University of Southern Queensland

Faculty of Health, Engineering & Sciences

Transitioning roadways from high-speed to low-speed environments when approaching regional towns in North Queensland

A dissertation submitted by

Jared West

In fulfilment of the requirements of

Bachelor of Engineering (Honours) (Civil)

October 2015

Abstract

This project combines a desktop study and field sampling to assess the effectiveness of traffic control devices currently in place to transition motorists from high-speed to low-speed environments. The project focuses on regional town approaches within North Queensland as there is limited research and experimentation on this sector of road safety in the area. Speed sampling, crash data and the analysis of relevant environmental factors form the basis of the evaluation of the effectiveness of traffic control devices in place.

Background information presented includes the physical and psychological elements which dictate the speed environment, speed and transition zones, current gateway treatments and other management strategies. International case study experiments relevant to transition zones approaching regional towns are evaluated and signal the performance of different treatments. The experimentation methodology employed was the speed sampling of five transition zones throughout North Queensland. Crash data within the five transition zones was critically evaluated to ascertain if a link between speed and crash data could be established.

Speed sample results indicate that the current traffic control devices are ineffective in achieving acceptable speed compliance. However, the evaluation also indicates that the crash rates in the focus areas are not significant enough to be considered high priority as current traffic control devices are effective in limiting ‘fatal crashes’. Site specific recommendations are provided for changes to improve speed compliance throughout the focus areas.

University of Southern Queensland

Faculty of Health, Engineering and Sciences

ENG4111/ENG4112 Research Project

Limitations of Use

University of Southern Queensland
Faculty of Health, Engineering and Sciences
ENG4111/ENG4112 Research Project

Certification of Dissertation

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.

Jared West

0050026255

Signed: J West

Dated: 29/10/15

Acknowledgements

I would like to take the opportunity to thank my supervisor, Professor Ron Ayers, for the support and guidance he has provided throughout this project.

Table of Contents

List of Figures

Abbreviations

ADT	Average daily traffic
AADT	Annual average daily traffic
DHV	Design hourly volume
MUTCD	Manual of Uniform Traffic Control Devices

Chapter 1

Introduction

Road transportation is a major platform for Australian's to carry out their lives and has become an integral component of modern society. The benefits road transportation provides Australians and their families are hard to rival. Unfortunately road transportation is also associated with a long history of incidents which too often result in fatalities or serious harm.

With the exponential societal increase in usage of road transport, a significant emphasis has been placed on improving road safety to combat the exposure to public harm. The focus on road safety has been implemented by all areas of Government and some private industry for many years. Over the past few decades the road transport network has transformed from humble beginnings to a truly spectacular segment of Australia's infrastructure. The major cities have motorways and freeways with impressive overpasses, ramps and bridges. North Queensland's regional town approaches however are generally serviced by significantly less complex infrastructure.

Queensland's sheer size, quality of roads and long stretches between built-up environments requires a real focus on road safety in order to allow for safe passage of residents and tourists alike. Observations have been made that the compliance to speed limits upon entering built-up areas can at times be poor in regional North Queensland. This lack of compliance is generally treated with additional police enforcement where resource allocations allow.

The project's importance is reinforced by the lack of research undertaken into the transition between the rural environment and the built-up regional environment throughout North Queensland. To date there has been no extensive research work undertaken in Australia regarding the effectiveness to reduce speeds at 'gateways' within regional townships.

The project will provide an understanding of the fundamental elements of transitioning roadways from high-speed to low-speed environment. The project compiles a comprehensive literature review of relevant traffic engineering and road safety elements in order to provide a local and global appreciation of roadway speed transitioning. The current performance in the North Queensland region is assessed by acquiring relevant crash data and undertaking speed sample field testing. A critical review of the results was undertaken to assess current compliance issues and recommend measures to improve speed conformance when transitioning from high-speed to low-speed environments.

1.1 Project Objectives

This project seeks to analyse the effectiveness of traffic control devices currently in place to transition motorists from high-speed to low-speed environments. The specific geographical focus will be on approaches to rural townships within North Queensland.

Specific project objectives are as follows;

- Develop a clear understanding of what current treatment and management strategies are in place to transition between speed environments.

- Attain crash data which may be associated with not effectively transitioning speeds in the North Queensland area.

- Undertake field survey's to measure compliance to the posted speed limits in speed reduction zones. The field surveys will require speed samples of motorists to be recorded with the use of a speed detection gun.

- Analyse recorded speed data from the field to develop an understanding of public compliance to current measures in place.

- Analyse environmental factors relevant to the region and determine whether that has an effect on the appropriateness of the strategies in place.

- Research additional treatments that exist outside of the region.

Initial works on this project required a literature review to be conducted in order to determine relevant characteristics which contribute to the project. This included background research on road design standards relevant to the focus area, an understanding of the speed environment and what treatments and management standards exist both nationally and internationally. Review of the Austroads publications has been crucial for the project's literature review. The Transport and Main Roads (QLD) website provides the Manual of Uniform Traffic Control Devices and the Road Planning and Design Manual which is used in conjunction with Austroads Guide to Road Design for the design of roads throughout Queensland.

1.2 Geographical focus

North Queensland has no official boundary to separate itself from the rest of Queensland. For the purposes of this study North Queensland will be defined as the area bounded by Ingham to the north, Pentland to the west and Home Hill to the south. This is aligned with the Queensland Department of Transport and Main Roads definition of the Northern District. The following map provided by the Queensland Department of Transport and Main Roads outlines the geographical boundaries.

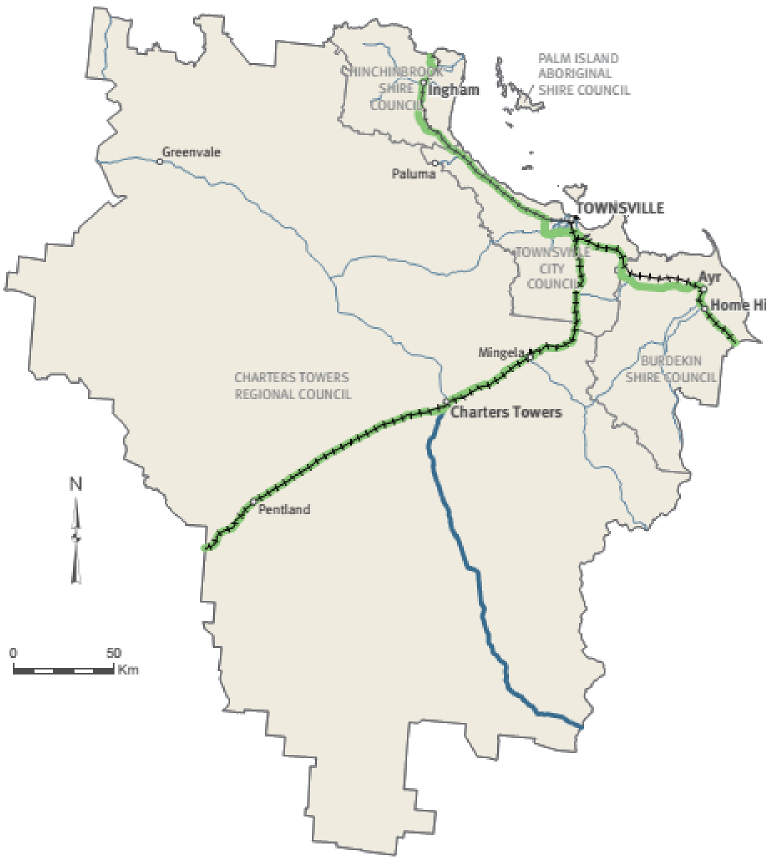

Figure 1.1: Geographical Focus Area – North Queensland

Source: (Department of Transport and Main Roads 2014)

North Queensland's largest urban centre is Townsville which is home to around 180,000 people and is approximately 1,350 kilometres north of Brisbane. Townsville has a large port which exports material from mines to the west along with cattle exports. The surrounding townships are much smaller and towns such as Ingham and Ayr are significant sugar cane growers whilst Charters Towers is based on gold mining and cattle farming. Annual temperatures and humidity throughout coastal areas are generally high and seasonal rainfall is usually significant.

The major highway for this area is the Bruce Highway which runs along the east coast of Queensland. The Bruce Highway begins in Brisbane and concludes in Cairns. The Bruce Highway is approximately 1,700km long and is entirely sealed. Within North Queensland the heavily trafficked highway passes along the coastal towns of Home Hill, Ayr, Townsville and Ingham. Due to increasing traffic volumes, numerous overtaking lanes have been constructed and retrofitted to provide better overtaking opportunities for vehicles trailing slower moving trucks or with caravans. The roadside development varies substantially along the route with sugarcane plantations, urban areas, cattle properties and consists of both flat and elevated terrain. The posted speed limit varies from 60km/hr in urban areas up to 100km/hr which is typically experienced on this highway within North Queensland. For the most part the roadway consists of two line-marked 3.5 metre wide lanes with 1 metre shoulders.

Figure 1.2: Typical depiction of Bruce Highway (Ayr to Townsville)

Source: (Google Maps)

The Flinders Highway extends from Townsville to the west, encompassing Charters Towers and Pentland within the defined geographical focus area of North Queensland. The Flinders Highway's roadside development generally consists of bushland with posted limits up to 110km/hr in areas. Two 3.5 metre wide lanes separated with line marking and 1 metre wide shoulders is the most common road layout of the Flinders Highway. Large kangaroos by the roadside are common along this stretch and due care needs to be taken to evade them wherever possible to prevent significant damage to the vehicle and or road user.

Figure 1.3: Typical depiction of Flinders Highway (Townsville to Charters Towers)

Source: (Google Maps)

Urban locations throughout the focus area which were assessed for driver compliance to transitioning from high-speed to low-speed environments included;

- Charters Towers (Flinders Highway Eastern approach)
- Ingham (Bruce Highway Northern approach)
- Ingham (Bruce Highway Southern approach)
- Pentland (Flinders Highway West Approach)
- Ayr (Bruce Highway Northern approach)

The projects geographic focus on North Queensland will add to the state-of-the-art literature base within the field of road safety engineering for this area.

The roadway characteristics, traffic control devices and infrastructure of regional North Queensland are similar to many regional centres throughout Australia. The project findings could be applied and transferred to a large majority of Australian regional areas. The findings would not be applicable to larger urban towns or cities due to the contrast of roadway features, traffic control devices and traffic volumes.

Chapter 2

Background - What Dictates the Speed Environment?

The speed environment can be described as the mean vehicle speeds of the traffic flow. The speed environment governs the speed at which vehicles are restricted to travel at or below and dictates the standard of road design to be implemented. It is achievable to increase the speed environment with a higher level of service road design however this generally incurs significant cost.

The speed environment is dictated by three elements; namely including roadside development, road characteristics and traffic characteristics. These elements influence the driver's perception of what is an acceptable maximum travel speed. This chapter explores these elements.

2.1 Roadside Development

Fildes & Lee (1993) describe roadside development as any aspect of the physical environment which is close enough to make impact on driving behaviour.

Generally road user's compliance to posted speed limits is poor in situations where the roadside development abutting the roadway does not have an acceptable relationship with the speed limit.

Austroads (2010b) identifies that rural roads are required to accommodate for a number of roadside features such as signage and open drain excavations. Urban roads generally need to cater for many other aspects such as footpaths, service utilities and landscaping. Application of best practise in design will lead to road safety improvements when considering the design of roadside features.

Significant roadside features applicable to the North Queensland region include guide posts and road lighting. Austroads (2009a) describe that the purpose of guide posts are to mark the edge of the road. Guide posts assist the road user by indicating upcoming road alignment. Guide posts are generally closely spaced when positioned adjacent to horizontal and vertical curves in order to reinforce their effect. During the night the road users headlights activate the guide posts retroreflective markers providing guidance at all times.

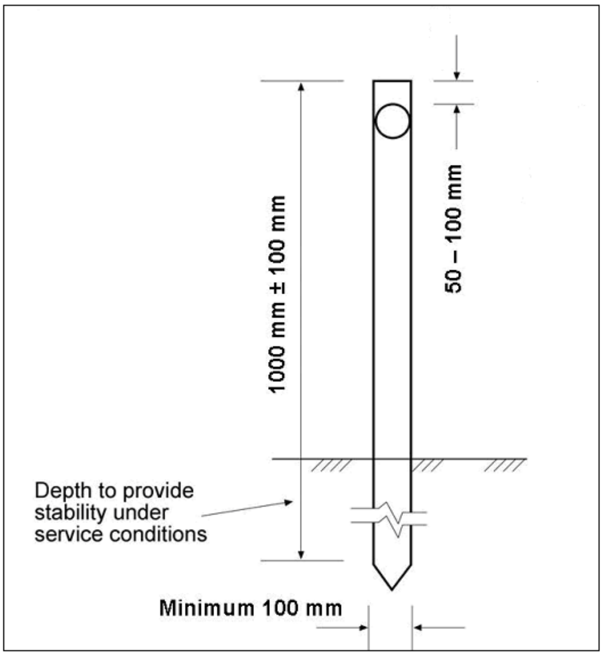

Figure 2.1: Typical guide post

Source: (Austroads 2009b)

The general concept of road lighting design is defined by Austroads (2009a) as ensuring the road environment is sufficiently visible to ensure that the driving task is performed successfully. Austroads (2009a) highlights the significant road safety improvements that road lighting provides by presenting the findings of their road safety engineering risk assessment project. The estimated results for various environments are tabulated below.

Environment		% reduction in all injury crashes at night*	Confidence
Improve lighting	All environments	30%	Medium
	Mid-block	30%	Low
	Intersections	40%	Low
Install lighting	All environments	35%	Medium
	Intersections	50%	Medium
	Mid-block	40%	Medium
	Rural	30%	Low
	Rural intersection	40%	Medium
	Urban	30%	Low
	Urban intersection	20%	Low

Figure 2.2: Estimated night-time crash reduction for road lighting

Source: (Austroads 2009a)

Austroads (2008) advises that the activity levels generated by bordering roadside environment have a significant impact on vehicle speeds. Speed zones should be assessed considering the relevant roadside factors such as; do access restrictions to the road exist such as rail lines, beaches, hill cuttings and parks? Is there a significant variation in development between opposing sides of the road? How many intersections are present whether controlled or uncontrolled? Also of interest is the number and setback distance of adjoining driveways and the nature of the environment (residential, industrial, commercial or rural).

Fildes et al (1987) undertook experimental testing to develop an appreciation of the effect the roadside environment had on vehicle speeds, comparing spacious roadside environment's to walled and congested environments. Their findings generally suggested that the environment had more effect on driver's safety responses rather than the travel speeds. They also found that the walling usually found in rural scenarios (such as trees, fencing and other vegetation) did not unduly influence driving speed.

2.2 Traffic Characteristics

(Austroads 2006) divides road users into three categories in relation to their vehicles. Categories include motorised vehicles such as trucks, buses, cars and motorcycles, non-motorised or low-powered vehicles and pedestrians who do not utilise a vehicle.

