 highest crash rates and developing suitable crash reduction strategies for each intersection. These 10 intersections have been individually analysed to ascertain the nature and severity of the crashes which have occurred. The 'Top 10 Intersections' are listed below and also displayed in Appendix E – Top 10 Intersection Crash Rates.

1. Warrego Hwy (Bridge Street) & Tor Street
2. Warrego Hwy (James Street) & Neil Street
3. Warrego Hwy (James Street) & Hume Street
4. West Street & Stephen Street
5. West Street & Margaret Street
6. Clifford Street & Herries Street
7. Warrego Hwy (Tor Street) & Taylor Street
8. Hume Street & Jellicoe Street
9. West Street & Alderley Street
10. Bridge Street & Holberton Street

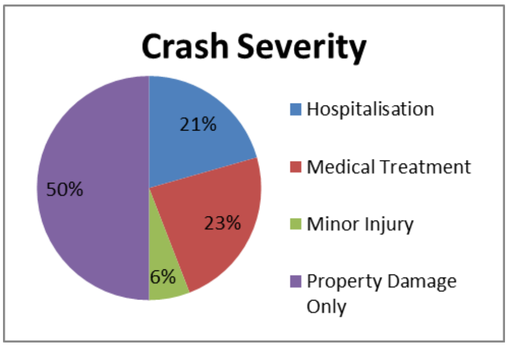
The locations of these 10 intersections have been marked on an aerial map shown below in Figure 19.

Figure 19 - Top 10 Intersection Crash Sites

5.3.1 Warrego Hwy (Bridge Street) & Tor Street (1)

The intersection of the Warrego Highway with Bridge Street and Tor Street has been found to produce the highest rate of crashes of any signalised intersection during the five year period from 2007 to 2011. The intersection crash rate was determined to be 6.98 crashes per 10 million vehicles entering the intersection. During the assessment period 34 road crashes have occurred, of which seven caused hospitalisations, eight required medical treatment, two involved a minor injury and 17 resulted in property damage only. This intersection was classified to be a class ‘A3’ intersection (Major Road – A, Minor Road – 3). The major direction of traffic flow is East/West via the Warrego Highway and Bridge Street with an AADT of over 20,000 vehicles per day. The minor direction of traffic flow is North/South via Tor Street with an AADT of over 6,000 vehicles per day. There are four lanes entering and exiting the intersection from the major direction of traffic flow. In addition to these lanes, two right turn lanes are also provided on the major road and there is two signal phases before it changes to the minor road. The minor road has four lanes entering and three exiting the intersection. There are no designated right turn lanes provided and only a single signal phase occurs before it changes back to the major road.

As displayed below the most common type of crashes which are occurring at this intersection are the DCA 200 classification, which are vehicles travelling in opposing directions. These account for 20 out of the 34 (59%) total road crashes which have occurred. These 20 crashes all fall under the DCA 202 classification which involves a vehicle turning right and colliding with a through vehicle travelling towards them. This is a significant number of similar road crashes occurring at this intersection and therefore a crash reduction strategy has been developed specifically to reduce the number of DCA 202 road crashes.



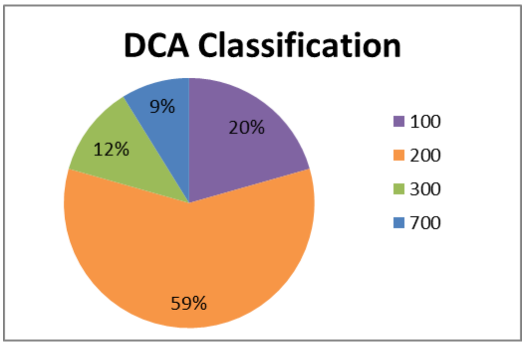


Figure 20 – Warrego Hwy & Tor St Crash Severity and Classification

As noted within Section 2.6.3 Austroads have indicated that the provision of fully controlled right turns will bring about a reduction of 60% to DCA 202 crashes and 45% to DCA 101 crashes. Austroads also advises that the provision of right turn lanes can reduce crashes by 30%. Across all Toowoomba intersections it has been found that there was a 23% reduction in crashes at intersections with four right turn lanes compared with intersections which only have two right turn lanes like this intersection. Toowoomba intersections, which also operate a four signal phase cycle, have 34% less crashes than intersections which operate a three signal phase cycle.

Therefore, to reduce road crashes at the Warrego Highway and Tor Street intersection it is recommended to install designated right turn lanes in Tor Street with an additional linked right turn phase. If fully controlled right turns are also introduced across the intersection a reduction of 60% of DCA 202 crashes and 45% of DCA 101 crashes could be expected. A 60% reduction in the 20 DCA 202 crashes would see them fall to eight crashes. A 45% reduction in the seven DCA 101 crashes would see them decrease to 4.6 crashes. This would result in the total crash count for the intersection reducing from 34 to 20 which would bring about a revised crash rate of 4.11 per 10 million vehicles.

If fully controlled right turns were not to be adopted and only the additional right turn lanes and signal phase were introduced, then based on crash statistics at other Toowoomba intersections a 34% reduction in crashes could be expected. This would reduce the number of crashes from 34 to 22 and would bring about a revised crash rate of 4.52 per 10 million vehicles.

5.3.2 Warrego Hwy (James St) & Neil Street (2)

The intersection of the Warrego Highway with Neil Street has been found to produce the second highest rate of crashes of any signalised intersection during the five year period from 2007 to 2011. The intersection crash rate was determined to be 5.83 crashes per 10 million vehicles entering the intersection. During the assessment period 20 road crashes have occurred, of which four caused hospitalisations, two required medical treatment, five involved a minor injury and nine resulted in property damage only. This intersection was classified to be a class 'D4' intersection (Major Road – D, Minor Road – 4). The major direction of traffic flow was East/West via the Warrego Highway with an AADT of 15,900 vehicles per day. The minor direction of traffic flow was North/South via Neil Street with an AADT of 2,800 vehicles per day. There are four lanes entering and exiting the intersection from the major direction of traffic flow. No designated right turn lanes are provided and there is only a single signal phase before it changes to the minor road. The minor road has four lanes entering and two exiting the intersection. There are no designated right turn lanes provided and only a single signal phase occurs before it changes back to the major road.

As displayed below in Figure 21 the most common type of crashes which are occurring at this intersection are the DCA 100 classification, which are vehicles travelling in adjacent directions. These account for 15 out of the 20 (75%) total road crashes which have occurred. Of these, 13 crashes fall under the DCA 101 classification, which involves a vehicle travelling through the intersection and colliding with another vehicle also travelling through but from an adjacent approach. For this type of collision to occur one of the vehicles would need to travel through a red signal. A crash reduction strategy has been developed specifically to reduce the number of DCA 101 road crashes.

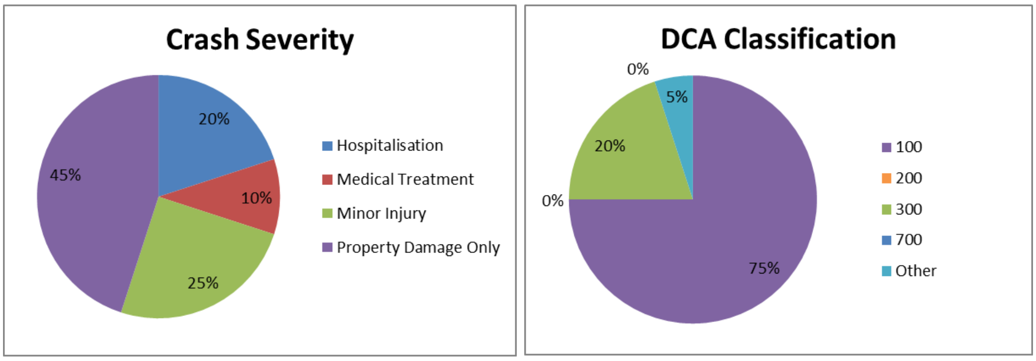


Figure 21 - Warrego Hwy & Neil St Crash Severity and Classification

Across all Toowoomba intersections it has been found that there was a 28% reduction in crashes at intersections with four right turn lanes compared with intersections which have no right turn lanes like this intersection. Toowoomba intersections, which also operate a four signal phase cycle, have 34% less crashes than intersections which operate a two signal phase cycle. There is an argument that because the majority of the collisions are being caused by drivers disobeying the traffic signals, that installing additional right turn lanes and signal phases may not achieve the desired result. However the crash data recorded in Toowoomba shows that 38% of all crashes which occurred at intersections with two signal phases were of the DCA 100 group (mostly DCA 101). Whereas only 27% of all crashes which occurred at intersections with three and four signal phases were of the DCA 100 group.

Therefore, to reduce road crashes at the Warrego Highway and Neil Street intersection it is recommended to install designated right turn lanes on both the Warrego Highway and Neil Street with two additional right turn phases, which would upgrade the intersection to a four signal phase cycle. Based on crash statistics at other Toowoomba intersections a 34% reduction in crashes could be expected. This would reduce the number of crashes from 20 to 13 and would bring about a revised crash rate of 3.79 per 10 million vehicles.

Another crash reduction method which could be employed to reduce the risk of drivers disobeying traffic signals is to increase the time of the yellow phase and ‘all red clearance time’. Red-light cameras are also recommended as a possible treatment however a red-light is already installed at this location.