As this projects focus is based on regional township approaches the large majority of road users will fall within the first category, namely motorised vehicles.

Traffic characteristics requiring consideration are outlined in (MUTCD 2003) highlighting traffic volume/pattern and traffic composition. The traffic volume and pattern needs to consider the amount of daily traffic incorporating fluctuations which may occur. These could include such activities as sporting events, school hours or the local town show. Traffic composition analysis provides an understanding of the proportion of heavy vehicles, pedestrians and cyclists.

Traffic volumes are described by AASHTO (2001). Average daily traffic (ADT) is a basic measure of highway traffic demand. ADT is defined as the total traffic volume over a period of time. The period of time is required to be greater than one whole day and less than three hundred and sixty five days. ADT volumes are essential in determining current usage of roadways. This understanding should lead to more effective allocation of funding to repair or provide efficiency increases to roadways. However the issues with ADT volumes is it will usually negate the variations in traffic volumes during months of the year, days of the week or hours of the day. This is an important distinction to be aware of as in some rural locations traffic volumes can be double the ADT during certain times of the year.

More locally the Department of Main Roads (2004) reinforce the importance of traffic demand and note that traffic patterns are of special interest due to the large tourist demand in coastal areas. The design of a road network should utilise localised traffic variations, which can be attained by collection of data. The term Annual Average Daily Traffic (AADT) defines the total yearly traffic volume divided by the number of days within that year. Similar to the ADT volumes the AADT also has limited use in relation to the design of roads due to the lack of detailed information on volume variation throughout the day, week or year. Hourly volumes will provide a more appropriate measure of the traffic conditions needing to be addressed by the road design. It is apparent all roads will experience fluctuations and periods of high activity throughout the day. The following figure provides an indication of the relationship between hourly volumes and AADT.

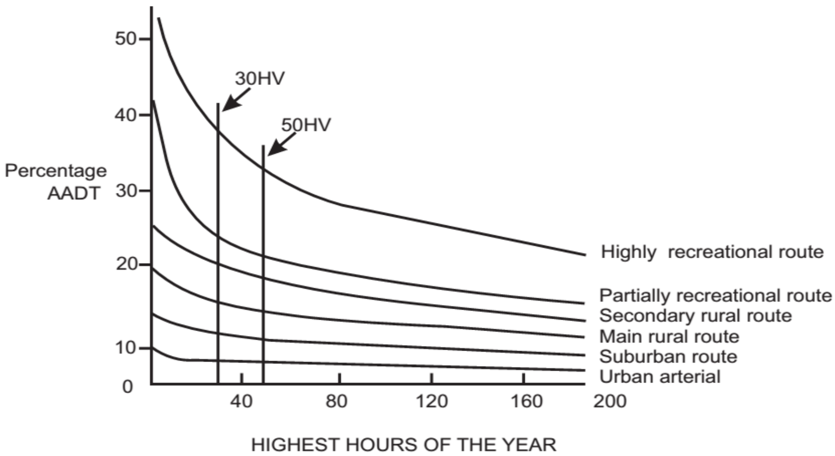

Figure 2.3: Relationship between hourly traffic volumes AADT

Source: (Department of Main Roads 2005)

The distribution of traffic also requires consideration when selecting a Design Hourly Volume (DHV). Department of Main Roads (2004) notes that that the volume of traffic flow in each direction can vary from 55 to 70 percent of overall flow. Therefore the design must incorporate the transverse distribution of vehicles to ascertain a proper design. Vehicle longitudinal distribution describes relative position in a direction of flow. This distribution is calculated from the travelling distance between the vehicles referred to as ‘gaps’ and the actual length of the vehicles. In rural situations it is common for vehicles to travel in bunches due to factors such as limited overtaking opportunities, roadworks or traffic signal control upstream. It is worth noting that consideration is required to estimate the projection of future traffic. This projection is incorporated via the selection of a design year which will allow for forecasted traffic volumes. Generally speaking designs are based on a working life of 20 years from the beginning of operation.

Traffic composition according to the Department of Main Roads (2004) is the division of groups within the traffic streams. These groups are divided into four categories namely passenger cars (cars and light trucks), trucks (includes all buses, combination vehicles and other multi combination vehicles, motorcycles and bicycles. It is noted that when a car tows a caravan it forms part of the truck group within the traffic stream due to the similarity in characteristics as a result of increased weight and decreased speed, acceleration and braking capability.

Austroads (2010a) highlights road user behaviour should be considered as central to the majority of the design decisions relating to roadways. The performance of the drivers is the single most important factor when considering the efficiency and safety of a road system. Past understanding of road user behaviours provides a basis for many elementary design perimeters such as geometric design and selecting a suitable operating speed. A better understanding of road user behaviour may result in designers producing more appropriate and beneficial road designs.

Further emphasis on the appreciation of driver performance is provided in AASHTO 2001 where it defines the appreciation as essential to produce suitable highway designs. Where a highway has been designed to accommodate driver capabilities and their limitations roadway performance is increased. Attention is drawn to the increase in older drivers in the highway user population. An ageing population may have the potential to undesirably change the highways efficiency and safety spectrum. Older drivers possess special needs which must to be considered in the design of roadways. These needs require consideration such as additional brightness at night to assist in understanding visual information. It was found that drivers need double the brightness for each decade following the age of twenty-five.

AASHTO (2001) divides the act of driving or riding a vehicle into three tasks. These tasks include navigation (planning and route following), guidance (following road markings and adjusting path in response to changes in a safe manner) and control (appropriate speed and steering inputs).

According to Austroads (2010a) a significant number of geometric design standards are guided by the sensory ability of driver's vision and hearing. Many traffic control devices incorporate vibration and hearing to provide a sensory cue to the operator; these include devices such as rumble strips and audio tactile edge lines. Critical attributes to an operators driving performance include colour sensitivity, peripheral vision and visual acuity. Lighting conditions can have a significant impact on those visual attributes along with aging and the consumption of drugs and or alcohol. Design factors such as sign design and sight distance are heavily reliant on visual recognition and response timings.

2.3 Road Characteristics and Design Standards

An informed decision is required when selecting the design speed to ensure the road is engineered to perform well and balance cost effectiveness.

Road characteristics which influence the speed environment are outlined in MUTCD (2003) and include alignment, road access, road junctions/intersections, adjoining road section, shoulder width/type, roadside hazards and lane width.

A traffic lane is described by Austroads (2010a) as part of a roadway allocated for one-way flow of single stream vehicles. The quantity and width of the lane has a substantial influence on the roadways comfort, capacity and safety. Lane characteristics such as number and width usually depend on volumes, percentage of heavy vehicles, cyclist or pedestrian usage, available corridor width, adjoining roadside development and accident rates. Lane widths on rural roads are desirably 3.5m. A width of this magnitude allows overtaking manoeuvres to be undertaken without any requirement for either vehicle to position the vehicle in close proximity to the edge of the road. Where wider lanes are provided in rural situations it is observed that the additional cost of construction is partly offset by reduced maintenance of the road shoulder in the long term. The concentration of wheel paths in the vicinity of pavement edge increase with narrow lanes and vehicle movement is laterally closer. It is also observed that when travelling through narrow lanes drivers reduce speed and try to position the vehicle closer to the centre of the road to provide more clearance to the road edge.

Another important element of roadway design is Crossfall. According to Austroads (2010a) crossfall is a measurement of the cross-sectional slope of the road away from the crown (highpoint in cross-section). Crossfall is required to drain the pavement surface and can be used to provide additional friction on curves. The following table provides some typical values for crossfall on straight roads for various pavement types.

Type of pavement	Crossfall (%)
Earth, loam	5
Gravel, water bound Macadam	4
Bituminous sprayed seal	3
Asphalt	2.5 – 3
Portland cement concrete	2 – 3

Figure 2.4: Typical pavement crossfall on straight roads

Source: (Austroads 2010a)

Austroads (2010a) advises that many Australian roads carry less than 150 vehicles each day. Single lane carriageways may be implemented throughout the road network in areas where the terrain is open and vast. It is suggested that the single lane carriageway be at least 3.7m wide to reduce the potential for disproportionate shoulder wear, however a width between 4.5m and 6.0m has the potential for vehicles to attempt passing without moving partially off the sealed pavement. The following table provides suitable design rural road width’s when considering volume characteristics.

Element	Design AADT				
	1 – 150	150 – 500	500 – 1,000	1,000 – 3,000	> 3,000
Traffic lanes(1)	3.7 (1 x 3.7)	6.2 (2 x 3.1)	6.2 – 7.0 (2 x 3.1/3.5)	7.0 (2 x 3.5)	7.0 (2 x 3.5)
Total shoulder	2.5	1.5	1.5	2.0	2.5
Minimum shoulder seal (2),(3),(4),(5),(6)	0	0.5	0.5	1.0	1.5
Total carriageway	8.7	9.2	9.2 – 10.0	11.0	12.0

Figure 2.5: Suitable design road widths

Source: (Austroads 2010a)

The sight distance is described by Austroads (2010a) as the length along the carriageway which allows visibility of an object by a driver, or between two drivers. Sufficient sight distance allows for drivers to recognise and react to upcoming hazards on the road. Roads without satisfactory sight distance will provide less safety, efficiency and driver comfort. Wherever possible the designer should endeavour to maximise sight distance whilst understanding that elements such as vertical curves and obstructions will provide restrictions.

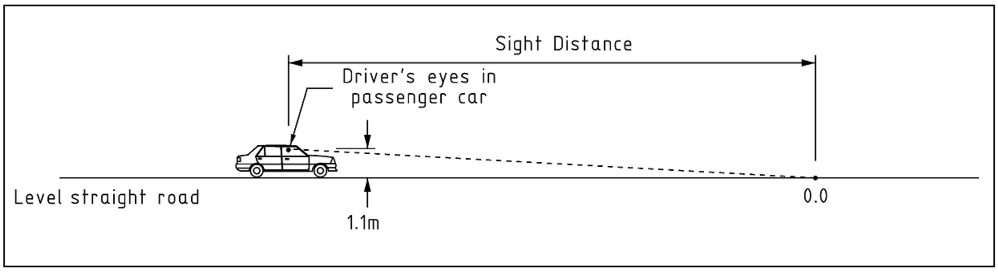

Figure 2.6: Sight distance depiction

Source: (Austroads 2010a)

Whilst road geometry has a significant impact on the operating speeds of drivers there are numerous other factors. Austroads (2010a) provides some insight into factors such as the amount of risk the drivers are prepared to carry, speed limits and the limits enforced by police and the vehicles performance (engine and transmission performance, braking and handling capability). It is recognised that these factors base themselves in the principles of behavioural science. Designers rely on a psychological understanding outside of safety and design to predict driver behaviour as a result of the perceived roadway and environment. Behaviour modifiers include the presence of a busy or stimulated environment which has the ability to distract road users or overload them to the point that they perceive higher risk and consequently reduce overall speed. Poor road conditions and high levels of pedestrian movements can lead to lower driver speeds whilst smooth roads resulting in reduced noise, vibration and harshness inside the vehicle can result in higher driver speeds. Other factors contributing to higher speeds include significant road lighting, increased clearing adjacent to roadway and user familiarity to the roadway. Other speed reduction modifiers include high levels of police enforcement or a high percentage of heavy vehicles within the traffic stream which causes an increased risk perception. It is worth noting that while all of these factors appear to correlate with most people's experiences they have yet to be formally researched or accepted by the academic community.

Chapter 3

Background - Speed and Transition Zones

This chapter explores in detail speed zones, speed limits along with transition zones and their place in modern roadway design and classification.

3.1 Speeding and Speed Management

Speeding is described within NCHRP Synthesis 412 (2011) as either travelling too fast for prevailing conditions or driving in excess of the posted speed limit. Speeding is well documented as a major contributor to road crashes. Speed contributed to 31% of fatal crashes throughout North America in 2008. It is estimated that the economic cost to society in North America for speed related crashes is in excess of $40 billion US Dollars.

According to NCHRP Synthesis 412 (2011) speeding within urban areas creates both a safety and quality of life concern. Higher speeds are well documented with an associated increased severity of road crashes, in particular with other road stakeholders such as cyclists and pedestrians. Conventional wisdom supports this documentation as a result of the increased distance travelled during perception-reaction time and a reduced visual field affecting periphery vision whilst travelling at higher speeds.

Closer to home, Austroads (2008) links travel speed and casualties directly. Research and evaluation has identified that even small reductions in travel speeds will significantly reduce crashes and their associated trauma. This is a result of lower speeds providing road users additional time for hazard assessment and crash avoidance, reduced reaction time and vehicle braking distance requirements.

The Australian Transport Council (2006) stated that speeds over the posted speed limited of more than 5km/hr in urban areas and 10km/hr in rural areas resulted in twice the risk of incurring a casualty in a road crash. It also found that small percentage reductions in speeds (such as one or two percent) had a significant impact on the reduction of death or injury. Methods implemented to establish these findings include reviewing other bodies of research which included before and after studies of the impact of speed limit changes and speed enforcement changes. Other methods include correlating crash rates of comparable roads with varying speed distributions, detailed investigation and crash reconstructions.

Austroads (2008) summarised the analysis of research undertaken by Elvik et al (2004) to present findings on travel speed and casualty rate relationships. The research was very extensive including 98 studies from 20 different countries between 1966 and 2004. Approximately 50% of the studies included were conducted after 1990, including both urban and rural roads with speed ranging from approximately 25km/hr to 120km/hr. Summary of the results are provided in the following figures.

	Change in mean speed					
	Speed reduction			Speed increase		
	-10%	-5%	-1%	+1%	+5%	+10%
Change in:						
Deaths	-38%	-21%	-4%	+5%	+25%	+54%
Serious injuries	-27%	-14%	-3%	+3%	+16%	+33%
Other injuries	-15%	-7%	-1%	+2%	+8%	+15%
Property damage crashes	-10%	-5%	-1%	+1%	+5%	+10%

Figure 3.1(a): Relationship between speed and casualty rates

Source: (Austroads 2008)

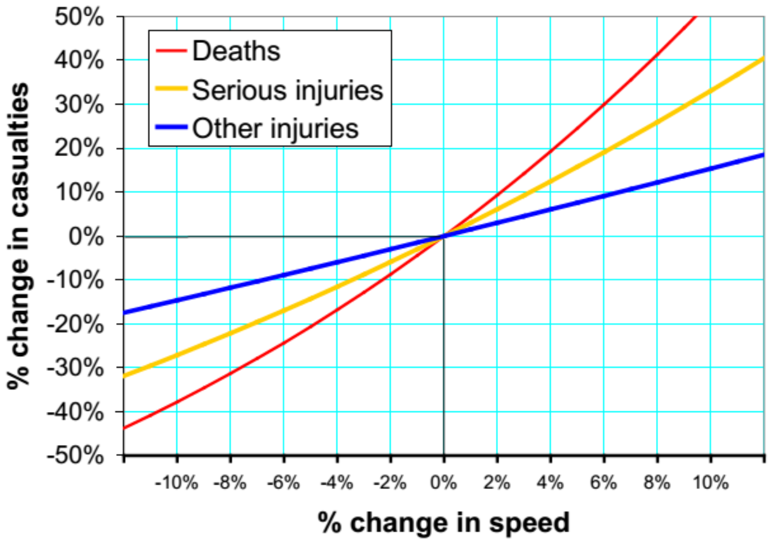

Figure 3.1(b): Relationship between speed and casualty rates – graphical

Source: (Austroads 2008)

The results demonstrate the significant and severe impact that speed has on road crash casualties and injuries reinforcing the importance of enforced speed limits on our roads.

3.2 Types of Speed Limits and Speed Zones

According to MUTCD (2003) in the absence of definitive means to establish speed limits, general speed limits are applied by law to classes of roads dependant on their environment. These general speed limits fall into two categories. Firstly a general urban speed limit is prescribed as 50km/hr which is applied to urbanised/built up areas without a defined speed zone. Secondly a general speed limit for rural areas is prescribed as 100km/hr, which is also applied in the absence of a defined speed zone. In Queensland the general speed limits are enforceable by policing bodies whether or not a posted sign is installed.

The MUTCD (2003) refers to criteria based speed limits as the selection of a speed limit corresponding with specific criteria relevant to that application or area. Examples of criteria based speed limits are as follows;

- Local street 50km/hr limit (this limit is applied to street where the prime function is to provide direct access to properties with limited neighbourhood travel movement)
- Undivided rural road 110km/hr limit (applicable to National and State Highways of very high standards)
- Divided roads 110km/hr limit (also applicable to National and State Highways of very high standards such as motorways and the adjoining divided carriageways)
- Rural residential speed limits

The rural residential speed limit is of particular interest where a risk management approach is the basis for speed limits. The functional road classification and number of property/driveway access are the prime considerations; MUTCD (2003) outlines the procedure for determining speed limits for roads in this category. The following table represents typical guidance on the appropriate speed limit for the road classification and average accesses relationship.

Road classification	Average Accesses per 100 m[1]	Speed Limit
Access road Collector road	>2 >4	50 km/h
Access road[2] Collector road[2] Trunk collector road	1 to 2 >2 to 4 >4	60 km/h
Access road Collector road[2] Trunk collector road	<1 1 to 2 >2 to 4	70 km/h
Collector road Trunk collector road[2]	<1 1 to 2	80 km/h

Figure 3.2: Typical speed limits for roads in rural residential areas

Source: (MUTCD 2003)

Additionally the MUTCD (2003) introduces special speed limits for a variety of applications. These include;

- Temporary limits (imposed during periods of roadworks and special events).
- Special area limits (imposed in areas such as campgrounds, forests or parks).

- Classes of vehicle or driver limits (imposed usually for safety, where certain classes of vehicles require a reduced limit).

An example of a vehicle class limit is the Burdekin River Bridge located between Ayr and Home Hill in Queensland. The speed limit for heavy vehicles is reduced from the posted 70km/hr limit to a special speed limit of 50km/hr by way of signage. This is required due to the long and narrow characteristics of the bridge which also facilitates a rail line. The following photos of the southern approach depict the sign implemented and the physical constraints of the bridge requiring the need for heavy vehicles to reduce speed.

Figure 3.3: Burdekin Bridge south approach

Source: (Google Maps)

Figure 3.4: Burdekin Bridge facing north

Source: (Google Maps)

MUTCD (2003) identifies the need for variable speed limits (VSL) to change limits periodically. This variability can be beneficial for reasons including change in weather condition or operating heavy vehicle inspection stations where the speed needs a temporary reduction to cater for trucks either leaving or re-joining the traffic flow. Other beneficial situations include high pedestrian areas, regulation of traffic flow and reduction of congestion.

MUTCD (2003) describes speed zones as locations which are always signed and take precedence over the general speed limits that may otherwise be applicable. Speed zones can consist of the following types;

- Linear speed zone – applied to a length of road with appropriate signage.
- Area speed zone – applied to a road network within a specific area.
- School zone – A short linear speed zone applied at the approaches to schools.
- Shared zone – applied when a section or area is shared by pedestrians and vehicles.
- Hospital zone – Similar to the school zone, a hospital zone is a reduced limit in the vicinity of the hospital. This is general used when high levels of pedestrian activity exist.

- Variable speed zone – speed varies throughout the day, such as a school zone or weather dependant speed classification.
- Special speed zones – applied for special situations and range from 10km/hr to 50km/hr.

3.3 Speed Zone Length

Guidance for the length of speed zone is provided in MUTCD (2003), where the minimum length is dependent on the speed limit. It is advised to maintain the absolute minimum speed zone length where the speed limit is less than that of the prevailing conditions. Generally speed zones with the exception of special zones should maximise length and achieve the normal minimum length specified below.

Speed limit reductions of only 10km/hr should generally not be utilised if possible. Further advice recommends usage of 50km/hr, 60km/hr, 80km/hr and 100km/hr speed zones when considering a new allocation of a speed zone.

The following table provides guidance on the minimum lengths suitable to specific speed zones.

Speed Limit (km/h)	Normal Minimum Length (km)	Absolute Minimum Length (km)
40: General	0.4	Not applicable
40: School zone only	Not applicable	0.2
40: High pedestrian activity zone only	Not applicable	0.2
50: Default urban limit	Not applicable	Not applicable
50	0.5	Not applicable
60	0.6	Not applicable
70	2.0	0.7
80	2.0	0.8
90	2.0	0.9
100	3.0	2.0
110	Not applicable	20.0 (see Section 3.3)

Figure 3.5: Minimum lengths of speed zones

Source: (MUTCD 2003)

3.4 Transition Zones

Transition zones represent sections of a roadway where vehicles change between speed environments, of particular interest is the change from high to low speed environments.

According to NCHRP (2012) transition zones are a unique portion of the roadway system. Generally road design continuity is desired and abrupt changes are avoided where possible. However within most transition zones a change occurs between rural environment and a community or urban environment. This change can sometimes be classified as abrupt and there is an expectation that the driver will make the necessary adjustments to match the change. Safety and community liveability is negatively affected when drivers do not respond appropriately.

Forbes (2011) defines the transition zone as the change from a rural to a community zone. It is within this zone where drivers are required to undertake measures to reduce their speed in order to facilitate safe passage through a developed area. NCHRP (2012) expresses that a series of characteristics determine the location of
and length of the zone. The zone may include a section with features remnant of a rural zone and also a section with characteristics similar to the edge of a built-up community. It is important however to ensure that this zone has differentiating features to the upstream and downstream zones to assist drivers to make a safe and efficient reduction in speed.

NCHRP (2012) divides the transition zone into the perception-reaction area and the deceleration area. The perception-reaction area is the segment of the transition zone where the focus is on ensuring that drivers are alerted and aware of an upcoming need to reduce their speed. This area has features similar to that of the upstream rural zone with the introduction of some changes to assist in alerting the driver to upcoming change. Drivers should be treated to good visibility of signs and other warning/psychological devices to alert them of the changes ahead. These devices may either be placed within the area of the upcoming deceleration area depending on the device and design requirements. Whilst some deceleration may take place within this zone the principal objective of the perception-reaction area is to psychologically prepare the drivers in order to get them prepared to adjust their speed and behaviour within the next area. Further downstream is the deceleration area, where the expectation is that all motorists will reduce speed to comply with the upcoming developed/built-up areas operating speed. The driver's awareness and mental astuteness should enhance along with the shift to a more passive driving style. Within this area, changes to the road environment and characteristics are generally beginning to take place. The length of the perception-reaction area is determined by sight visibility, design criteria and the speed profile whilst the deceleration zone should be positioned based on land-use, roadway and safety conditions.

NCHRP (2010) states that the ultimate goal of designing and selecting transition zone treatments is for drivers to be travelling at lower speed limit prior to entering the developed area. This is achieved by first notifying the motorist of the upcoming change with the use of warning devices and psychological measures followed by physical changes in the transition zone. It is within this transition zone where a majority of the speed reduction should occur. The following figure provides a clear understanding of this process.

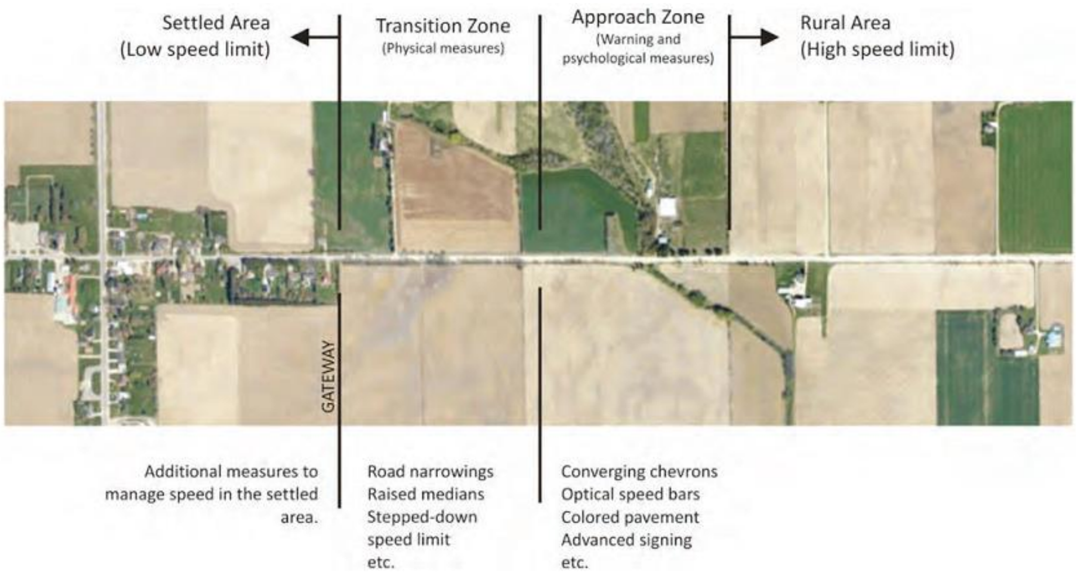

Figure 3.6: Transition zone and approach zone concepts

Source: (Federal Highway Administration, 2009)

Cruzador & Donnell (2010) note that whilst it is desirable for significant speed reductions to take place within transition zones it is uncommon for the design speed to be modified to aid in facilitating this reduction. It is identified that more flexibility in geometric design criteria is required to further reduce vehicle operating speeds.

Chapter 4

Background - Current Gateway Treatments and Management Strategies

This chapter investigates the current gateway treatment and management strategies in place to allow safe and efficient passage from high speed to low speed environments. Treatments consist of various traffic control devices which guide and regulate traffic. A combination of national and international text has been reviewed to provide a broad understanding of these domains.

‘Gateways’ are defined by Makwasha & Turner (2013) as a combination of traditional and non-traditional traffic calming measures designed to slow traffic entering low speed environments. Makwasha & Turner (2013) describe a wide variety of gateway treatments including but not limited to signage, lighting, wall and fence structures, lane narrowing, linemarking, medians and vegetation. The selection of a treatment usually depends on location, geometry, costs and local standards. Makwasha & Turner (2013) note that although gateways have been used to a great extent throughout the world there has been no assessment of their effectiveness in either Australia or New Zealand.

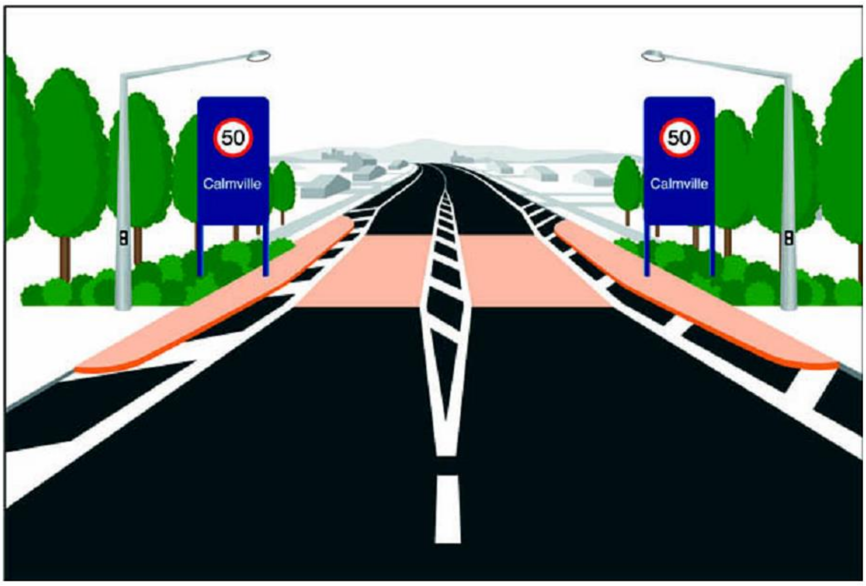

Figure 4.1: Depiction of gateway

Source: (Makwasha & Turner 2013)

4.1 Signage

Signage is a common and predominant measure for speed management and speed transitioning throughout regional North Queensland. Austroads (2009b) advises that road signs are provided to inform, alert, guide and regulate road users. Signs are generally standardised throughout their application in Queensland in order to provide the road user with more meaningful and familiar cues.

MUTCD (2003) outlines the signs used in various applications throughout Queensland. The speed restriction sign is the most common sign for transitioning motorists approaching townships from high to low speeds. The MUTCD code for the Speed Restriction sign is (R4-1) and a depiction is provided below.

Figure 4.2: Speed restriction sign – 60km/hr (R4-1)

Source: (MUTCD 2003)

Another commonly used sign referenced in the MUTCD (2003) in preparing motorists for a transition of speed is the 'Speed Limit Ahead sign' (G9-79). This sign's purpose is to inform the driver that they are approaching an area where the speed limit is reduced by more than 20km/hr and there is no requirement for an intermediate speed zone. Generally this sign should be installed 300m in advance of the lower speed limited area.

Austroads (2009b) provides guidance on lateral placement and height of signage. The sign lateral position should be as close as practical to the roadway edge whilst considering elements such as vehicle clearance requirements, road safety requirements and road user obstruction. Signs along the edge of unkerbed roads should have a minimum lateral clearance of 600mm to the road shoulder whilst ensuring the offset from the travel edge does not exceed the limits of <2m or >5m. Throughout Australia in rural and urban areas where there is limited pedestrian presence the bottom of the sign face should be positioned at a height greater then 1.5m above the road pavement.

Austroads (2009b) advises that designers should consider the following factors when considering the application a new (standard) sign. Will drivers be overloaded with information? Are drivers likely to identify and respond to the message? Do existing devices need to be relocated or removed? Is a new sign the appropriate response to the problem? Is road layout modification necessary?

Driving throughout North Queensland it is apparent that other signage measures are in place which may aid in the effective transitioning of vehicle speed and subsequent road user compliance to the lower speed limit. The following sign was photographed approaching the suburb of Cungulla located approximately 40km south of Townsville, QLD.