5.3.3 Warrego Hwy (James St) & Hume Street (3)

The intersection of the Warrego Highway with Hume Street has been found to produce the third highest rate of crashes of any signalised intersection during the five year period from 2007 to 2011. The intersection crash rate was determined to be 5.72 crashes per 10 million vehicles entering the intersection. During the assessment period 28 road crashes have occurred, of which four caused hospitalisations, eight required medical treatment, two involved a minor injury and 14 resulted in property damage only. This intersection was classified to be a class ‘D3’ intersection (Major Road – D, Minor Road – 3). The major direction of traffic flow was East/West via the Warrego Highway with an AADT of 15,900 vehicles per day. The minor direction of traffic flow was North/South via Hume Street with an AADT of 10,900 vehicles per day. There are four lanes entering and exiting the intersection from the major direction of traffic flow. No designated right turn lanes are provided and there is only a single signal phase before it changes to the minor road. The minor road has four lanes entering and three exiting the intersection. There is one designated right turn lane provided to south bound traffic and two signal phases occur before it changes back to the major road.

As displayed below the most common type of crashes which are occurring at this intersection are the DCA 200 classification, which are vehicles travelling in opposing directions. These account for 15 out of the 28 (54%) total road crashes which have occurred. Of these crashes, 14 fall under the DCA 202 classification which involves a vehicle turning right and colliding with a through vehicle travelling towards it. This is a significant number of similar road crashes occurring at this intersection and therefore a crash reduction strategy has been developed specifically to reduce the number of DCA 202 road crashes.

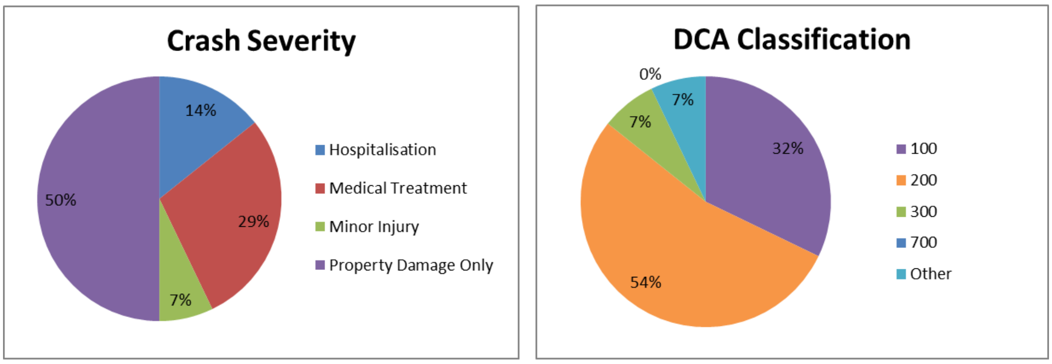


Figure 22 - Warrego Hwy & Hume St Crash Severity and Classification

As noted within Section 2.6.3 Austroads have indicated that the provision of fully controlled right turns will bring about a reduction of 60% to DCA 202 crashes and 45% to DCA 101 crashes. Austroads also advises that the provision of right turn lanes can reduce crashes by 30%. Across all Toowoomba intersections it has been found that there was a 28% reduction in crashes at intersections with four right turn lanes compared with intersections which have no right turn lanes. Toowoomba intersections, which also operate a four signal phase cycle, have 34% less crashes than intersections which operate a three signal phase cycle.

Therefore, to reduce road crashes at the Warrego Highway and Hume Street intersection it is recommended to install designated right turn lanes in Hume Street with an additional linked right turn phase. If fully controlled right turns are also introduced across the intersection a reduction of 60% of DCA 202 crashes and 45% of DCA 101 crashes could be expected. A 60% reduction in the 13 DCA 202 crashes would see them fall to five crashes. A 45% reduction in the nine DCA 101 crashes would see them decrease to five crashes. This would result in the total crash count for the intersection reducing from 28 to 16 which would bring about a revised crash rate of 3.27 per 10 million vehicles.

If fully controlled right turns were not to be adopted and only the additional right turn lanes and signal phase were introduced, then based on crash statistics at other Toowoomba intersections a 34% reduction in crashes could be expected. This would reduce the number of crashes from 28 to 18 and would bring about a revised crash rate of 3.68 per 10 million vehicles.

5.3.4 West Street & Stephen Street (4)

The intersection of West Street with Stephen Street has been found to produce the fourth highest rate of crashes of any signalised intersection during the five year period from 2007 to 2011. The intersection crash rate was determined to be 4.85 crashes per 10 million vehicles entering the intersection. During the assessment period 18 road crashes have occurred, of which five caused hospitalisations, four required medical treatment, one involved a minor injury and eight resulted in property damage only. This intersection was classified to be a class 'B4' intersection (Major Road – B, Minor Road – 4). The major direction of traffic flow was North/South via West Street with an AADT of 14,400 vehicles per day. The minor direction of traffic flow was East/West via Stephen Street with an AADT of 5,800 vehicles per day. There are four lanes entering and exiting the intersection from the major direction of traffic flow. In addition to these lanes, two right turn lanes are also provided on the major road and there is two signal phases before it changes to the minor road. The minor road has four lanes entering and two exiting the intersection. There are no designated right turn lanes provided and only a single signal phase occurs before it changes back to the major road.

As displayed below the most common type of crashes which are occurring at this intersection are the DCA 200 classification, which are vehicles travelling in opposing directions. These account for 12 out of the 18 (67%) total road crashes which have occurred. All 12 of these crashes fall under the DCA 202 classification which involves a vehicle turning right and colliding with a through vehicle travelling towards it. This is a significant number of similar road crashes occurring at this intersection and therefore a crash reduction strategy has been developed specifically to reduce the number of DCA 202 road crashes.

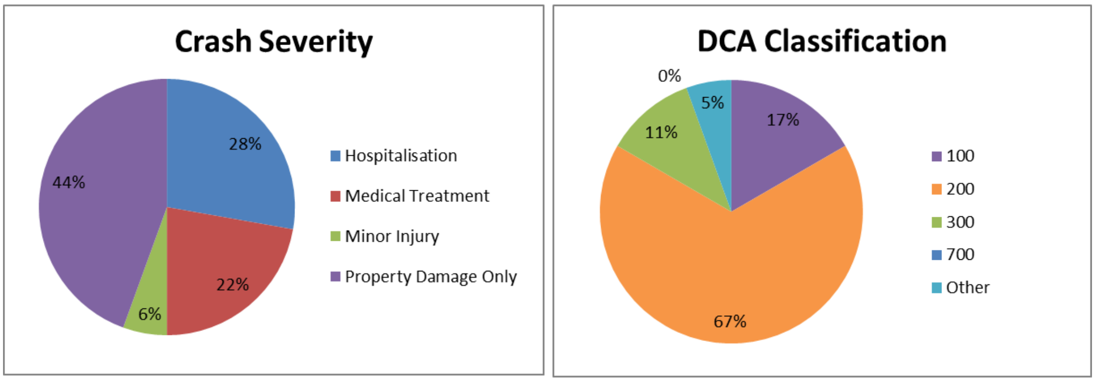


Figure 23 – West St & Stephen St Crash Severity and Classification

As noted within Section 2.6.3 Austroads have indicated that the provision of fully controlled right turns will bring about a reduction of 60% to DCA 202 crashes and 45% to DCA 101 crashes. Austroads also advises that the provision of right turn lanes can reduce crashes by 30%. Across all Toowoomba intersections it has been found that there was a 23% reduction in crashes at intersections with four right turn lanes compared with intersections which only have two right turn lanes like this intersection. Toowoomba intersections, which also operate a four signal phase cycle, have 34% less crashes than intersections which operate a three signal phase cycle.

Therefore, to reduce road crashes at the West Street and Stephen Street intersection it is recommended to install designated right turn lanes in Stephen Street with an additional linked right turn phase. If fully controlled right turns are also introduced across the intersection a reduction of 60% of DCA 202 crashes and 45% of DCA 101 crashes could be expected. A 60% reduction in the 12 DCA 202 crashes would see them fall to five crashes. A 45% reduction in the three DCA 101 crashes would see them decrease to two crashes. This would result in the total crash count for the intersection reducing from 18 to 10 which would bring about a revised crash rate of 2.69 per 10 million vehicles.

If fully controlled right turns were not to be adopted and only the additional right turn lanes and signal phase were introduced, then based on crash statistics at other Toowoomba intersections a 34% reduction in crashes could be expected. This would reduce the number of crashes from 18 to 12 and would bring about a revised crash rate of 3.23 per 10 million vehicles.

5.3.5 West Street & Margaret Street (5)

The intersection of West Street with Margaret Street has been found to produce the fifth highest rate of crashes of any signalised intersection during the five year period from 2007 to 2011. The intersection crash rate was determined to be 4.68 crashes per 10 million vehicles entering the intersection. During the assessment period 20 road crashes have occurred, of which three caused hospitalisations, four required medical treatment, one involved a minor injury and 12 resulted in property damage only. This intersection was classified to be a class ‘D4’ intersection (Major Road – D, Minor Road – 4). The major direction of traffic flow was North/South via West Street with an AADT of 15,700 vehicles per day. The minor direction of traffic flow was East/West via Margaret Street with an AADT of 7,600 vehicles per day. There are four lanes entering and exiting the intersection from the major direction of traffic flow. No designated right turn lanes are provided and there is only a single signal phase before it changes to the minor road. The minor road has four lanes entering and two exiting the intersection. There are no designated right turn lanes provided and only a single signal phase occurs before it changes back to the major road.