Figure 4.3: Alternative speed reduction sign – Cungulla, QLD

This sign is at the approach to Cungulla which has quite a significant transition zone reducing from 100km/hr to 50km/hr and implements a T-Intersection entrance.

An alternative measure which may be effective in persuading road users to undertake a speed transition is the “wheelie bin speed reminder sticker” as depicted in figure 4.4. Although this sign would get limited time exposure throughout the week it would serve as an additional reminder to users travelling into the township.

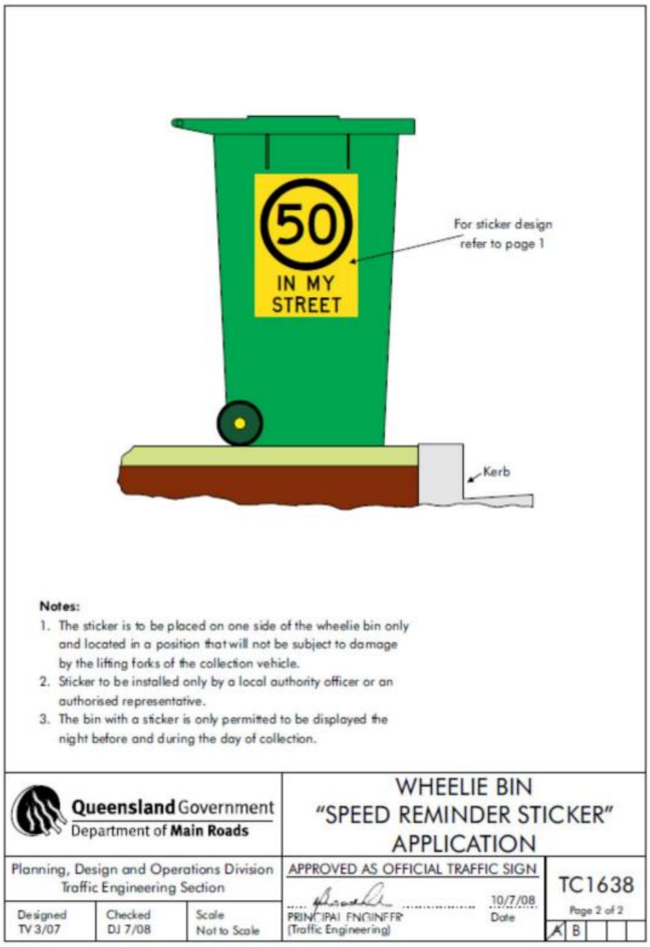

Figure 4.4: Wheelie bin – speed reminder sticker

Source: (MUTCD 2015)

NCHRP (2011) investigated studies undertaken on techniques to reduce speed for rural high-to-low speed transitions. One treatment undertaken by Barker and Helliar-Symons (1997) involved the installation of Countdown Speed Signs/Markers in the U.K. The countdown marker signs were installed below traditional speed signs in a longitudinal series of three. The most upstream complementary sign consisted of a white background with three black diagonal slashes which reduced back to one diagonal slash 100m upstream of the reduced speed limit. The following figure illustrates the series of signs used.

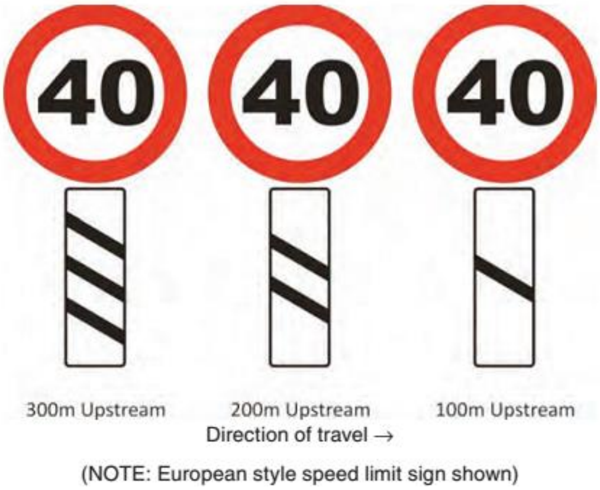

Figure 4.5: Speed count down marker signs

Source: (NCHRP 2011)

Results showed no significant reduction in mean speeds upon approaching villages. It was found that this non-numeric, coded information would require public education and long-term exposure to provide any significant improvements in speed compliance.

A modern traffic control device adeptly named ‘speed feedback sign’ has produced promising results. Speed feedback signs are electronic signs which have the capability to measure oncoming vehicle speeds and display that travel speed to the driver. Cruzado & Donnell (2008) installed speed feedback signs in transition zones in Pennsylvania, USA. Findings included mean speed reductions of approximately 6 mph (10km/hr) at both the actual location and downstream of the device. It was also noted that the reduction effect was only present when the signs were in place. When the signs were removed, travel speeds defaulted to the higher speed within a week. An example of a speed feedback sign is provided in the figure below.

Figure 4.6: Speed Feedback Sign Example

Source: (NCHRP 2011)

These signs require power and if a power source is unable to be easily installed then significant installation costs could be expected. Solar power is an alternative however theft could be an ongoing issue or concern. The real-time feedback serves an interactive notice to the driver and is a very effective device in reducing speeds and improving compliance.

Another treatment of similar nature is speed-activated speed limit sign. These signs are also electronic however only activate a message when the measured speed of the oncoming vehicle exceeds the legal speed limit. When activated the electronic sign displays the legal speed limit accompanied by a message such as ‘slow down’.

Figure 4.7: Speed-activated speed limit sign

Source: (Winnett and Wheeler 2002)

Winnett and Wheeler (2002) recorded a reduction of up to 80% of vehicles exceeding the posted speed limit when this device was used at village approaches. Similar to the speed feedback sign this device also requires power and has the associated problems or costs in attaining power. It is also worth noting that devices such as these which are installed in rural or regional locations may be subject to vandalism and as such appropriate measures would need to be carried out to ensure their long term use.

Transitional Speed Limit treatments are a commonly used treatment throughout Australia where an intermediate speed limit sign is installed between the 100km/hr speed zone and the 60km/hr speed zone. Generally throughout North Queensland this sign consists of the 80km/hr speed limit sign. Hildebrand et al. (2004) tested the effectiveness of this practice in the province of New Brunswick, Canada and found that the inclusion of the transitional speed limit sign had no significant impact on the mean speed or the number of drivers exceeding the speed limit. Hildebrand et al (2004) also concluded that these signs are not very effective in reducing speeds if there is not a corresponding change in road characteristics.

4.2 Rumble Strips

Rumble strips can be used as a road safety feature to warn drivers of the need to transition speed. The rumble strip alerts the driver as they pass over via vibration and sound.

According to Austroads (2009) common forms of transverse rumble strips include; raised bars, grooved bars and corrugated concrete. Rumble strips formed from grooves within hot asphalt or retrofitted by grinding grooves into in-situ roadways can require ongoing maintenance. Issues arise with this treatment when soil and debris collects with the groove reducing the rumble strips effectiveness. The treatment is suited to asphalt surfacing and is found to be not suitable for areas with thin bitumen sealing as the grooves would expose the upper base gravel pavement layer.

Throughout North Queensland there is a combination of asphalt and bitumen sealing so consideration to the site surfacing type is essential. If installing rumble strips within thin bitumen sealed areas, it is necessary for the treatment footprint to be replaced with asphalt surfacing.

Austroads (2009b) identifies findings from previous studies into rumble strip outcomes as shown below;

- When installed on intersection approaches they can substantially reduce crashes.
- There have been very few studies which quantify crash reduction potential of rumble strips outside of intersection locations.
- When used on rural town approaches they are an effective alerting device and may reduce speed at the devices, but are unlikely to reduce speeds at other locations within the town.

Adverse effects identified in Austroads (2009b) include continuous noise, attempts by the driver to make dangerous manoeuvres in order to avoid the rumble strip and the stability problems presented to cyclist and motorcyclists as a result of abrupt rise or depressions in the roadway. It is advised that this device should be accompanied by appropriate signage to express the nature of the possible hazard.

The following two examples are applications which are relevant to aiding the transition of speed from a high to low speed zone. The rumble strip can be constructed over the entire lane or just over the vehicles wheel paths. An example of a full width rumble strip is shown below.

Figure 4.8: Full width rumble strip

Source: (Corkle et al, 2001)

In-lane rumble strips installed on the wheel paths only is depicted below.

Figure 4.9: Rumble strip – wheel paths only

Source: (Corkle et al, 2001)

Corkle et al, (2001) describes the use of rumble strips to alert drivers to changing conditions as common however notes that there is minimal information available to support that the rumble strips are effective in reducing crash rates. The report also highlights the issues of loss of effectiveness as a result of overuse.

In New Zealand however, Charlton and Bass (2006) found up to a 6% reduction in speed following installation of rumble strips during their research carried out between July 2004 and June 2005. This research supports the merits of installing rumble strips and in providing an effective measure to assist in successfully transitioning vehicle speeds.

4.3 Pavement Marking

Similar in design intent to rumble strips, pavement markings also alert drivers to an upcoming change in the road environment.

Federal Highway Administration (2009) evaluated the effects of pavement marking traffic calming devices when employed as transition treatments between high-speed rural environments and low-speed townships in Iowa.

The locations and treatment are summarised in the table below.

City (population)	Treatment	Roadway	AADT (veh/day)	Cross section (all are two-lane)
Union (427)	Transverse pavement markings[1] with speed feedback sign	D-65 (west edge of City)	830	Asphalt (22.4 ft), unpaved shoulders
	Transverse pavement markings[1] with speed feedback sign	S-62/SH 215 (from intersection with D-65 to north city limit)	1,680	Concrete (40.0 ft), curb and gutter
	Lane narrowing using painted center island and edge line markings			
	Transverse pavement markings[1]	SH 215 (near south city limit)	1,000	Asphalt (22.4 ft), unpaved shoulders
Roland (1,324)	Converging chevrons[1] with "25 MPH" pavement legend	E-18 (near east and west city limits)	2,300	Asphalt (22.6 ft), unpaved shoulders
	Lane narrowing using shoulder widening and "25 MPH" pavement legend	E-18 (from intersection with R-77 to east city limit)	2,300	Concrete (36.0 ft), curb and gutter
	"25 MPH" pavement legend	E-18 (from intersection with R-77 to west city limit)	2,300	Asphalt (22.6 ft), unpaved shoulders
Gilbert (987)	Speed table	E-23 (center of community)	1,480	Asphalt (22.0 ft), shoulders
Slater (1,306)	Lane narrowing with center island using tubular markers channelizing markers	R-38 (from intersection with SH 210 to south city limit)	2,060	Concrete (25.8 ft), curb and gutter
	Speed feedback sign	R-38 (near north city limit)	2,870	Asphalt (22.6 ft), unpaved shoulders
	"SLOW" pavement legend	SH 210 (west from intersection with R-38 to west city limit)	2,940	Asphalt (22.5 ft), unpaved shoulders
Dexter (689)	"35 MPH" pavement legend with red background[1]	F-65 (near east and west city limits as well as at curve before west city limit)	1,000	Asphalt (25.4 ft), unpaved shoulders

Figure 4.10: Summary of treatments in Iowa, USA

Source: (Federal Highway Administration 2009)

Federal Highway Administration (2009) describes transverse markings as a series of parallel bars painted onto the inside edges of the paved travel lane. The longitudinal spacing is reduced as the driver approaches the built-up community. The intention of this reduction is to give drivers the perception that the vehicle is increasing in speed, resulting in the driver becoming aware of the upcoming need to reduce speed. The study employed transverse marking which were 12 inches (305mm) wide and 18 inches (457mm) long. It is important to note speed feedback signs were also included with the transverse markings in two of the three locations. However the speed feedback signs were not able to be installed until nine months into the experiment as a result of purchasing and installation issues. The speed feedback signs consisted of a posted sign on the footpath with an electronic/digital speed display identifying the approaching vehicle's speed.

Installation locations and results for Federal Highway Administration (2009) evaluation of transverse pavement markings with and without speed feedback signs are depicted in the following three figures.

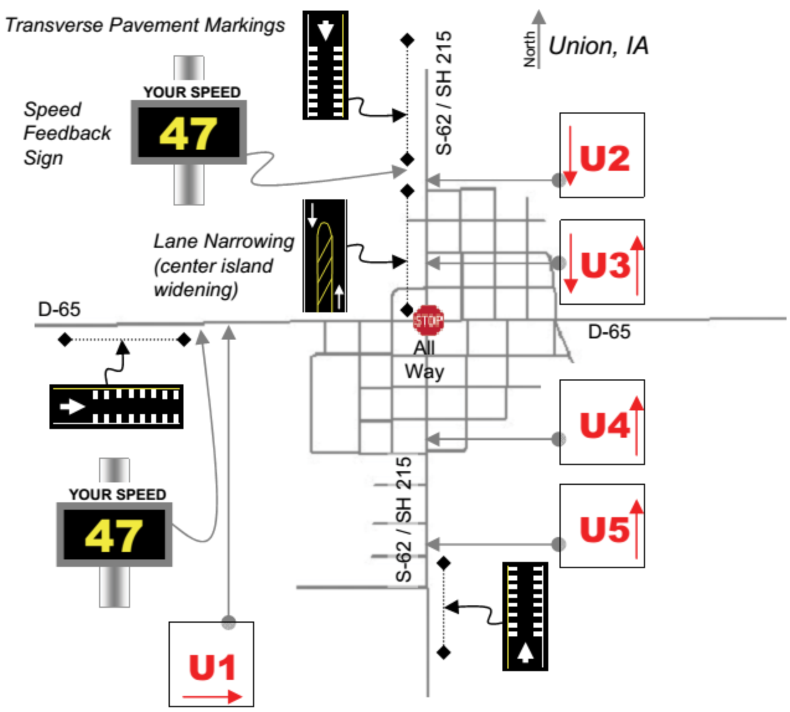

Figure 4.11: Treatment and data collection locations in Union, USA

Source: (Federal Highway Administration, 2009)

Figure 4.12: Experimental transverse markings at entrance to Union, USA

Source: (Federal Highway Administration, 2009)

Location and analysis period	Sample size (veh)	Posted speed (mi/h)	85th percentile (mi/h)	Change in 85th percentile speed from "before" period (mi/h)
U2 SB Before	1,870	30	41	
1-month	1,785	30	41	0
3-month	1,794	30	40	-1
9-month (+SFS)	1,737	30	35	-6
12-month (+SFS)	1,693	30	34	-7
U5 NB Before	886	25	46	
1-month	783	25	45	-1
3-month	943	25	45	-1
9-month	908	25	44	-2
12-month	871	25	45	-1
U1 EB Before	893	25	53	
1-month	659	25	51	-2
3-month	684	25	52	-1
9-month (+SFS)	749	25	49	-4
12-month (+SFS)	666	25	50	-3

Figure 4.13: Results of transverse pavement markings with and without speed feedback signs at entrances to Union, USA

Source: (Federal Highway Administration, 2009)

Federal Highway Administration (2009) reported that the samples were collected immediately downstream of the treatments via pneumatic road tubes. The results show a significant spike in the reduction of speed at the 9 month period when the speed feedback sign is installed. The combination of the speed feedback signs and transverse marking resulted in speed reductions ranging from 3-7mi/h (4.8-11.3km/hr). The transverse pavement markings installed alone appear to have a limited impact in reducing speed with reductions ranging between 1-2mi/h (1.6 – 3.2km/hr).