As displayed below the most common type of crashes which are occurring at this intersection are the DCA 100 and 200 classifications. These account for nine crashes each out of the 20 (90%) total road crashes which have occurred. Nine of these crashes fall under the DCA 101 classification and nine fall under the DCA 202 classification. A crash reduction strategy has been developed specifically to reduce both the number of DCA 101 and 202 road crashes.

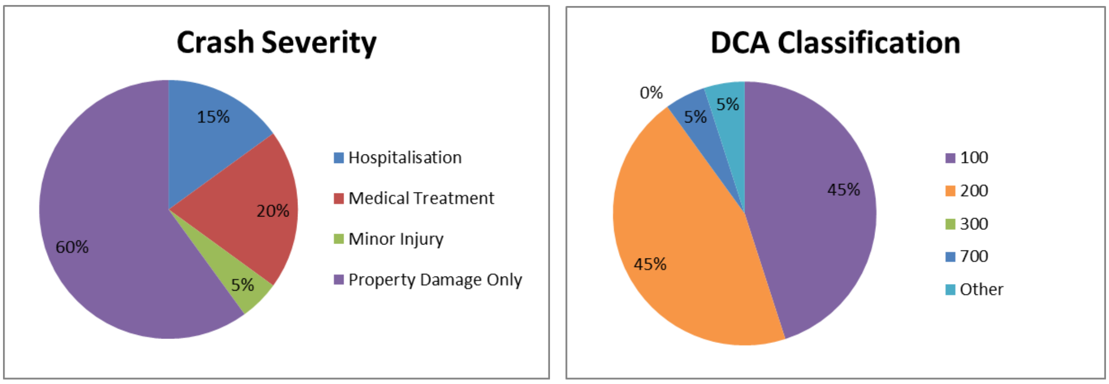


Figure 24 - West St & Margaret St Crash Severity and Classification

As noted within Section 2.6.3 Austroads have indicated that the provision of fully controlled right turns will bring about a reduction of 60% to DCA 202 crashes and 45% to DCA 101 crashes. Austroads also advises that the provision of right turn lanes can reduce crashes by 30%. Across all Toowoomba intersections it has been found that there was a 28% reduction in crashes at intersections with four right turn lanes compared with intersections which provide no right turn lanes like this intersection. Toowoomba intersections, which also operate a four signal phase cycle, have 34% less crashes than intersections which operate a two signal phase cycle.

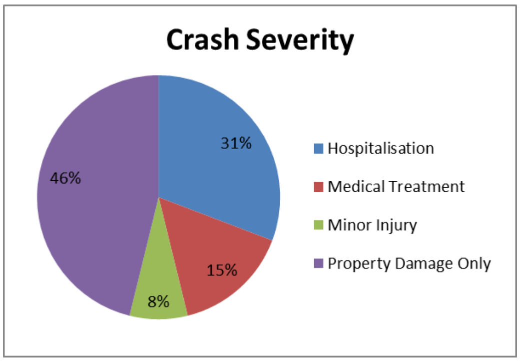
Therefore, to reduce road crashes at the West Street and Margaret Street intersection it is recommended to install designated right turn lanes on both West Street and Margaret Street with two additional right turn phases, which would upgrade the intersection to a four signal phase cycle. If fully controlled right turns are also introduced across the intersection a reduction of 60% of DCA 202 crashes and 45% of DCA 101 crashes could be expected. A 60% reduction in the nine DCA 202 crashes would see them fall to four crashes. A 45% reduction in the nine DCA 101 crashes would see them decrease to five crashes. This would result in the total crash count for the intersection reducing from 20 to 11 which would bring about a revised crash rate of 2.58 per 10 million vehicles.

If fully controlled right turns were not to be adopted and only the additional right turn lanes and signal phases were introduced, then based on crash statistics at other Toowoomba intersections a 34% reduction in crashes could be expected. This would reduce the number of crashes from 20 to 13 and would bring about a revised crash rate of 3.05 per 10 million vehicles.

5.3.6 Herries Street & Clifford Street (6)

The intersection of Clifford Street with Herries Street has been found to produce the sixth highest rate of crashes of any signalised intersection during the five year period from 2007 to 2011. The intersection crash rate was determined to be 4.58 crashes per 10 million vehicles entering the intersection. During the assessment period 13 road crashes have occurred, of which four caused hospitalisations, two required medical treatment, one involved a minor injury and six resulted in property damage only. This intersection was classified to be a class 'D3' intersection (Major Road – D, Minor Road – 3). The major direction of traffic flow was East/West via Herries Street with an AADT of 8,400 vehicles per day. The minor direction of traffic flow was North/South via Clifford Street with an AADT of 7,000 vehicles per day. There are four lanes entering and exiting the intersection from the major direction of traffic flow. No designated right turn lanes are provided and there are two signal phases before it changes to the minor road. The minor road has four lanes entering and three exiting the intersection. There are no designated right turn lanes provided and only a single signal phase occurs before it changes back to the major road.

As displayed below the most common type of crashes which are occurring at this intersection are the DCA 100 and 200 classifications. These account for 11 out of the 13 (85%) total road crashes which have occurred. Four of these crashes fall under the DCA 101 classification and six fall under the DCA 202 classification. A crash reduction strategy has been developed specifically to reduce both the number of DCA 101 and 202 road crashes.



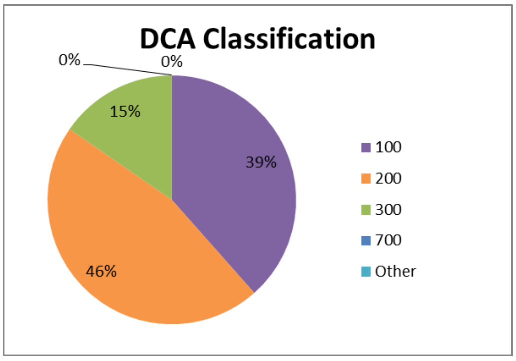


Figure 25 – Herries St & Clifford St Crash Severity and Classification

As noted within Section 2.6.3 Austroads have indicated that the provision of fully controlled right turns will bring about a reduction of 60% to DCA 202 crashes and 45% to DCA 101 crashes. Austroads also advises that the provision of right turn lanes can reduce crashes by 30%. Across all Toowoomba intersections it has been found that there was a 28% reduction in crashes at intersections with four right turn lanes compared with intersections which provide no right turn lanes like this intersection. Toowoomba intersections, which also operate a four signal phase cycle, have 34% less crashes than intersections which operate a three signal phase cycle.

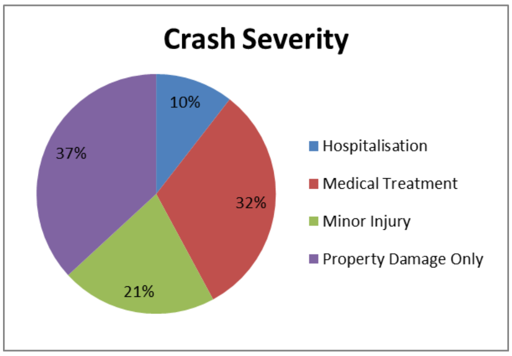
Therefore, to reduce road crashes at the Clifford Street and Herries Street intersection it is recommended to install designated right turn lanes on both Clifford Street and Herries Street with two additional right turn phases, which would upgrade the intersection to a four signal phase cycle. If fully controlled right turns are also introduced across the intersection a reduction of 60% of DCA 202 crashes and 45% of DCA 101 crashes could be expected. A 60% reduction in the six DCA 202 crashes would see them fall to two (2.4) crashes. A 45% reduction in the four DCA 101 crashes would see them decrease to two (2.2) crashes. This would result in the total crash count for the intersection reducing from 13 to 7 which would bring about a revised crash rate of 2.47 per 10 million vehicles.

If fully controlled right turns were not to be adopted and only the additional right turn lanes and signal phases were introduced, then based on crash statistics at other Toowoomba intersections a 34% reduction in crashes could be expected. This would reduce the number of crashes from 13 to 9 and would bring about a revised crash rate of 3.17 per 10 million vehicles.

5.3.7 Warrego Hwy (Tor Street) & Taylor Street (7)

The intersection of the Warrego Highway with Taylor Street has been found to produce the seventh highest rate of crashes of any signalised intersection during the five year period from 2007 to 2011. The intersection crash rate was determined to be 4.41 crashes per 10 million vehicles entering the intersection. During the assessment period 19 road crashes have occurred, of which two caused hospitalisations, six required medical treatment, four involved a minor injury and seven resulted in property damage only. This intersection was classified to be a class ‘D2’ intersection (Major Road – D, Minor Road – 2). The major direction of traffic flow was North/South via the Warrego Highway with an AADT of over 15,500 vehicles per day. The minor direction of traffic flow was East/West via Taylor Street with an AADT of over 8,000 vehicles per day. There are four lanes entering and exiting the intersection from the major direction of traffic flow. No designated right turn lanes are provided on the major road and there is a single signal phase before it changes to the minor road. The minor road has four lanes entering and exiting the intersection. In addition to these lanes, two right turn lanes are also provided on the minor road and there is two signal phases before it changes back to the major road.

As displayed below the most common type of crashes which are occurring at this intersection are the DCA 200 classification, which are vehicles travelling in opposing directions. These account for 11 out of the 19 (58%) total road crashes which have occurred. These 11 crashes all fall under the DCA 202 classification which involves a vehicle turning right and colliding with a through vehicle travelling towards it. This is a significant number of similar road crashes occurring at this intersection and therefore a crash reduction strategy has been developed specifically to reduce the number of DCA 202 road crashes.