In Dexter, USA, The Federal Highway Administration (2009) installed the experimental red background with speed limit markings as depicted below.

Figure 4.14: Speed limit markings with experimental red background in Dexter, USA

Source: (Federal Highway Administration, 2009)

Speed sampling was taken for a 12-month period following the painting of the roadway. The results are tabulated below.

Location	Analysis period	Sample size (veh)	Posted speed (mi/h)	85th percentile (mi/h)	Change in 85th percentile speed from "before" period (mi/h)
Before curve	Before	2,190	35	52	
	1-month	2,150	35	47	-5
	3-month	2,022	35	47	-5
	9-month	4,033	35	43	-9
	12-month	2,031	35	51	-1
West entrance	Before	2,369	35	45	
	1-month	2,256	35	40	-5
	3-month	2,119	35	41	-4
	9-month	4,027	35	37	-8
	12-month	3,168	35	41	-4
East entrance	Before	4,254	35	40	
	1-month	3,998	35	38	-2
	3-month	2,900	35	39	-1
	9-month	4,087	35	40	0
	12-month	4,031	35	39	-1

Figure 4.15: Experimental results of "35 MPH" pavement legend in Dexter, USA

Source: (Federal Highway Administration, 2009)

The table shows that the pavement marking has had an immediate speed reduction effect. The locations 'Before curve' and 'West entrance' have experienced significant speed reduction as a result up to the 9 month period. The samples taken at 12 months however show that driver speeds increased from the 9 month period. This may be a result of drivers becoming familiar with the markings as time progresses and taking less notice of the marked pavement 35MPH speed limit.

Summary of other selected results from the Federal Highway Administration (2009) investigations were as follows;

<u>Lane Narrowing using Painted Centre island and Edge line Markings (Installed in Union)</u>

The existing roadway with between kerbs was 40ft (12.2m). The treatment consisted of a 10ft (3.05m) wide painted centre island having the net effect of reducing lane widths from 16ft (4.9m) to 11ft (3.4m) whilst catering for a 8ft (2.4m) parking lane.

Figure 4.16: Painted centre island and edgeline used to narrow lane

Source: (Federal Highway Administration, 2009)

Location and analysis period	Sample size (veh)	Posted speed (mi/h)	85th percentile (mi/h)	Change in 85th percentile speed from "before" period (mi/h)
U3 NB Before	2,055	30	35	
1-month	1,808	30	36	+1
3-month	1,840	30	32	-3
9-month	1,807	30	36	+1
12-month	2,064	30	35	0
U3 SB Before	2,058	30	33	
1-month	1,930	30	33	0
3-month	1,911	30	37	+4
9-month	1,881	30	32	-1
12-month	1,771	30	34	+1

Figure 4.17: Experimental results of narrowing lane using painted centre island and edge line marking

Source: (Federal Highway Administration, 2009)

The table of results above clearly shows the treatment had variable positive and negative results and is considered to be an ineffective treatment, at least for that location.

Converging Chevrons with "25 MPH" Pavement Marking Legend

The converging chevron markings treatment pictured below was installed at both entrances to Roland, USA. The markings started at the speed limit sign and carried on upstream a further 221ft (67.4m). The longitudinal distance between the chevrons started at 25ft (7.6m) and gradually decreased to 18ft (5.5m). Additionally the marking widths also decreased from 36 inches (914mm) to 6 inches (152mm) to increase the perception that the vehicle was increasing in speed. A legend denoting the "25MPH" speed limit was painted to the end of each chevron to reinforce the treatments impact.

Figure 4.18: Converging Chevrons installed at Roland, USA

Source: (Federal Highway Administration, 2009)

Location	Analysis period	Sample size (veh)	Posted speed (mi/h)	85th percentile (mi/h)	Change in 85th percentile speed from "before" period (mi/h)
West entrance	Before	4,216	25	35	
	1-month	4,135	25	34	-1
	3-month	3,812	25	32	-3
	9-month	3,958	25	35	0
	12-month	3,945	25	34	-1
East entrance	Before	2,397	25	36	
	1-month	2,426	25	35	-1
	3-month	3,413	25	35	-1
	9-month	2,196	25	34	-2
	12-month	1,778	25	32	-4

Figure 4.19: Experimental results of converging chevron markings and "25 MPH" pavement legend

Source: (Federal Highway Administration, 2009)

The results shown above for the combination of converging chevron markings and the "25MPH" pavement legend indicate a mild positive improvement on driver compliance to the posted speed. At the West entrance location it is clear that the 3 month test period produced the best results with a 3mi/h (4.8km/hr) reduction of the 85^{th} percentile speed. Following this time period it appears that the treatment lost its effectiveness resulting in no reduction in the original 85^{th} percentile speed at the 9 month test period and a 1mi/h (1.6km/hr) reduction at the 12 month post installation test period. On the contrary the east entrance location showed a gradual improvement in driver compliance to posted speeds over the yearlong testing period. At the 12 month analysis period the treatment had produced a 4mi/h (6.4km/hr) reduction of the 85th percentile speed. The east entrance treatment has been moderately successful in increasing driver's compliance to the posted speed limit. It is apparent however that driver speeds were still 7-9mi/h (11-14.5km/hr) over and above the posted speed limit after 12 months of the installed treatment.

"SLOW" Pavement Legend

Federal Highway Administration (2009) installed two pavement legends denoting the text 'SLOW' at two locations in Slater, USA. One pavement marking was installed near the western community entrance where a park and crossing used by children existed; the second was installed around 1500ft (approx. 460m) downstream of the first treatment. An image of the actual treatment and the experiment results are provided in the following two figures.

Figure 4.20: "SLOW" pavement legend in Slater, USA

Source: (Federal Highway Administration, 2009)

Location	Analysis period	Sample size (veh)	Posted speed (mi/h)	85th percentile (mi/h)	Change in 85th percentile speed from "before" period (mi/h)
First legend	Before	2,812	25	41	
	1-month	2,888	25	44	+3
	6-month	2,901	25	42	+1
	9-month	2,570	25	42	+1
Second legend	Before	3,503	25	34	
	1-month	3,294	25	34	0
	6-month	2,886	25	32	-2
	9-month	3,084	25	33	-1

Figure 4.21: Experimental results of "SLOW" pavement legend in Slater, USA

Source: (Federal Highway Administration, 2009)

The results shown above for this experiment demonstrate the lack of effectiveness this treatment had on reducing the 85th percentile speed. Remarkably the speeds in the first legend location actually increased up to an additional 3mi/h (4.8km/hr) with mixed results and some minor improvement found in the second location. It is clear that this treatment has proved to be ineffective at this location.

Speed Table

A speed table, commonly referred to within Australia as a speed bump was installed by the Federal Highway Administration (2009) within the centre of Gilbert. The speed table was installed on a two-lane asphalt road with a posted speed limit of 25mi/h (40km/hr). The speed table was 3 inches (76mm) high and 22 inches (approx. 560mm) long in the travel direction. The speed table was accompanied by white line marking denoting the speed table's presence. The following figure shows the actual location and installed device in Gilbert, USA.

Figure 8. Driver view of speed table in Gilbert.

Figure 4.22: Driver view of speed table in Gilbert, USA

Source: (Federal Highway Administration, 2009)

The Federal Highway Administration (2009) found the treatment to be a very effective tool to reduce driver speeds with consistent reductions of up to 5mi/h (8km/hr). Refer to the following figure for details of the results.

Location	Analysis period	Sample size (veh)	Posted speed (mi/h)	85th percentile (mi/h)	Change in 85th percentile speed from "before" period (mi/h)
200 ft downstream	Before	2,257	25	34	
	1-month	2,199	25	30	-4
	3-month	2,763	25	30	-4
	9-month	3,885	25	30	-4
	12-month	3,886	25	30	-4
15 ft downstream	Before	3,685	25	32	
	1-month	3,355	25	27	-5
	3-month	3,413	25	28	-4
	9-month	3,982	25	27	-5
	12-month	3,279	25	27	-5

Figure 4.23: Experimental results of speed table in Gilbert, USA

Source: (Federal Highway Administration, 2009)

Vertical measures such as a speed table need to be designed and installed with due consideration to ensure the public are adequately warned of the treatments presence as traversing at unsuitably high speeds may result in loss of control or vehicle damage.

The Federal Highway Administration (2009) summarised the impacts and costs of their experimental traffic calming treatments with the results provided in the following figure.

Treatment	Change in 85th percentile speed (mi/h)	Cost	Maintenance	Application
Transverse pavement markings[1]	-2 to 0	$	Regular painting	community entrance
Transverse pavement markings[1] with speed feedback signs	-7 to -3	$$$	Regular painting	community entrance
Lane narrowing using painted center island and edge marking	-3 to +4	$	Regular painting	entrance or within community
Converging chevrons[1] and "25 MPH" pavement markings	-4 to 0	$	Regular painting	community entrance
Lane narrowing using shoulder markings and "25 MPH" pavement legend	-2 to 4	$	Regular painting	entrance or within community
Speed table	-5 to -4	$$	Regular painting	within community
Lane narrowing with center island using tubular markers	-3 to 0	$$$	Tubes often struck needing replacement	within community
Speed feedback sign (3-months after only)	-7	$$$	Troubleshooting electronics	entrance or within community
"SLOW" pavement legend	-2 to 3	$	Regular painting	entrance or within community
"35 MPH" pavement legend with red background[1]	-9 to 0	$	Background faded quickly; accelerated repainting cycle	entrance or within community

$ = under $2,500
$$ = $2,500 to $5,000
$$$ = $5,000 to $12,000
[1]Experimental approval required per Section 1A.10 of MUTCD.

Figure 4.24: Summary of impact and cost of rural traffic calming treatments

Source: (Federal Highway Administration, 2009)

It is clear that the Federal Highway Administration (2009) experiments improved driver compliance overall and that it was a relatively successful experiment. It could be linked to improving driver's compliance to transitioning to low speed zones in regional North Queensland, should markings such as the posted speed on a coloured background, transverse pavement markings or a speed table be installed. Care needs to be taken to ensure treatments are not overused as this may result in potential motorist familiarisation and the subsequent decrease in speed reduction effects.

Chapter 5

Project Methodologies

The following chapter outlines the methods utilised to achieve the project objectives outlined in the introduction.

5.1 Methodology – Field Speed Sample Analysis

This project involved undertaking field surveys at various sites throughout North Queensland to measure compliance to the posted speed limits in speed transition zones, and to observe motorist behaviour.

The study area was determined as a result of accessibility constraints and limitations. The approach of narrowing the focus area results in more detailed and specific project outcomes. Further refinement was undertaken to decide on the field survey sites. Time was spent analysing all potential locations within the focus area via a desktop mapping study. An initial pilot survey was undertaken on the Charters Towers (Flinders Highway East Approach) as a result of finding a suitable location during the desktop study. Undertaking the first pilot study provided an appreciation of what makes an acceptable site to undertake a survey and subsequent limitations which may exclude other survey sites. Following the completion of the first study a field investigation of the Charters Towers (Flinders Highway West Approach) was undertaken to check suitability for speed sampling. There was insufficient shoulder width to safely park for the sampling duration on the south side of the Flinders Highway. The north side of the Flinders Highway was not suitable as the parking was adjacent to a town park which was not considered an acceptable location to park for long durations.

After reviewing the results of the pilot study it was clear that a set of sampling guidelines would need to be established in order to provide meaningful results. A further desktop study of the North Queensland found suitable locations at the Ingham

(Bruce Highway North and South approach), Ayr (Bruce Highway North approach) and Pentland (West approach). Areas excluded due to site constraints included Ayr (Bruce Highway South approach) as a result of the curved horizontal geometry at the commencement of the low speed environment along with lack of suitable area to park the study vehicle. Pentland (Flinders Highway East approach) was also excluded due to time constraints and low traffic.

Prior to selecting the sample sites consideration was given to how vehicle speeds would be recorded. Following the review of a number of speed measurement devices available, two products were considered. The first product was an automatic vehicle/speed counter. The device is placed off to the side of the road and collects readings from two rubber hoses (tubes) placed over the road. This device is able to collect accurate readings and requires only setup and removal by the operator. However the device can be subject to vandalism and would cost over $2000 to hire. The second option was a handheld radar gun which would require a lot more operator input to collect and record the speed sample. Benefits of a handheld radar gun over the automatic speed counter included the ability to develop a closer understanding of traffic behaviour by visualising the vehicle whilst sampling. Other benefits included the discretion to exclude vehicles whose speed could be influenced the lead/platoon vehicle and significant cheaper rental costs then the automatic vehicle/speed counter.

After considering accuracy requirements and funding limitations the device chosen was a handheld radar gun. The selected Phantom 53550 radar gun is manufactured in the United States. The procurement proved difficult as the local rental company was initially unable to source the device. As their rental pricing was also quite expensive some time was spent investigating other options. An alternate supplier was found in the United States but the costs were 20% higher than the local supplier once postage and currency conversion was included. The accuracy of the device is ±0.1 – 1 Mph (±0.16 – 1.6 km/hr) which is considered acceptable for the purpose of this project. The radar gun is depicted below.

Figure 5.1: Phantom 53550 radar gun

The following technical specifications were included with the phantom radar gun.

Technical Specifications

TYPE: Hand held stationary Doppler radar

OPERATING FREQUENCY: 24.150 +/- .1 GHZ (K Band)

POWER REQUIREMENTS: +10.5 to +16.5 VDC., 13.5 VDC Nominal, 1.5 Amp. Max.

REVERSE POLARITY PROTECTION: Inline diode protection.

ELECTRONIC COMPONENTS: 100% solid state, integrated circuits and transistors and associated components.

ENVIRONMENTAL: -20 to +60 degrees C; 90% relative humidity at +37 degrees C. (Non-condensing)

ACCURACY (INTERNAL): +/- 0.1MPH

ACCURACY (EXTERNAL): + 0.1/-1 MPH

ACCURACY VERIFICATION (EXTERNAL): Tuning fork (K-Band)

INTERNAL TEST: 60MPH simulated Doppler signal checks internal circuits.

DISPLAY: 3 Full digits. Indicators for: Power on; RF interference; and Low Voltage.

LOCK TIME: Instantaneous; No error introduced.

Microwave Data

ANTENNA TYPE: Conical

LENSE TYPE: Precision Ground ""Rexalita""

POLARIZATION: Right hand circular

BEAM WIDTH: 12 Degrees Nominal at 3dB

RECEIVER TYPE: Low-noise schottky barrier mixer diode

MICROWAVE SOURCE: Gunn-effect diode

POWER OUTPUT: 10-20 MW

FREQUENCY OUTPUT: 24.150 +/- .1 GHz (K-Band)

Physical Data

CONSTRUCTION: Lightweight aluminum chassis. PVC Cover. 6 Foot power cord with fused lighter plug.