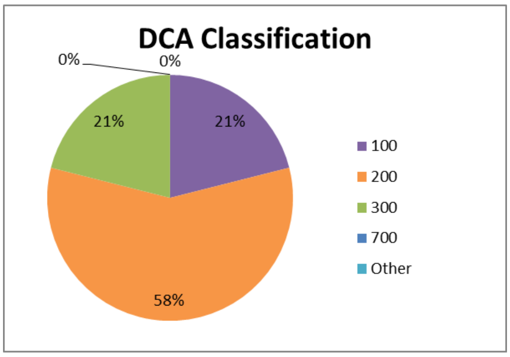


Figure 26 – Warrego Hwy & Taylor St Crash Severity and Classification

As noted within Section 2.6.3 Austroads have indicated that the provision of fully controlled right turns will bring about a reduction of 60% to DCA 202 crashes and 45% to DCA 101 crashes. Austroads also advises that the provision of right turn lanes can reduce crashes by 30%. Across all Toowoomba intersections it has been found that there was a 23% reduction in crashes at intersections with four right turn lanes compared with intersections which only have two right turn lanes like this intersection. Toowoomba intersections, which also operate a four signal phase cycle, have 34% less crashes than intersections which operate a three signal phase cycle.

Therefore, to reduce road crashes at the Warrego Highway and Taylor Street intersection it is recommended to install designated right turn lanes on the Warrego Highway with an additional linked right turn phase. If fully controlled right turns are also introduced across the intersection a reduction of 60% of DCA 202 crashes and 45% of DCA 101 crashes could be expected. A 60% reduction in the 11 DCA 202 crashes would see them fall to four crashes (4.4). A 45% reduction in the four DCA 101 crashes would see them decrease to two (2.2) crashes. This would result in the total crash count for the intersection reducing from 19 to 10 which would bring about a revised crash rate of 2.55 per 10 million vehicles.

If fully controlled right turns were not to be adopted and only the additional right turn lanes and signal phase were introduced, then based on crash statistics at other Toowoomba intersections a 34% reduction in crashes could be expected. This would reduce the number of crashes from 19 to 13 and would bring about a revised crash rate of 3.02 per 10 million vehicles.

5.3.8 Hume Street & Jellicoe Street (8)

The intersection of Hume Street with Jellicoe Street has been found to produce the eighth highest rate of crashes of any signalised intersection during the five year period from 2007 to 2011. The intersection crash rate was determined to be 4.15 crashes per 10 million vehicles entering the intersection. During the assessment period five road crashes have occurred, of which one required medical treatment, one involved a minor injury and three resulted in property damage only. This intersection was classified to be a class ‘E4’ intersection (Major Road – E, Minor Road – 4). The major direction of traffic flow was North/South via Hume St with an AADT of 4,600 vehicles per day. The minor direction of traffic flow was East/West via Jellicoe Street with an AADT of 1,900 vehicles per day. There are four lanes entering and two exiting the intersection from the major direction of traffic flow. No designated right turn lanes are provided on the major road and there is a single signal phase before it changes to the minor road. The minor road has four lanes entering and two exiting the intersection. There are no designated right turn lanes provided and only a single signal phase occurs before it changes back to the major road.

As displayed below the most common type of crashes which are occurring at this intersection are the DCA 100 classification, which are vehicles travelling in adjacent directions. These account for three out of the five (60%) total road crashes which have occurred. These crashes all fall under the DCA 101 classification, which involves a vehicle travelling through the intersection and colliding with another vehicle also travelling through but from an adjacent approach. For this type of collision to occur one of the vehicles would need to travel through a red signal. A crash reduction strategy has been developed specifically to reduce the number of DCA 101 road crashes.

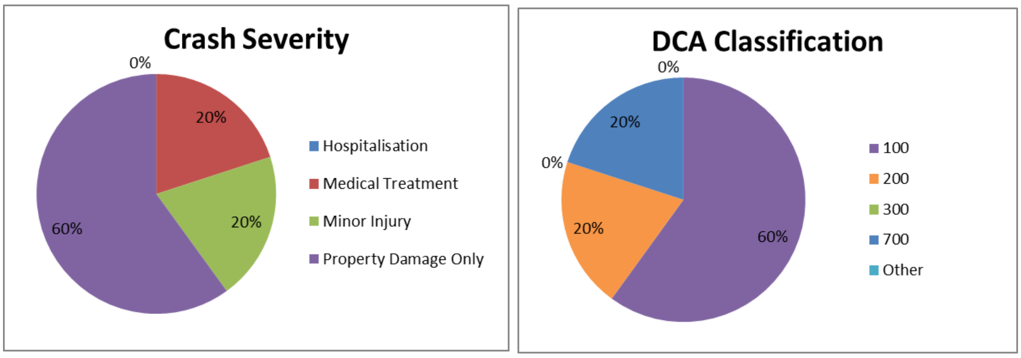


Figure 27 – Hume St & Jellicoe Crash Severity and Classification

Across all Toowoomba intersections it has been found that there was a 28% reduction in crashes at intersections with four right turn lanes compared with intersections which have no right turn lanes like this intersection. Toowoomba intersections, which also operate a four signal phase cycle, have 34% less crashes than intersections which operate a two signal phase cycle. There is an argument that because the majority of the collisions are being caused by drivers disobeying the traffic signals, that installing additional right turn lanes and signal phases may not achieve the desired result. However the crash data recorded in Toowoomba shows that 38% of all crashes which occurred at intersections with two signal phases were of the DCA 100 group (mostly DCA 101). Whereas only 27% of all crashes which occurred at intersections with three and four signal phases were of the DCA 100 group.

However, due to the very low traffic volume at this intersection and low number of crashes, the addition of right turn lanes and additional signal phases may not be warranted or economical. More data may need to be collected to determine if a problem exists at this intersection. In the meantime a crash reduction method which could be employed to reduce the risk of drivers disobeying traffic signals is to increase the time of the yellow phase and ‘all red clearance times’.

5.3.9 West Street & Alderley Street (9)

The intersection of West Street with Alderley Street has been found to produce the ninth highest rate of crashes of any signalised intersection during the five year period from 2007 to 2011. The intersection crash rate was determined to be 3.92 crashes per 10 million vehicles entering the intersection. During the assessment period 17 road crashes have occurred, of which five caused hospitalisations, two required medical treatment, four involved a minor injury and six resulted in property damage only. This intersection was classified to be a class 'E4' intersection (Major Road – E, Minor Road – 4). The major direction of traffic flow was North/South via West Street with an AADT of 13,000 vehicles per day. The minor direction of traffic flow was East/West via Alderley Street with an AADT of 10,600 vehicles per day. There are four lanes entering and two lanes exiting the intersection from the major direction of traffic flow. No designated right turn lanes are provided on the major road and there is a single signal phase before it changes to the minor road. The minor road also has four lanes entering and two lanes exiting the intersection. There are no designated right turn lanes provided and only a single signal phase occurs before it changes back to the major road.

As displayed below the most common type of crashes which are occurring at this intersection are the DCA 200 classification, which are vehicles travelling in opposing directions. These account for 10 out of the 17 (59%) total road crashes which have occurred. These 10 crashes all fall under the DCA 202 classification which involves a vehicle turning right and colliding with a through vehicle travelling towards it. This is a significant number of similar road crashes occurring at this intersection and therefore a crash reduction strategy has been developed specifically to reduce the number of DCA 202 road crashes.

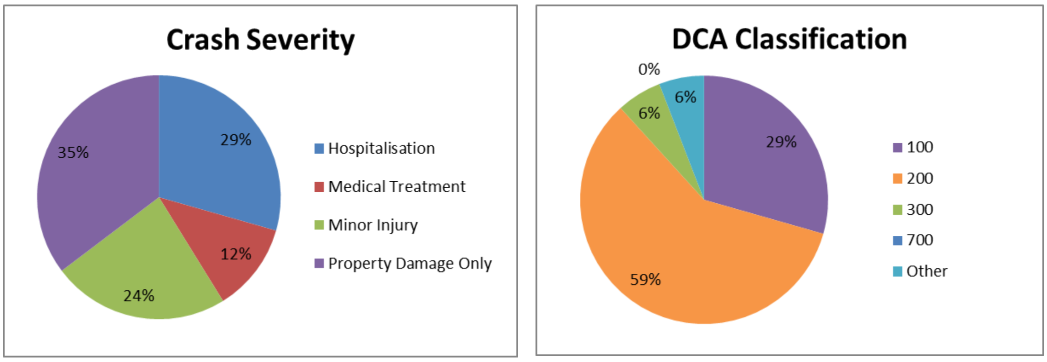


Figure 28 – West St & Alderley Crash Severity and Classification

As noted within Section 2.6.3 Austroads have indicated that the provision of fully controlled right turns will bring about a reduction of 60% to DCA 202 crashes and 45% to DCA 101 crashes. Austroads also advises that the provision of right turn lanes can reduce crashes by 30%. Across all Toowoomba intersections it has been found that there was a 28% reduction in crashes at intersections with four right turn lanes compared with intersections which have no right turn lanes like this intersection. Toowoomba intersections, which also operate a four signal phase cycle, have 34% less crashes than intersections which operate a two signal phase cycle.

Therefore, to reduce road crashes at the West Street and Alderley Street intersection it is recommended to install designated right turn lanes on both West Street and Alderley Street with two additional right turn phases, which would upgrade the intersection to a four signal phase cycle. If fully controlled right turns are also introduced across the intersection a reduction of 60% of DCA 202 crashes and 45% of DCA 101 crashes could be expected. A 60% reduction in the 10 DCA 202 crashes would see them fall to four crashes. A 45% reduction in the five DCA 101 crashes would see them decrease to three (2.8) crashes. This would result in the total crash count for the intersection reducing from 17 to 9 which would bring about a revised crash rate of 2.08 per 10 million vehicles.