WEIGHT: 1 lb. 12 oz.

HEIGHT: 6.5 inches including handle.

Length: 7.5 inches

Width: 3.375 inches

Figure 5.2: Phantom 53550 radar gun – technical specifications

The rental company undertook yearly calibrations and provided a tuning fork for testing prior to using the device. The device was tested at each site on every occasion to ensure the device was functioning correctly.

The manufacturer has included a conversion table for the user to allow for inaccuracies caused if the radar gun and the vehicle are not directly in line. The vehicle speed indicated by the radar is lower than the actual vehicle speed. As the angle between the radar gun and the vehicle increases, the inaccuracy also increases. The conversion table is provided below.

OPERATING CONDITIONS

There are several conditions which will affect the operation of this type of radar unit:

1. Cosine angle - This is the angle created by a target which is not moving directly toward or away from the operator. This angle with the road causes the speed reading to be LESS than the actual speed of the vehicle. This difference is illustrated in the chart below:

Vehicle Speed Indicated by Radar				Actual Vehicle Speed(MPH)							
30	30.03	30.12	30.48	31.08	31.94	33.11	34.64	36.58	38.65	42.43
35	35.03	35.14	35.56	36.26	37.27	38.63	40.41	42.72	45.10	49.50
40	40.04	40.16	40.65	41.45	42.59	44.15	46.18	48.82	51.54	56.57
45	45.04	45.18	45.73	46.63	47.92	49.66	51.96	54.93	57.98	63.64
50	50.05	50.20	50.81	51.81	53.24	55.18	57.73	61.03	64.43	70.72
55	55.05	55.22	55.89	56.99	58.57	60.70	63.51	67.13	70.87	77.79
60	60.06	60.24	60.97	62.17	63.89	66.22	69.28	73.24	77.31	84.86
65	65.06	65.26	66.05	67.35	69.22	71.74	75.05	79.34	83.76	91.93
70	70.07	70.26	71.13	72.53	74.54	77.26	80.83	85.44	90.20	99.00
75	75.07	75.30	76.21	77.72	79.87	82.78	86.60	93.55	96.64	106.05
80	80.08	80.32	81.30	82.90	85.19	88.30	92.37	97.65	103.09	113.15
85	85.08	85.34	86.38	88.08	90.52	93.81	95.15	103.75	109.53	120.22
angle between vehicle and antenna	1"	5"	10"	15"	20"	25"	30"	35"	40"	45"

Figure 5.3: Cosine angle adjustment table for Phantom 53550

Microsoft Excel was utilised to calculate the cosine adjustment for each locations angle allowance. The data presented in this text has been adjusted to account for the adjustment.

The operating manual provided by the manufacturer also made mention that the study vehicles cabin fan (for air conditioning/heater) would cause the device to pick up and

read irregular frequency. In order to eliminate this issue the study vehicle’s fan was left off for all testing despite the warm North Queensland weather.
The specific locations for the field studies within North Queensland included;

- Charters Towers (Eastern Approach)
- Ingham (Northern Approach)
- Ingham (Southern Approach)
- Pentland (West Approach)
- Ayr (Northern Approach)

Being based in Townsville it was a requirement to travel to these locations in the morning and establish a suitable location to park and setup the device.

The following speed survey guidelines were established after reviewing Appendix G within MUTCD (2003).

- Ensure no roadworks or maintenance works are being undertaken and that no notifications are in place for upcoming works.
- Clear fine weather.
- No special events (such as town shows, parades or sporting events).
- Safe location to park to undertake the analysis.
- Ensure parking site is suitably spaced and discrete from the collection point to ensure that any influence or bias for drivers is minimised.
- Sampling to be undertaken between Monday to Friday whilst trying to commence sampling in the early afternoon.

These guidelines were important in collecting samples which were representative of how drivers travel in optimal conditions.

The minimum sample size adopted by MUTCD (2003) for a 60km/hr speed limit is 85 samples. The minimum sample size and the timing restraints dictated the final sample size for each location but in all cases at least eighty-five sample sizes were achieved. The collection point was set approximately 50m downstream of the 60km/hr regulatory sign in all cases to allow the target vehicle to decelerate post signage.

For the purposes of this study a Heavy Vehicle (HV) was classified as a medium rigid truck. In Queensland a medium rigid truck is defined as truck or bus with two axles, a gross vehicle mass (GVM) not exceeding 8 tonne. On the rare occasion where it was difficult to identify whether the truck was medium rigid a judgement was made with preference being to classify vehicles of this description in the heavy vehicle category. Vehicles with caravans in tow were classified as light vehicles for this study.

It is typical for vehicles to travel in groups in these environments as a result of limited overtaking opportunities, varying speeds and vehicle performance, presence of heavy vehicles and vehicles towing trailers and caravans. The vehicle positioned in front of the group is referred to in the MUTCD (2003) as the platoon leader. This study focused on attaining samples from the platoon leaders and more preferably the vehicles travelling independently in free flowing conditions. All other vehicles travelling within groups were ignored from the study as their speed was governed by the platoon leader and as such is not an independent speed.

There were a number of difficulties faced which included vehicles travelling in both directions towards the collection point. In this instance it was difficult to ascertain with any certainty that the detection device was relaying the speed of the approaching vehicle. In this instance the result was discarded. In low traffic volume areas such as Pentland the grouping of vehicles lead to long wait times between sampling vehicles.

The following spreadsheet was produced in excel after reviewing a speed study spreadsheet contained within CTRE (2002).

Date:	Start Time:
Site Location:	End Time:
Speed Limit:	Anything out of Ordinary:
Flow Direction:	Weather:

Speed	Passenger Vehicle		Heavy Vehicles (Trucks, Bus etc)		Total
	Record	No	Record	No	
<50					
50					
51					
52					
53					
54					
55					
56					
57					
58					
59					
60					
61					
62					
63					
64					
65					
66					
67					
68					
69					
70					
71					
72					
73					
74					
75					
76					
77					
78					
79					
80					
>80					
Total					

Figure 5.4: Speed sample data spreadsheet

This example data sheet would suit an environment with a posted speed limit of 60km/hr. During the field study the raw results where directly entered into a 10 inch Samsung Netbook Laptop to facilitate efficient data entry immediately after taking the sample reading. The captured speed was briefly 'locked' on the display of the radar which futher reduces any risk of human error upon entering the speed reading into the spreadsheet.

Upon returning from site the raw results were converted into the adapted spreadsheet (refer figure 5.4) with the use of the 'COUNTIF' Microsoft excel function to further help eliminate human error. The 50th and 85th percentile speeds were then extracted from the raw data. Microsoft Excel was used to calculate the percentile speeds with the use of the function 'PERCENTILE'.

5.2 Methodology – Crash Data Analysis

An application was made to the Queensland Department of Transport and Main Roads in order to ascertain crash data for a time period within the study region.

The data is extensive and considers the entirety of the North Queensland region. The data includes the following time periods;

- Fatal crashes – 1 January 2007 to 31st December 2014.
- Hospitalisation crashes – 1 January 2007 to 31 December 2013.
- Non-serious casualty (medical treatment / minor injury) – 1 January 2007 to 30 June 2012.
- Property damage only crashes – 1 January 2007 to 31 December 2010.

Review of data and extraction of the relevant focus areas was undertaken and aided by the department's inclusion of a software file, which when imported into Google Earth provided the ability to search locations in geographic view format and find data relevant to a specific focus area.

Due to the large number of incidents within North Queensland as a whole it was initially difficult to search within a specific region in Google Earth with the crash data file loaded. This was a result of insufficient computing power to load the vast amount of data; the issue was resolved by turning off the crash data layer, locating the specific approach location and turning the crash data layer on. The crash identification numbers were then recorded and filtered within the extensive excel spreadsheets provided by the department. Unfortunately the crash data did not provide contributing driver factors relevant to the incidents such as excessive speed or inattention.

5.3 Project Methodology – Flow Chart

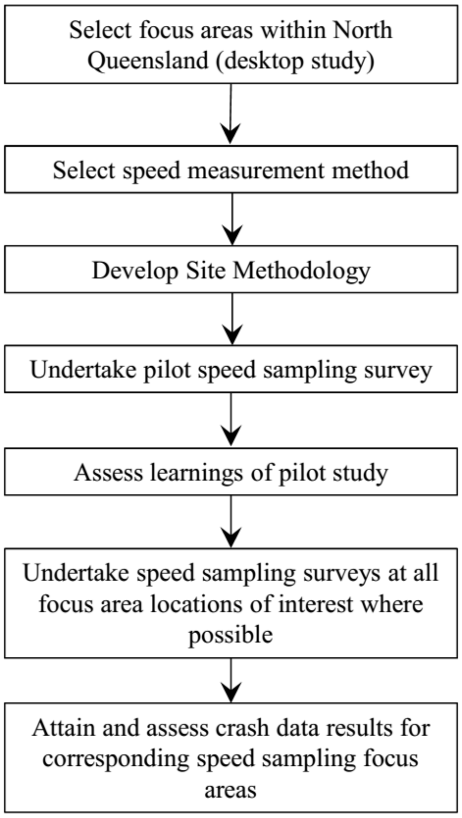

Figure 5.5: Project methodology – flow chart

Chapter 6

Field Speed Sample Results

6.1 Charters Towers – Flinders Highway (East Approach)

Charters Towers has a population of approximately 8,000 people and is well known for its past gold mining operations. The Flinders Highway carries a large contingency of tourists and freight trucks, making their way east, west and south of Charters Towers.

The Charters Towers - Flinders Highway (East Approach) is a two-lane highway which connects the intersection of the Flinders Highway and the Gregory Developmental Road to the eastern side of the built up suburb of Queenton. The road has smooth asphalt surfacing and clearly visible line marking. The low speed environment commences at 60km/hr posted speed signs which are installed on both sides of the roadway to increase signage impact. The longitudinal grade slopes downwards as you approach and enter the low-speed environment which increases the difficulty to reduce vehicle speeds as the car requires more braking power. The roadside environment is fairly rural with sparse vegetation and a residential property located on the southern side of the roadway sufficiently setback from the road shoulder. The northern side of the road consists of bushland and power lines with poles spaced at lengthy centres. The 80km/hr speed environment preceding the 60km/hr low speed environment is in excess of 1.5km.

Figure 6.1: Charters Towers east approach (facing west)

An aerial layout of speed sampling at this location is depicted below.

Figure 6.2: Charters Towers east approach – speed sample survey layout

The raw speed samples from the testing undertaken on the 25th June 2015 are tabulated below.

RAW DATA (SAMPLES)

	Light Vehicles						HV
1	62	75	51	65	71	74	57
2	60	59	72	58	62	60	63
3	65	77	65	69	63	61	52
4	69	59	65	56	51	62	69
5	65	68	56	72	63	63	61
6	70	65	59	57	66	57	62
7	63	54	66	58	60	60	54
8	64	70	65	62	76	59	66
9	60	63	67	67	69	57	74
10	63	59	62	66	58	72	62
11	78	64	58	67	59	75	59
12	52	61	58	72	69	73	63
13	66	62	76	55	62	60	60
14	75	67	72	63	69		62
15	67	62	55	72	58		69
16	57	57	61	65	63		59
17	62	64	66	55	70		62
18	65	59	75	61	71		58
19	67	59	58	58	68		60
20	63	72	73	64	61		57
21	65	57	71	63	58		60
22	62	61	71	67	71		59
23	69	63	57	64	68		
24	56	62	61	60	55		
25	66	60	58	59	67		

Figure 6.3: Charters Towers east approach – raw speed sample data

The raw data has been adjusted to include allowance for the angle between vehicle and radar device in the following results.

Charters Towers - East Approach
Adjusted (angle between vehicle and radar)

	degrees	radians	Cos
Angle	2	0.035	0.999

LV	LV	LV	LV	LV	LV		HV
62	75	51	65	71	74		57
60	59	72	58	62	60		63
65	77	65	69	63	61		52
69	59	65	56	51	62		69
65	68	56	72	63	63		61
70	65	59	57	66	57		62
63	54	66	58	60	60		54
64	70	65	62	76	59		66
60	63	67	67	69	57		74
63	59	62	66	58	72		62
78	64	58	67	59	75		59
52	61	58	72	69	73		63
66	62	76	55	62	60		60
75	67	72	63	69			62
67	62	55	72	58			69
57	57	61	65	63			59
62	64	66	55	70			62
65	59	75	61	71			58
67	59	58	58	68			60
63	72	73	64	61			57
65	57	71	63	58			60
62	61	71	67	71			59
69	63	57	64	68			
56	62	61	60	55			
66	60	58	59	67			

Figure 6.4: Charters Towers east approach – angle adjusted speed sample data

The adjusted data is then tabulated into the speed sample data table format below.

Date:	25/06/2015	Start Time:	2:00pm
Site Location:	**Charters Towers East Approach**	End Time:	5:15pm
Speed Limit:	60	Anything out of Ordinary:	no
Flow Direction:	West Bound	Weather:	fine

Speed	**Passenger Vehicle**		**Heavy Vehicles (Trucks, Bus etc)**		**Total**
	Record	**No**	**Record**	**No**	
<50	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
50	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
51	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
52	*Refer converted data field*	**1**	*Refer converted data field*	**1**	**2**
53	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
54	*Refer converted data field*	**1**	*Refer converted data field*	**1**	**2**
55	*Refer converted data field*	**4**	*Refer converted data field*	**0**	**4**
56	*Refer converted data field*	**3**	*Refer converted data field*	**0**	**3**
57	*Refer converted data field*	**7**	*Refer converted data field*	**2**	**9**
58	*Refer converted data field*	**10**	*Refer converted data field*	**1**	**11**
59	*Refer converted data field*	**9**	*Refer converted data field*	**3**	**12**
60	*Refer converted data field*	**8**	*Refer converted data field*	**3**	**11**
61	*Refer converted data field*	**7**	*Refer converted data field*	**1**	**8**
62	*Refer converted data field*	**11**	*Refer converted data field*	**4**	**15**
63	*Refer converted data field*	**11**	*Refer converted data field*	**2**	**13**
64	*Refer converted data field*	**5**	*Refer converted data field*	**0**	**5**
65	*Refer converted data field*	**10**	*Refer converted data field*	**0**	**10**
66	*Refer converted data field*	**6**	*Refer converted data field*	**1**	**7**
67	*Refer converted data field*	**8**	*Refer converted data field*	**0**	**8**
68	*Refer converted data field*	**3**	*Refer converted data field*	**0**	**3**
69	*Refer converted data field*	**6**	*Refer converted data field*	**2**	**8**
70	*Refer converted data field*	**3**	*Refer converted data field*	**0**	**3**
71	*Refer converted data field*	**5**	*Refer converted data field*	**0**	**5**
72	*Refer converted data field*	**7**	*Refer converted data field*	**0**	**7**
73	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
74	*Refer converted data field*	**1**	*Refer converted data field*	**1**	**2**
75	*Refer converted data field*	**4**	*Refer converted data field*	**0**	**4**
76	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
77	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
78	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
79	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
80	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
>80	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
Total					**160**

Figure 6.5: Charters Towers east approach – raw speed sample data

The following graph tabulates the number of light vehicle samples attained for each speed at this location. It is apparent a normal distribution of results exists with the centre of the distribution being located between 60-70km/hr.