If fully controlled right turns were not to be adopted and only the additional right turn lanes and signal phases were introduced, then based on crash statistics at other Toowoomba intersections a 34% reduction in crashes could be expected. This would reduce the number of crashes from 17 to 11 and would bring about a revised crash rate of 2.54 per 10 million vehicles.

5.3.10 Bridge Street & Holberton Street (10)

The intersection of Bridge Street and Holberton Street has been found to produce the tenth highest rate of crashes of any signalised intersection during the five year period from 2007 to 2011. The intersection crash rate was determined to be 3.45 crashes per 10 million vehicles entering the intersection. During the assessment period 14 road crashes have occurred, of which four caused hospitalisations, four required medical treatment, three involved a minor injury and three resulted in property damage only. This intersection was classified to be a class ‘A4’ intersection (Major Road – A, Minor Road – 4). The major direction of traffic flow was East/West via Bridge Street with an AADT of 14,100 vehicles per day. The minor direction of traffic flow was North/South via Holberton Street with an AADT of 8,090 vehicles per day. There are four lanes entering and exiting the intersection from the major direction of traffic flow. In addition to these lanes, two right turn lanes are also provided on the major road and there is two signal phases before it changes to the minor road. The minor road has four lanes entering and two exiting the intersection. There are no designated right turn lanes provided and only a single signal phase occurs before it changes back to the major road.

As displayed below the most common type of crashes which are occurring at this intersection are the DCA 100 and 200 classifications. These account for 11 out of the 14 (79%) total road crashes which have occurred. Six of these crashes fall under the DCA 101 classification and five fall under the DCA 202 classification. It should also be noted that 79% of all the crashes resulted in some kind of injury to the road users. A crash reduction strategy has been developed specifically to reduce both the number of DCA 101 and 202 road crashes.

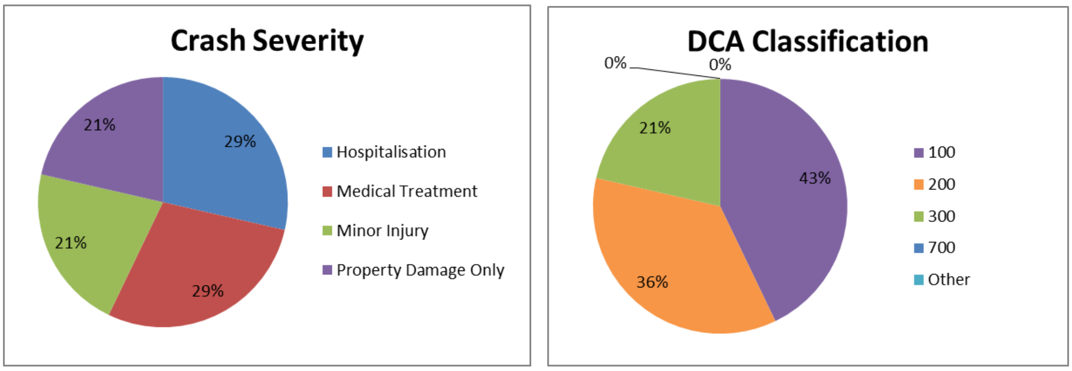


Figure 29 – Bridge St & Holberton Crash Severity and Classification

Across all Toowoomba intersections it has been found that there was a 23% reduction in crashes at intersections with four right turn lanes compared with intersections which have two right turn lanes like this intersection. Toowoomba intersections, which also operate a four signal phase cycle, have 34% less crashes than intersections which operate a three signal phase cycle. There is an argument that because the majority of the collisions are being caused by drivers disobeying the traffic signals, that installing additional right turn lanes and signal phases may not achieve the desired result. However the crash data recorded in Toowoomba shows that 38% of all crashes which occurred at intersections with two signal phases were of the DCA 100 group (mostly DCA 101). Whereas only 27% of all crashes which occurred at intersections with three and four signal phases were of the DCA 100 group.

Therefore, to reduce road crashes at Bridge Street and Holberton Street intersection it is recommended to install designated right turn lanes on Holberton Street with an additional right turn phase, which would upgrade the intersection to a four signal phase cycle. Based on crash statistics at other Toowoomba intersections a 34% reduction in crashes could be expected. This would reduce the number of crashes from 14 to 9 and would bring about a revised crash rate of 2.22 per 10 million vehicles.

Another crash reduction method which could be employed to reduce the risk of drivers disobeying traffic signals is to increase the time of the yellow phase and ‘all red clearance time’. Red-light cameras are also recommended as a possible treatment however a red-light camera is already installed at this location. Traffic entry speed could also be reviewed as the percentage of crashes resulting in an injury is considerably higher than most intersections across Toowoomba.

5.4 TRC Road Safety Strategy

A review of the recently adopted TRC Road Safety Strategy has been conducted and comparisons to current strategies utilised by other road authorities have been identified.

The TRC Road Safety Strategy has been formulated based on the Safe System Framework, as discussed in Section 2.7, and specifically encompasses the first three Pillars of road safety, which are Safe Roads and Roadsides, Safe Speeds and Safe People (road users). Both the National and State road safety strategies are firmly based on this Safe System Framework approach to road safety. Internationally, the safe system is recognised as current best practice.

The TRC has little opportunity or ability to influence the Fourth Pillar of the Safe System Framework 'Safe Vehicles'. Local Government authorities like the Toowoomba Regional Council would generally not be able to heavily influence vehicle design or manufacture. Whereas organisations like the Qld State Government and the Federal Government are able to improve and influence vehicle safety through legislation and enforcement. However, one way the TRC could contribute towards safe vehicles in the safe system is by purchasing vehicles with improved safety features and passenger protection for use within their own operational fleet.

Of the Four Pillars, the TRC has the greatest ability to improve the safety of residents and visitors within the region through focusing on road safety engineering initiatives within the core functions of 'safe speeds' and 'safe roads and roadsides'.

These successes are clearly demonstrated with the success with *Black Spot* funding applications. Council has had 12 road safety engineering projects approved and funded between 2013 and 2015. The total value of these projects has been estimated at $5.6 million with the TRC contributing $1.0 million and a Federal contribution of $4.6 million. This has been a significant achievement for the TRC.

It is important to note that each level of Government is responsible for planning, designing and managing the operation of a safe road transport system. They are each expected to provide guidance and resources to improve road safety, by developing and enforcing laws, setting standards, providing safer roads, advising the public about road safety issues and requiring continuous improvements in vehicle safety.

The Australian Federal Government is responsible for allocating infrastructure resources and funding across the national highway and the local road networks, and for regulating safety standards for new vehicles. State and Territory governments are responsible for the funding, planning, design and operation of the road network, managing vehicle registration, driver licensing and enforcing road user responsibilities. Finally, local governments like the Toowoomba Regional Council are responsible for funding, planning, design and operation of the road networks in their local areas. All of these parties must work collaboratively towards the provision of a safe transportation system and therefore, reliance should not be placed upon one organisation to solely address this issue. Since the adoption of the TRC Road Safety Strategy evidence exists of a very successful cooperative network between the TRC and the Qld State Government with assistance provided by the Federal Government through funding allocations.

6 Conclusion

This project has been successful in achieving its aim and core objectives which were identified early in the project formation.

Firstly, a signalised intersection classification system has been developed which was successful in classifying 50 out of 71 intersections into similar groups, based upon intersection geometry, signal phasing and traffic volume. Not all signalised intersections in Toowoomba fitted into the classification criteria developed and some intersections had undergone recent improvements and were omitted from the study.

Road crash trends were analysed at these 50 intersections and common crash types and contributing factors have been identified. The key findings were:

1. Significant crash reductions and reductions in crash severity were observed at intersections with four phase signal cycles when compared to intersections with two and three phase cycles.
2. Similar crash reductions and reductions in crash severity were also observed at intersections with additional designated right turn lanes.
3. Intersections with two phase signal cycles had an increased proportion of road crashes caused by drivers disobeying traffic signals, when compared to intersections with three and four phase cycles.

Engineering solutions to enhance Road User Safety within the region have been proposed for the intersections with the 10 highest crash rates. Significant crash rate reductions could be achieved by adding additional controls to these 10 intersections.
A comparison between the Toowoomba Regional Council safety programs and other initiatives developed nationally and internationally has been carried out, which highlights the roles the Local, State and Federal Governments perform when providing a safe transport system. It had been hoped to assess the effectiveness of the TRC Road Safety Strategy in detail during the period of its operation, by comparing crash data prior to the introduction of the strategy and after its introduction. However as previously discussed obtaining current road crash data has been a problem during this project, which meant that this comparison could not be carried out.

7 Further Work

If there is some interest in progressing this research further, then the following suggestions would form a reasonable starting point.

Repeating a similar study of signalised intersections in Toowoomba with more current crash data would be significant. Primarily to observe if the crash trends identified in this study are still present. Some of the problematic intersections identified in this study have undergone improvements after the collection of this study's crash data. A study of the potential crash reductions at these intersections would also be significant and could support further TRC funding applications.

The need for an intersection classification system appears to be warranted and therefore further development of the classification system proposed in this study or other classification systems could be undertaken.

The establishment of a 'benchmark' crash rate for the intersection classes described in this study would allow an intersection's performance to be easily assessed.

8 Reference List

Andreassen, D 1991, 'Model Guidelines for Road Accident Data and Accident Types', Version 1.1 (ATM29), Australian Road Research Board, Melbourne.

Andreassen, D 1994, 'Model Guidelines for Road Accident Data and Accident Types', Version 2.1 (ATM29), Australian Road Research Board, Melbourne.

Australian Bureau of Statistics 2016, *Regional Population Growth, Australia, 2013-14*, Australian Bureau of Statistics, Canberra, Viewed 23 May 2016, <http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3218.02013-14>

Australian Transport Council 2006, National road safety action plan 2007 and 2008, ATC, Canberra, ACT.

Austroads 2009, 'Guide to Road Safety Part 8: Treatment of Crash Locations', Sydney, Austroads Incorporated.

Austroads 2012, 'Austroads Research Report: Effectiveness of Road Safety Engineering Treatments', Sydney, Austroads Incorporated

Austroads 2013, 'Guide to Traffic Management Part 6: Intersections, Interchanges and Crossings', Sydney, Austroads Incorporated.

Austroads 2015, 'Guide to Traffic Management Part 1: Introduction to Traffic Management', Sydney, Austroads Incorporated.

Department of Transport and Main Roads 2012, '2011 Fatal road traffic crashes in Queensland', Brisbane.

Department of Transport and Main Roads 2015, '2014 Summary Road Crash Report - Queensland Road Fatalities, Brisbane.

Garber, NJ & Hoel, LA 1999, *Traffic and Highway Engineering*, Second Edition, PWS Publishing, Pacific Grove.

Mannering, FL & Washburn, SS 2012, *Principles of Highway Engineering and Traffic Analysis*, Fifth Edition, Wiley, Hoboken.

Morocoima-Black, R, Chavarría, S & Kang, H 2003, Selected Intersection Crash Analysis for 1996-2000, viewed 21 May 2016, <www.ccrpc.org/planning/ transportation/pdf/SCIL>, Champaign-Urbana Urbanized Area Transportation Study (CUUATS), Florida, USA.

Ogden, KW 1994, 'Factors Affecting Crashes at Signalised Intersections', Monash University.

Ogden, KW 1996, 'Safer Roads: A Guide to Road Safety Engineering', Avebury Technical, Great Britain.

Queensland Police Service 2015, *Traffic Crash FAQ*, Queensland Police Service, Brisbane, viewed 26 July 2016, <https://www.police.qld.gov.au/programs/roadSafety/tcfaq.htm#03>

Roads and Traffic Authority 2008, 'Traffic Signal Design: Section 7 Phasing and Signal Group Display Sequence', Sydney.

Rocchi, S 2003, 'Safer City Intersection Master Plan - Model Guidelines for Intersection Design & Operation', Vancouver Canada

Sharp, C.A 2006, 'Investigation of Toowoomba Intersection Crashes', Faculty of Engineering and Surveying, Toowoomba, University of Southern Queensland, Bachelor of Engineering.

Toowoomba Regional Council 2015, 'Road Safety Strategic Plan 2011-2015 Review', Toowoomba.

Toowoomba Regional Council 2016a, *Part 4 Priority Infrastructure Plan, 4.5 Desired standard of service*, Toowoomba Regional Council, Toowoomba, viewed 7 May 2016, <https://pdonline.toowoombarc.qld.gov.au/masterplan/modules/eplan/eplanviewer.aspx?I+Agree=I+Agree#>

Toowoomba Regional Council 2016b, *Part 3 Strategic Framework, 3.7 Access and Mobility*, Toowoomba Regional Council, Toowoomba, viewed 7 May 2016, <https://pdonline.toowoombarc.qld.gov.au/masterplan/modules/eplan/eplanviewer.aspx?I+Agree=I+Agree#>

Toowoomba Regional Council 2016c, *Schedule 6 Planning scheme policies (PSP), SC6.2 PSP No. 2 - Engineering Standards – Roads and Drainage Infrastructure*, Toowoomba Regional Council, Toowoomba, viewed 7 May 2016, <https://pdonline.toowoombarc.qld.gov.au/masterplan/modules/eplan/EplanViewer.aspx#>

WHO 2004, 'World report on road traffic injury prevention'. World Health Organisation, Geneva.

9 Appendix A – Project Specification

ENG4111/4112 Research Project

Project Specification

For: Ross John Milton

Title: Analysis of Road Safety Trends at Signalised Intersections in Toowoomba

Major: Civil Engineering

Supervisor: Dr Soma Somasundaraswaran

Enrolment: ENG4111 – ONC S1, 2016
ENG4112 – ONC S2, 2016

Project Aim: To identify intersections which are performing well in terms of Road User Safety and to identify intersection features which aid in the reduction of road crashes at signalised intersections in Toowoomba.

Programme: Issue A – 16 March 2016

1. Analyse currently available road crash data for signalised intersections in Toowoomba

2. Develop a signalised intersection classification system which will enable similar intersections to be grouped together. This system will allow the analysis of intersection crash data by intersection configuration and characteristics.

3. For each intersection configuration conduct an analysis of the crash data to determine how a particular configuration performs compared to other configurations.

4. Quantify, characterise, and interpret trends in road crashes reported including identification of the common crash natures (angle, head on, HV vs. car) and contributing factors (road, user and environments.)

5. Evaluate the effectiveness of the strategies adapted in Australia to propose initiatives to enhance road safety in the Toowoomba Region.

6. Develop innovative engineering solutions to enhance the road safety of the region.

7. Compare Toowoomba Regional Council safety initiatives and programs to other initiatives developed nationally and internationally.

8. Discuss the issues faced in developing suitable strategies

10 Appendix B – Example Intersection Profile

Intersection Profile

Intersecting Streets – **New England Hwy (Ruthven St) & Warrego Hwy (James St)**

Suburb – Toowoomba City

Major Road – Warrego Hwy AADT – 15911 (19.8% HV)

Minor Road – New England Hwy AADT – 14436 (5.9% HV)

Intersection Configuration

	Major Road	Minor Road
No. of Lanes Entering	4	4
No. of Lanes Exiting	4	4
Designated Right turn lane	2	2
Designated Left turn lane	1	1
No. of Slip lanes	0	0
No. of Signal Phases	2	2

11 Appendix C – Intersection Configurations

Intersection (Major / Minor)	Lanes Entering	Lanes Exiting	Right turn lane	Left turn lane	Slip lanes	No. of Phases	Total Phases in Cycle
Warrego Hwy / Tor St	4	4	2	0	2	2	3
	4	3	0	0	1	1	
Warrego Hwy / Neil	4	4	0	2	0	1	2
	4	2	0	0	0	1	
Warrego Hwy / Hume	4	4	0	0	1	1	3
	4	3	1	0	0	2	
West / Stephen	4	4	2	0	0	2	3
	4	2	0	0	0	1	
West / Margaret	4	4	0	0	0	1	2
	4	2	0	0	0	1	
Clifford / Herries	4	3	0	0	0	1	3
	4	4	0	0	0	2	
Warrego Hwy / Taylor	4	4	0	0	2	1	3
	4	4	2	0	0	2	
Hume / Jellicoe	4	2	0	0	0	1	2
	4	2	0	0	0	1	
West / Alderley	4	2	0	0	0	1	2
	4	2	0	0	0	1	
Bridge / Holberton	4	4	2	0	1	2	3
	4	2	0	0	1	1	
Warrego Hwy / Hursley	4	4	0	0	1	1	2
	4	2	0	0	0	1	
Taylor / Greenwattle	4	4	2	0	0	1	2
	4	2	0	0	0	1	
Warrego Hwy / West	4	4	2	0	2	2	4
	4	4	2	0	2	2	
West / Taylor	4	4	2	0	0	2	3
	4	2	0	0	0	1	
West / Stenner	4	2	0	0	0	1	2
	4	2	0	0	0	1	
Warrego Hwy / Mackenzie	4	4	0	0	0	1	2
	4	4	0	0	0	1	
Bridge / Mort	4	2	0	0	1	1	2
	4	2	0	0	0	1	
Warrego Hwy / New England Hwy	4	4	2	1	0	2	4
	4	4	2	1	0	2	
Drayton / South	4	2	0	0	0	1	2
	4	2	0	0	0	1	
Gore Hwy / Alderley	4	4	0	0	1	1	2
	4	2	0	0	0	1	

Intersection (Major / Minor)	Lanes Entering	Lanes Exiting	Right turn lane	Left turn lane	Slip lanes	No. of Phases	Total Phases in Cycle
Warrego Hwy / Kitchener St	4	4	2	0	1	2	4
	4	4	2	0	1	2	
Margaret / Mary	4	2	0	0	0	1	2
	4	2	0	0	0	1	
Bridge / Hume	4	2	0	0	0	1	2
	4	2	0	0	0	1	
West / Bridge	4	4	2	0	1	2	4
	4	4	2	0	1	2	
West / South	4	2	0	0	0	1	2
	4	2	0	0	0	1	
Kitchener / Herries	3	3	0	0	1	1	2
	4	3	0	0	0	1	
Gore Hwy / South	4	4	0	0	2	1	2
	4	2	0	0	0	1	
Taylor / Holberton	4	2	0	0	0	1	2
	4	2	0	0	0	1	
New England Hwy / Spring	4	4	2	0	0	1	2
	4	3	0	0	0	1	
Taylor / McDougall	4	4	2	0	2	2	3
	4	3	0	0	2	1	
New England Hwy / Stenner	4	4	2	0	2	2	4
	4	4	2	0	2	2	
New England Hwy / North	4	4	2	0	0	2	3
	4	2	0	0	0	1	
Warrego Hwy / Anzac Ave	4	4	2	0	1	2	4
	4	4	2	0	2	2	
Warrego Hwy / McDougall St	4	4	2	0	2	2	3
	4	2	0	0	0	1	
North / Mort	4	2	0	0	0	2	3
	4	2	0	0	0	1	
Ramsay / South	4	2	0	0	0	1	2
	4	2	0	0	0	1	
Warrego Hwy / Peachy	4	4	2	1	0	2	3
	4	2	0	0	0	1	
New England Hwy / Bridge	4	4	2	0	0	2	4
	4	4	2	0	0	2	
New England Hwy / Margaret	4	4	2	0	2	2	4
	4	3	2	1	0	2	
West / Herries	4	4	2	0	0	2	4
	4	3	2	0	0	2	
Herries / Ruthven	4	4	2	0	0	2	4
	2	2	2	2	0	2	