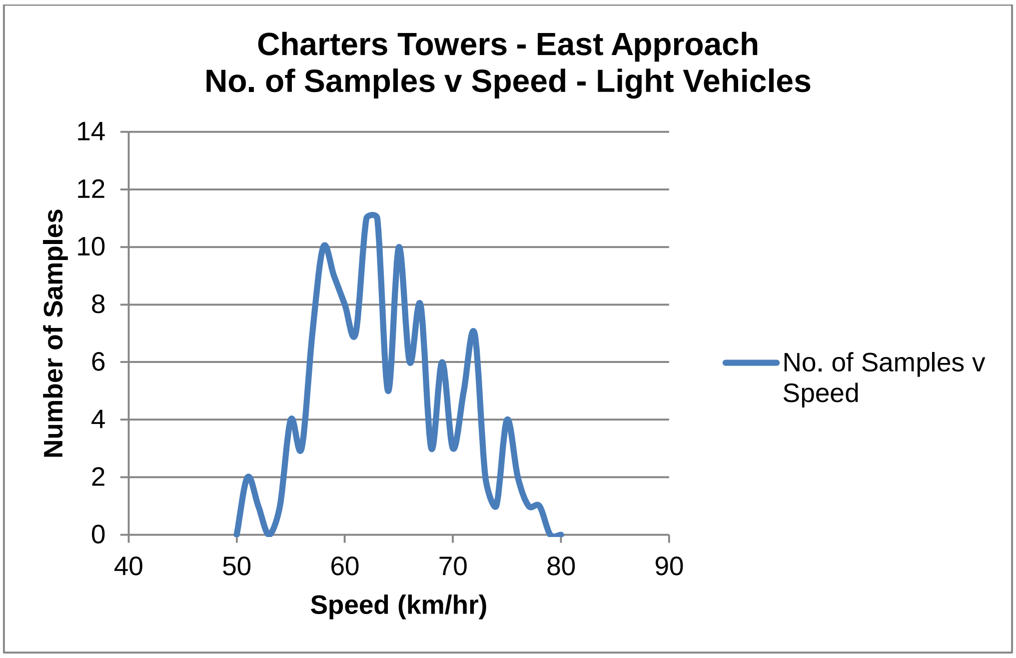

Figure 6.6: Charters Towers east approach – light vehicle sampling graph

The number of samples attained at each speed for the heavy vehicles is provided below.

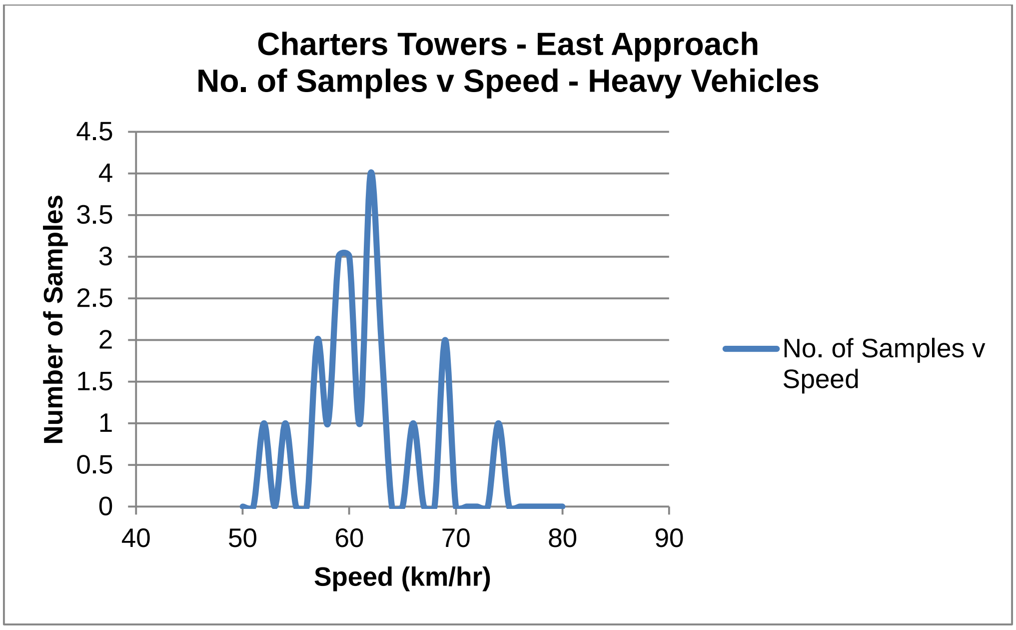

Figure 6.7: Charters Towers east approach – heavy vehicle sampling graph

Additionally the number of samples attained at each speed for the combined case, including both light and heavy vehicles is provided below.

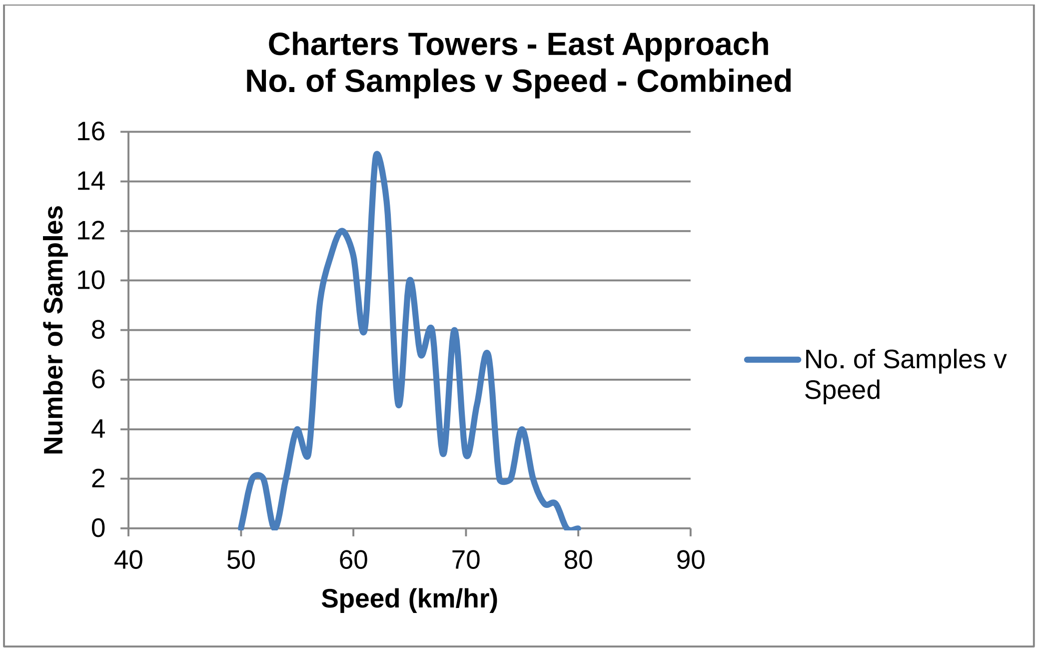

Figure 6.8: Charters Towers east approach – combined vehicles sampling graph

From this data we are able to calculate the 85th Percentile speeds for each vehicle type to gain a further understanding of current compliance to the posted 60km/hr speed limit.

- 85th Percentile (Light Vehicles) – 71km/hr
- 85th Percentile (Heavy Vehicles) – 64km/hr
- 85th Percentile (All Vehicles) – 70km/hr

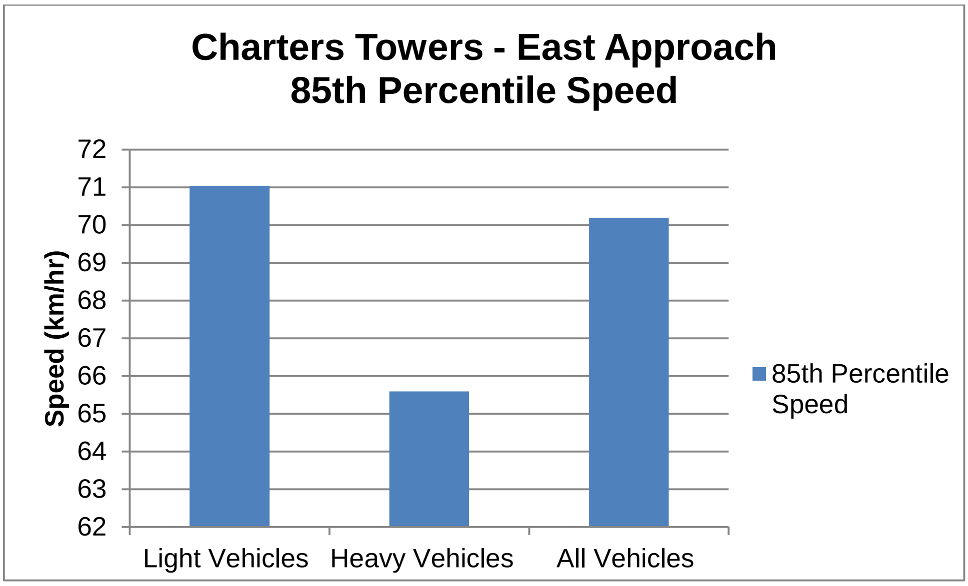

Figure 6.9: Charters Towers east approach – 85th Percentile speed graph

The analysed results for the Charters Towers – Flinders Highway (East Approach) suggests that there is currently poor compliance for light vehicles to the posted speed. The surveyed 85th percentile speed in this location exceeded the posted speed limit by 11km/hr or 18%.

6.2 Ingham

Ingham has a population of approximately 5,000 people and is a centre hub for many sugarcane plantations. The Bruce highway passes through Ingham and carries a large contingency of tourists and freight trucks, making their way north and south.

6.2.1 Bruce Highway (North Approach)

The Ingham - Bruce Highway (North Approach) is a two-lane highway which connects the township of Ingham to the north. The road has a nice riding asphalt surfacing and clearly visible line marking. The low speed environment commences at a 60km/hr posted speed sign which is installed on the east side of the roadway. The longitudinal grade is relatively flat when entering the low-speed environment. The roadside environment prior to the 60km/hr sign consists of sugarcane plantations on both sides of the road setback approximately 5m from the shoulder. Upon passing the 60km/hr speed sign and entering the low-speed environment a residential property, street lighting poles and an adjoining intersection is located on the eastern side of the roadway sufficiently setback from the road shoulder. The road then begins to become divided as it approaches a grassed central median which separates the traffic flow. The 80km/hr speed environment preceding the 60km/hr low speed environment has an approximate length of 350m. This length was among the shortest preceding 80km/hr speed environment within the project's focus areas.

Figure 6.10: Ingham north approach (facing north)

An aerial layout of speed sampling at this location is depicted below.

Figure 6.11: Ingham north approach – speed sample survey layout

The raw speed samples, angle adjusted data and output spreadsheet from the testing undertaken on the 3rd July 2015 have been provided in Appendix B.

The following graph tabulates the number of light vehicle samples attained for each speed at this location. It is apparent a normal distribution of results exists with the centre of the distribution being located between 60-70km/hr.

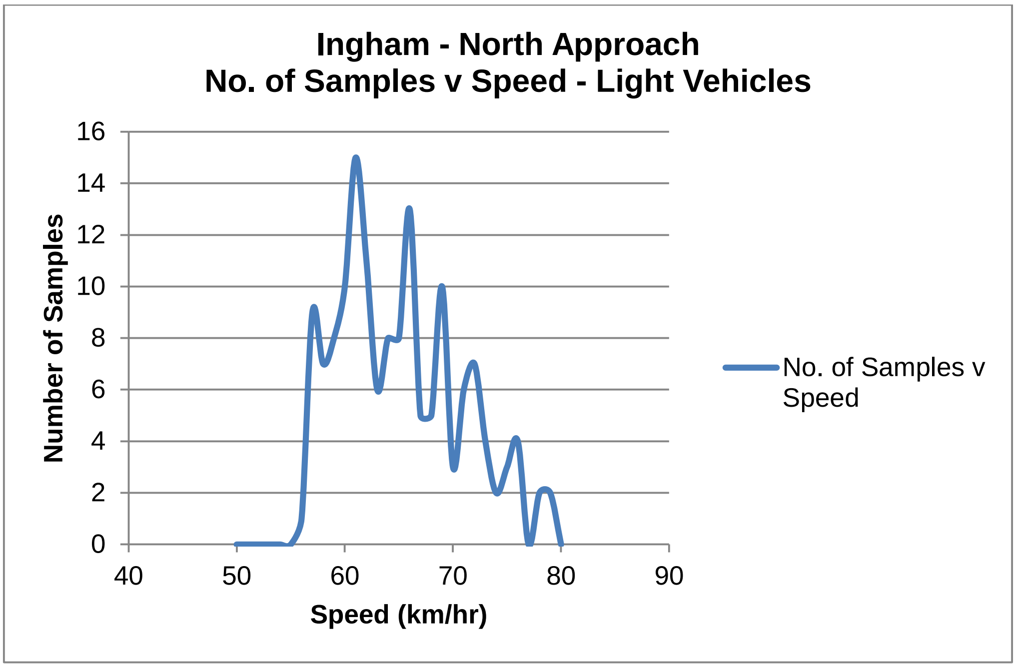

Figure 6.12: Ingham north approach – light vehicle sampling graph

The number of samples attained at each speed for the heavy vehicles is provided below.

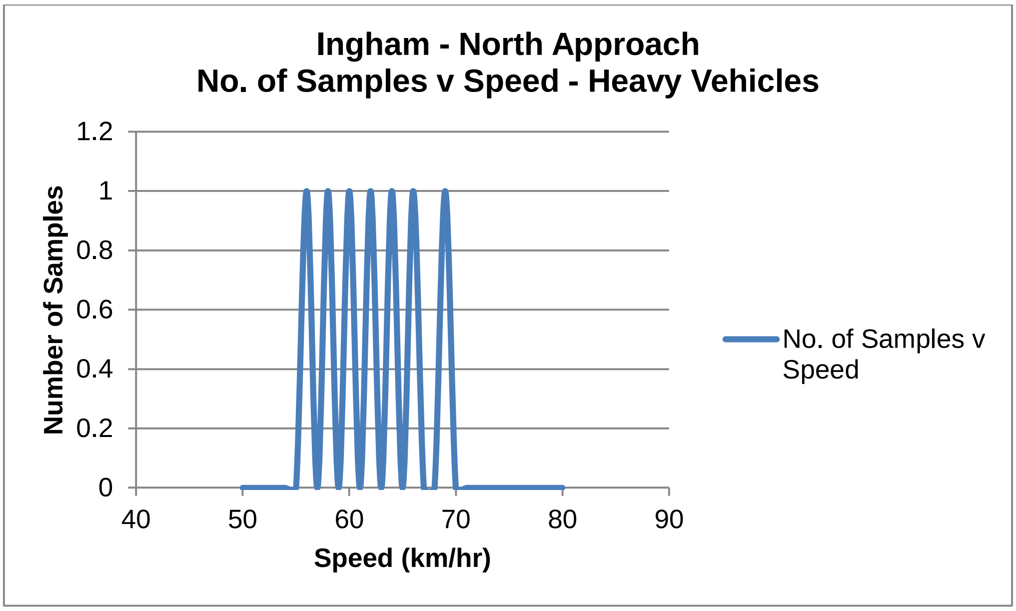

Figure 6.13: Ingham north approach – heavy vehicle sampling graph

Additionally the number of samples attained at each speed for the combined case, including both light and heavy vehicles is provided below.