Intersection (Major / Minor)	Lanes Entering	Lanes Exiting	Right turn lane	Left turn lane	Slip lanes	No. of Phases	Total Phases in Cycle
Taylor / Boundary	4	4	2	0	2	1	2
	4	3	0	0	2	1	
Hume / Campbell	4	2	0	0	0	1	2
	4	2	0	0	0	1	
New England Hwy / Perth	4	4	2	0	0	2	3
	4	4	0	0	0	1	
Warrego Hwy / Boundary	4	4	2	1	0	2	3
	4	2	0	1	0	1	
Bridge / Mary	4	2	0	0	0	1	3
	4	2	0	0	0	2	
New England Hwy / Herries	4	4	2	0	0	2	4
	4	4	2	0	0	2	
New England Hwy / Campbell	4	4	2	1	0	2	3
	3	2	0	0	0	1	
Gore Hwy / Stephen	4	4	0	0	1	1	2
	4	2	0	0	0	1	
Margaret / Ruthven	4	2	0	0	0	2	4
	4	2	0	0	0	2	

12 Appendix D – Intersection Classifications

Intersection (Major / Minor)	AADT	Road Type	Intersection Class	Crash Count 2007-2011	Crash Rate per 10M Vehicles
Warrego Hwy / Tor St	20501	A	A3	34	6.98
	6172	3			
Warrego Hwy / Neil	15911	D	D4	20	5.83
	2892	4			
Warrego Hwy / Hume	15911	D	D3	28	5.72
	10902	3			
West / Stephen	14461	B	B4	18	4.85
	5881	4			
West / Margaret	15787	D	D4	20	4.68
	7606	4			
Herries / Clifford	8478	D	D3	13	4.58
	7059	3			
Warrego Hwy / Taylor	15551	D	D2	19	4.41
	8047	2			
Hume / Jellicoe	4666	E	E4	5	4.15
	1941	4			
West / Alderley	13055	E	E4	17	3.92
	10693	4			
Bridge / Holberton	14153	A	A4	14	3.45
	8093	4			
Warrego Hwy / Hursley	15551	D	D4	16	3.43
	10011	4			
Taylor / Greenwattle	11716	C	C4	10	3.39
	4440	4			
Warrego Hwy / West	21784	A	A1	22	3.33
	14461	1			
West / Taylor	15429	B	B4	13	3.27
	6351	4			
West / Stenner	11165	E	E4	12	3.13
	9830	4			
Warrego Hwy / Mackenzie	14919	D	D3	11	3.10
	4543	3			
Bridge / Mort	12130	E	E4	9	3.00
	4329	4			
Warrego Hwy / New England Hwy	15911	A	A1	16	2.89
	14436	1			
Drayton / South	8326	E	E4	6	2.87
	3134	4			
Gore Hwy / Alderley	14538	D	D4	12	2.84
	8627	4			

Intersection (Major / Minor)	AADT	Road Type	Intersection Class	Crash Count 2007-2011	Crash Rate per 10M Vehicles
Warrego Hwy / Kitchener St	15911	A	A1	14	2.81
	11352	1			
Margaret / Mary	9291	E	E4	6	2.79
	2499	4			
Bridge / Hume	8851	E	E4	7	2.58
	6003	4			
West / Bridge	13307	A	A1	13	2.53
	14837	1			
West / South	12164	E	E4	7	2.51
	3134	4			
Kitchener / Herries	8991	D	D3	7	2.41
	6942	3			
Gore Hwy / South	14538	D	D4	10	2.36
	8692	4			
Taylor / Holberton	7378	E	E4	6	2.13
	8093	4			
New England Hwy / Spring	21768	C	C3	11	2.10
	6955	3			
Taylor / McDougall	11716	A	A3	7	2.08
	6682	3			
New England Hwy / Stenner	21768	A	A1	13	2.01
	13681	1			
New England Hwy / North	17913	B	B4	9	1.96
	7293	4			
Warrego Hwy / Anzac Ave	21784	A	A1	12	1.88
	13139	1			
Warrego Hwy / McDougall St	20501	A	A4	9	1.82
	6624	4			
North / Mort	8583	E	E4	4	1.79
	3678	4			
Ramsay / South	7729	E	E4	4	1.78
	4613	4			
Warrego Hwy / Peachy	21784	A	A4	8	1.57
	6069	4			
New England Hwy / Bridge	17913	B	B2	8	1.55
	10332	2			
New England Hwy / Margaret	14436	A	A1	8	1.52
	14419	1			
West / Herries	14461	B	B2	6	1.52
	7222	2			
Herries / Ruthven	16456	B	B1	8	1.47
	13398	1			

Intersection (Major / Minor)	AADT	Road Type	Intersection Class	Crash Count 2007-2011	Crash Rate per 10M Vehicles
Taylor / Boundary	11716	C	C3	4	1.11
	7986	3			
Hume / Campbell	7115	E	E4	3	1.04
	8670	4			
New England Hwy / Perth	14436	B	B3	3	1.02
	1737	3			
Warrego Hwy / Boundary	14647	A	A4	4	1.01
	7048	4			
Bridge / Mary	6222	E	E4	2	0.96
	5224	4			
New England Hwy / Herries	14436	B	B2	3	0.79
	6350	2			
New England Hwy / Campbell	17913	A	A4	3	0.62
	8670	4			
Gore Hwy / Stephen	14538	D	D4	1	0.29
	4529	4			
Margaret / Ruthven	11024	E	E4	1	0.24
	11693	4			

13 Appendix E – Top 10 Intersection Crash Rates

Intersecting Streets - **Warrego Hwy (Bridge St) & Tor St**

Suburb – Wilsonton

Major Road – Warrego Hwy (Bridge St) AADT – 20501 (7.8% HV)

Minor Road – Tor St AADT – 6172 (6.0% HV)

Intersection Configuration

	Major Road	Minor Road
No. of Lanes Entering	4	4
No. of Lanes Exiting	4	3
Designated Right turn lane	2	0
Designated Left turn lane	0	0
No. of Slip lanes	2	1
No. of Signal Phases	2	1

Intersection Class – A3

Crash Rate – 6.98 / 10 million vehicles

Intersecting Streets - **Warrego Hwy (James St) & Neil St**

Suburb – Toowoomba City

Major Road – Warrego Hwy (James St) AADT – 15911 (19.8% HV)

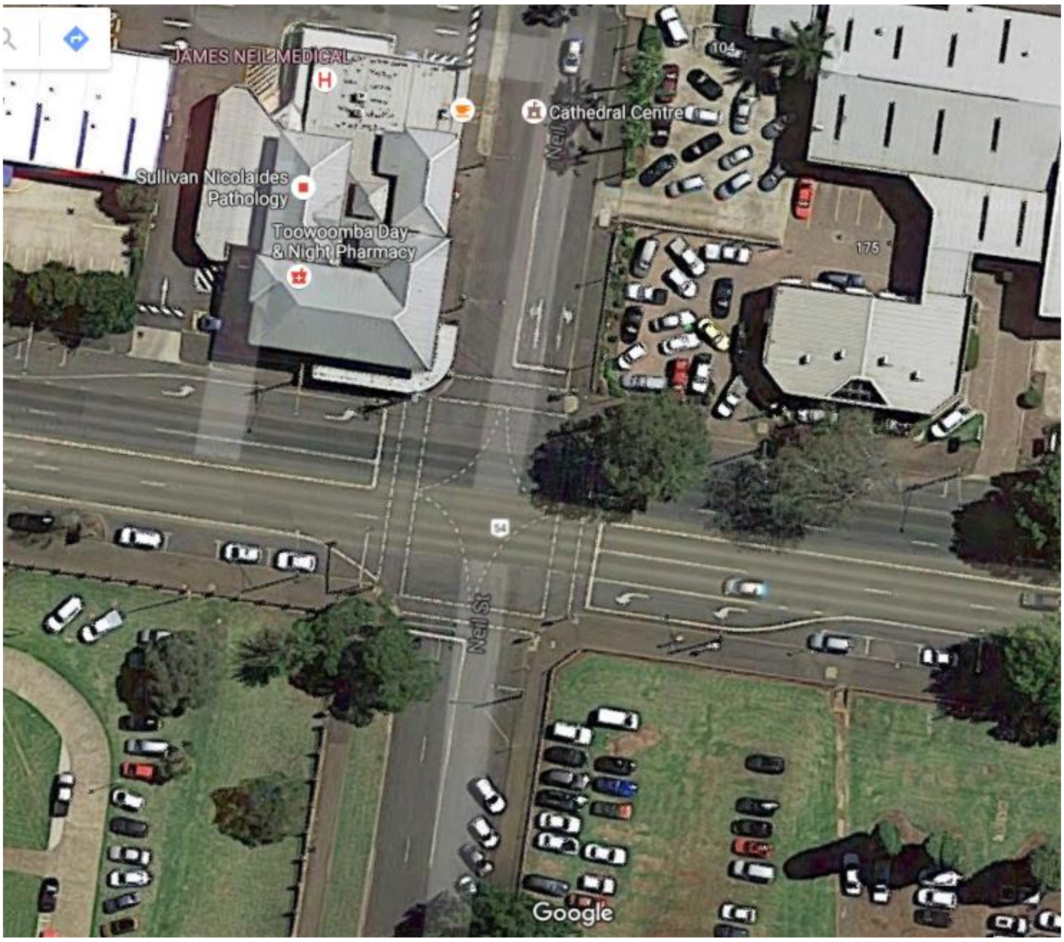
Minor Road – Neil St AADT – 2892 (7.0% HV)

Intersection Configuration

	Major Road	Minor Road
No. of Lanes Entering	4	4
No. of Lanes Exiting	4	2
Designated Right turn lane	0	0
Designated Left turn lane	2	0
No. of Slip lanes	0	0
No. of Signal Phases	1	1

Intersection Class – D4

Crash Rate – 5.83 / 10 million vehicles



Intersecting Streets – **Warrego Hwy (James St) & Hume St**

Suburb – Toowoomba City

Major Road – Warrego Hwy (James St) AADT – 15911 (19.8% HV)

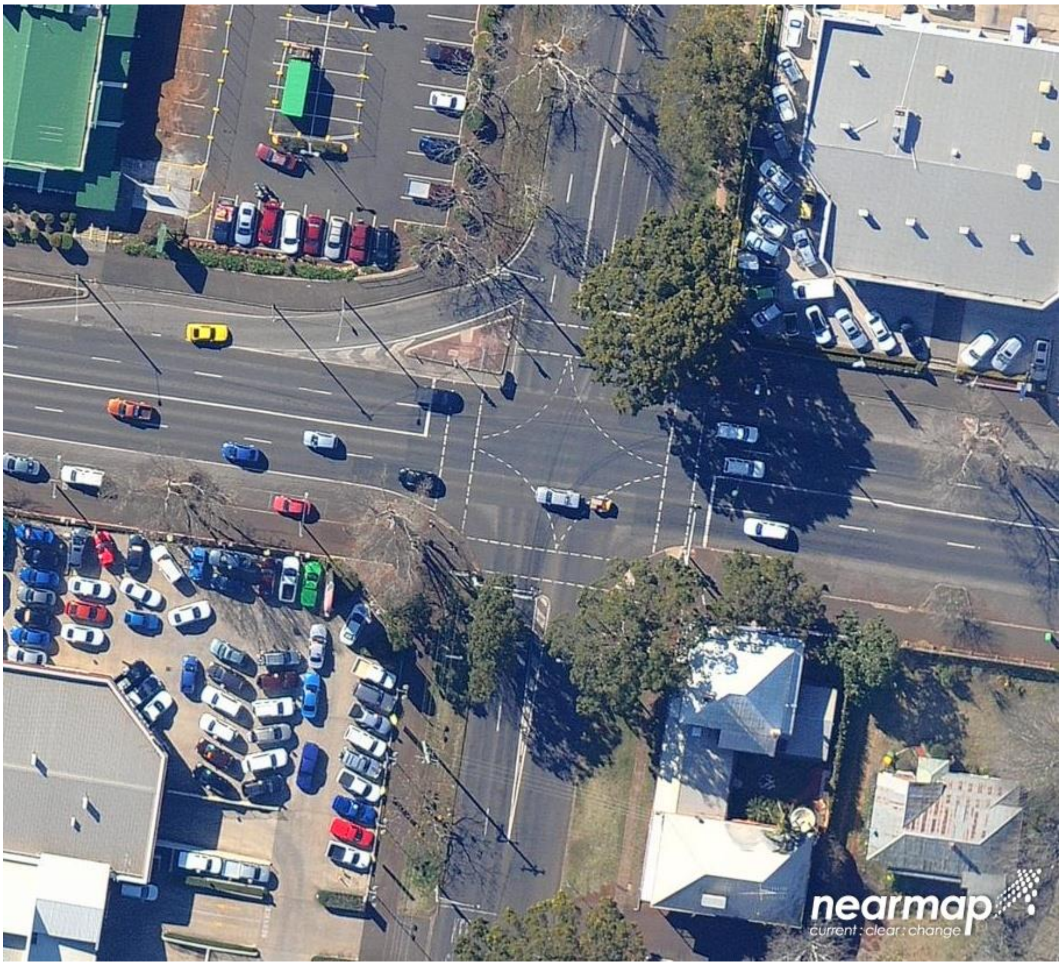
Minor Road – Hume St AADT – 10902 (4.0% HV)

Intersection Configuration

	Major Road (60km/h)	**Minor Road (60km/h)**
No. of Lanes Entering	4	4
No. of Lanes Exiting	4	3
Designated Right turn lane	0	1
Designated Left turn lane	0	0
No. of Slip lanes	1	0
No. of Signal Phases	1	2

Intersection Class – D3

Crash Rate – 5.72 / 10 million vehicles



Intersecting Streets – **West St & Stephen St**

Suburb – Harristown

Major Road – West St AADT – 14461 (6.3% HV)

Minor Road – Stephen St AADT – 5881 (4.0% HV)

Intersection Configuration

	Major Road (60km/h)	Minor Road (60km/h)
No. of Lanes Entering	4	4
No. of Lanes Exiting	4	2
Designated Right turn lane	2	0
Designated Left turn lane	0	0
No. of Slip lanes	0	0
No. of Signal Phases	2	1

Intersection Class – B4

Crash Rate – 4.85 / 10 million vehicles

Intersecting Streets – **West St & Margaret St**

Suburb – Newtown

Major Road – West St AADT – 15787 (6.5% HV)

Minor Road – Margaret St AADT – 7606 (4.2% HV)

Intersection Configuration

	Major Road (60km/h)	Minor Road (50km/h)
No. of Lanes Entering	4	4
No. of Lanes Exiting	4	2
Designated Right turn lane	0	0
Designated Left turn lane	0	0
No. of Slip lanes	0	0
No. of Signal Phases	1	1

Intersection Class – D4

Crash Rate – 4.68 / 10 million vehicles

Intersecting Streets - **Herries St & Clifford St**

Suburb – Toowoomba City

Major Road – Herries St AADT – 8478 (3.6% HV)

Minor Road – Clifford St AADT – 7059 (5.0% HV)

Intersection Configuration

	Major Road (60km/h)	Minor Road (60km/h)
No. of Lanes Entering	4	4
No. of Lanes Exiting	4	3
Designated Right turn lane	0	0
Designated Right turn lane	0	0
No. of Slip lanes	0	0
No. of Signal Phases	2	1

Intersection Class – D3

Crash Rate – 4.58 / 10 million vehicles

Intersecting Streets –**Warrego Hwy & Taylor St**

Suburb – Newtown

Major Road – Warrego St AADT – 15551 (17.9% HV)

Minor Road – Taylor St AADT – 8047 (7.2% HV)

Intersection Configuration

	Major Road (60km/h)	**Minor Road (60km/h)**
No. of Lanes Entering	4	4
No. of Lanes Exiting	4	4
Designated Right turn lane	0	2
Designated Left turn lane	0	0
No. of Slip lanes	2	0
No. of Signal Phases	1	2

Intersection Class – D2

Crash Rate – 4.41 / 10 million vehicles

Intersecting Streets – **Hume St & Jellicoe St**

Suburb – North Toowoomba

Major Road – Hume St AADT – 4666 (5.0% HV)

Minor Road – Jellicoe St AADT – 1941 (7.5% HV)

Intersection Configuration

	Major Road (60km/h)	Minor Road (60km/h)
No. of Lanes Entering	4	4
No. of Lanes Exiting	2	2
Designated Right turn lane	0	0
Designated Left turn lane	0	0
No. of Slip lanes	0	0
No. of Signal Phases	1	1

Intersection Class – E4

Crash Rate – 4.15 / 10 million vehicles

Intersecting Streets – **West St & Alderley St**

Suburb – Harristown

Major Road – West St AADT – 13055 (4.2% HV)

Minor Road – Alderley St AADT – 10693 (3.3% HV)

Intersection Configuration

	Major Road (60km/h)	Minor Road (60km/h)
No. of Lanes Entering	4	4
No. of Lanes Exiting	2	2
Designated Right turn lane	0	0
Designated Left turn lane	0	0
No. of Slip lanes	0	0
No. of Signal Phases	1	1

Intersection Class – E4

Crash Rate – 3.92 / 10 million vehicles

Intersecting Streets - **Bridge St & Holberton St**

Suburb – Newtown

Major Road –Bridge St AADT – 14153 (10% HV)

Minor Road – Holberton St AADT – 8093 (5.0% HV)

Intersection Configuration

	Major Road (60km/h)	**Minor Road (60km/h)**
No. of Lanes Entering	4	4
No. of Lanes Exiting	4	2
Designated Right turn lane	2	0
Designated Left turn lane	0	0
No. of Slip lanes	1	1
No. of Signal Phases	2	1

Intersection Class – A4

Crash Rate – 3.45 / 10 million vehicles