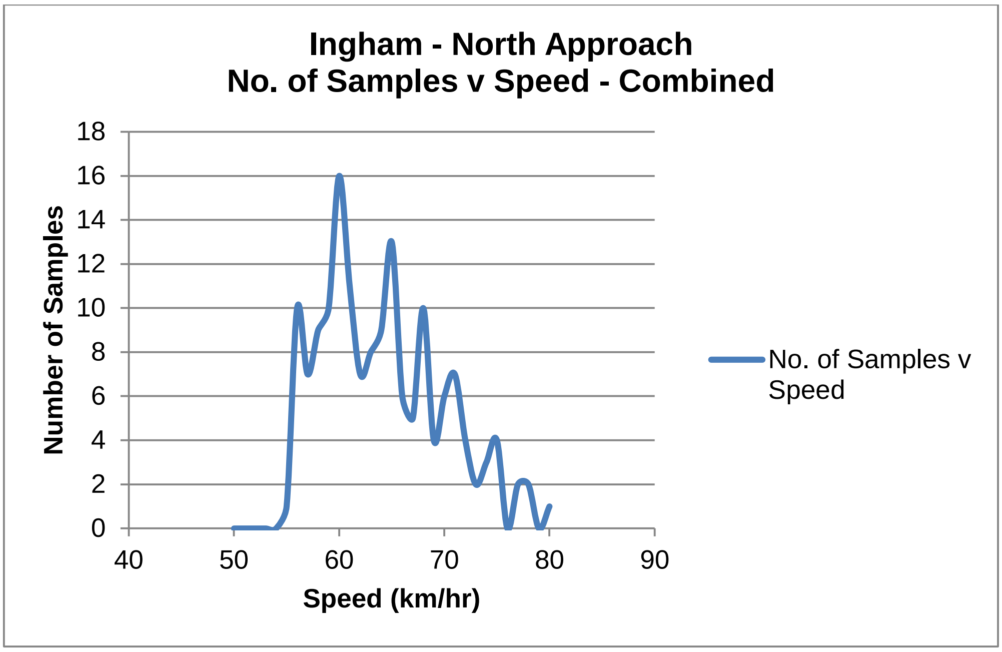

Figure 6.14: Ingham north approach – combined vehicles sampling graph

From this data we are able to calculate the 85th Percentile speeds for each vehicle type to gain a further understanding of current compliance to the posted 60km/hr speed limit.

- 85th Percentile (Light Vehicles) – 71km/hr
- 85th Percentile (Heavy Vehicles) – 66km/hr
- 85th Percentile (All Vehicles) – 71km/hr

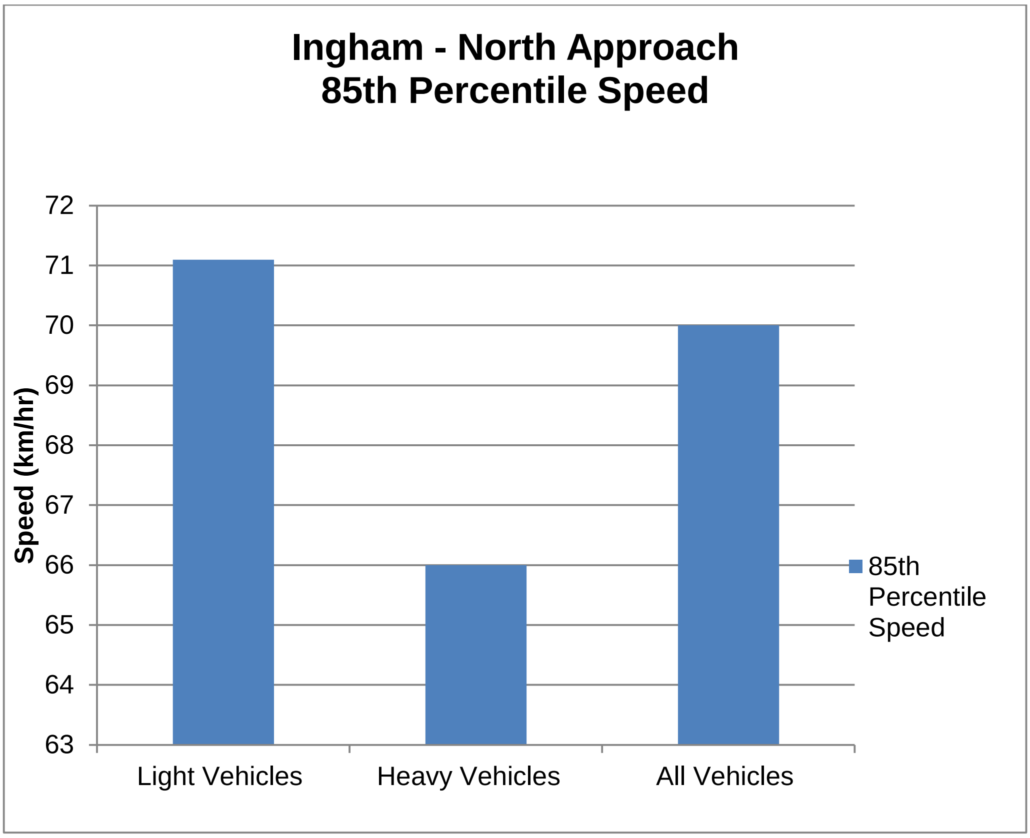

Figure 6.15: Ingham north approach – 85^{th} Percentile speed graph

The analysed results for the Ingham – Bruce Highway (North approach) suggests that there is currently poor compliance for both light and heavy vehicles to the posted speed limit. The surveyed 85th percentile speed for light vehicles in this location exceeded the posted speed limit by 11km/hr or 18%. The 85^{th} percentile speed for heavy vehicles exceeded the posted speed limit by 6km/hr or 10%.

6.2.2 Bruce Highway (South Approach)

The Ingham - Bruce Highway (South Approach) is a two-lane highway connecting Ingham to the south. Similar to the north approach this area also has smooth finish asphalt surfacing and clearly visible line marking. The low speed environment commences at a 60km/hr posted speed sign which is installed on the west side of the roadway. The longitudinal grade is flat when entering the low-speed environment. Roadside environment prior to the 60km/hr sign consists of a combination of open space and residential properties set back on the eastern side and open space and service roads on the western side of the road. Multiple street-lit intersections connect to the highway at the approach to the low-speed environment. Roadside development after the 60km/hr speed limit sign is very similar to the upstream environment however does enter a urbanised centre at a signalised T-junction intersection several hundred metres closer to the CBD. This section of highway was redeveloped in 2007-2008 during the TMR Alliance project named “Ingham Alliance – (Larsens to Lannercost Street)”. The road was built up to a higher elevation (RL 12m AHD) to provide greater flood immunity along with new service roads to increase road safety as a result of reducing the amount of properties with direct access onto the Bruce Highway. The upgrade produced a combination of centre line marked separating medians and centre turning lanes to further improve safety. The 80km/hr speed environment preceding the 60km/hr low speed environment is in excess of 750m.

Figure 6.16: Ingham south approach (facing south)

An aerial layout of speed sampling at this location is depicted below.

Figure 6.17: Ingham south approach – speed sample survey layout

The raw speed samples, angle adjusted data and output spreadsheet from the testing undertaken on the 3rd July 2015 have been provided in Appendix B.

The following graph tabulates the number of light vehicle samples attained for each speed at this location. It is apparent a normal distribution of results exists with the centre of the distribution being located around 60km/hr.

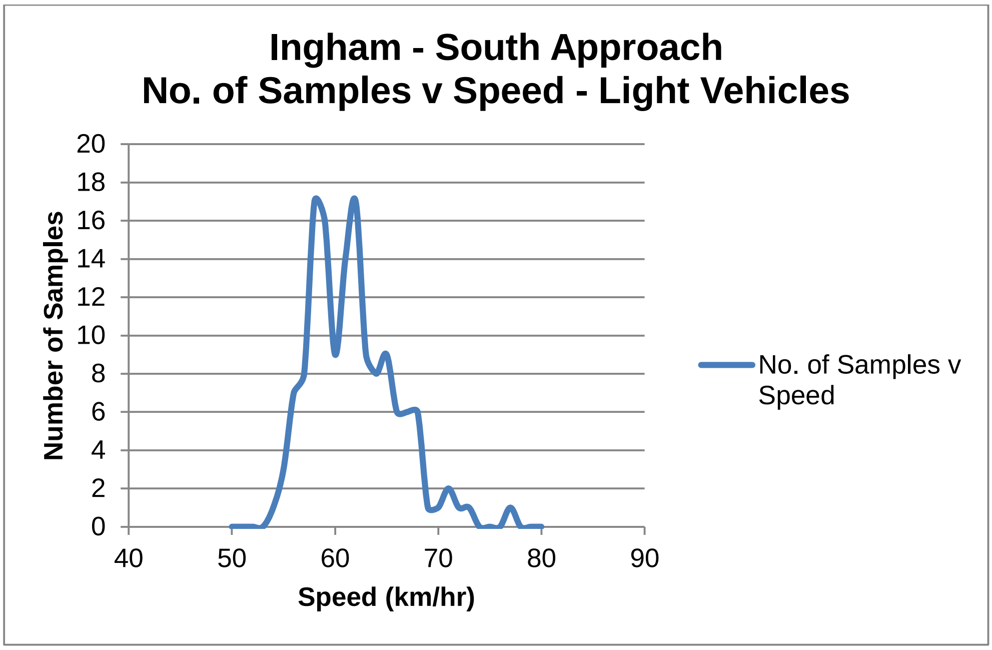

Figure 6.18: Ingham south approach – light vehicle sampling graph

The number of samples attained at each speed for the heavy vehicles is provided below.

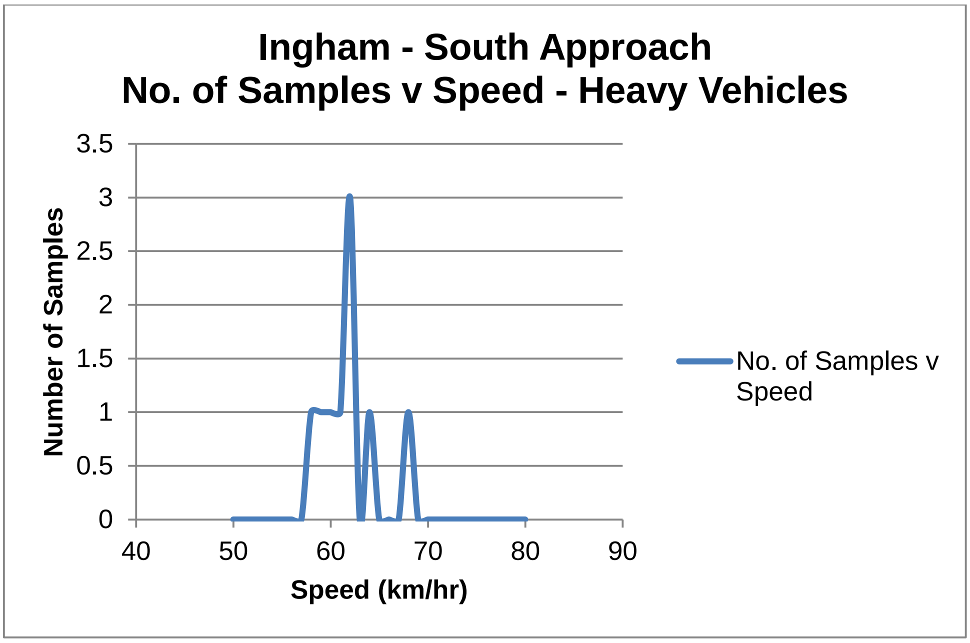

Figure 6.19: Ingham south approach – heavy vehicle sampling graph

Additionally the number of samples attained at each speed for the combined case, including both light and heavy vehicles is provided below.

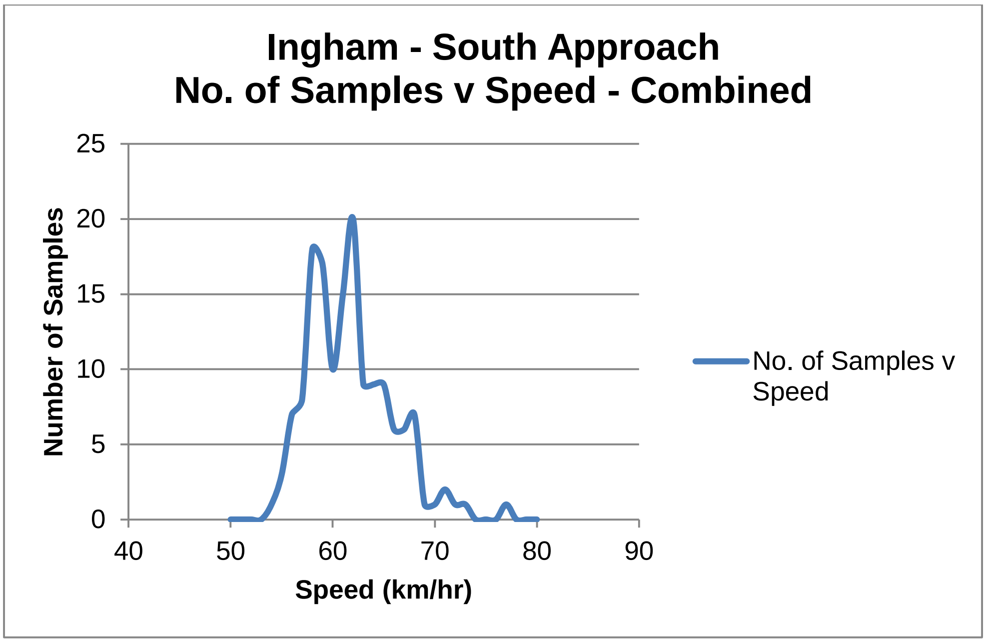

Figure 6.20: Ingham south approach – combined vehicles sampling graph

From this data we are able to calculate the 85th percentile speeds for each vehicle type to gain a further understanding of current compliance to the posted 60km/hr speed limit.

- 85th Percentile (Light Vehicles) – 66km/hr
- 85th Percentile (Heavy Vehicles) – 64km/hr
- 85th Percentile (All Vehicles) – 66km/hr

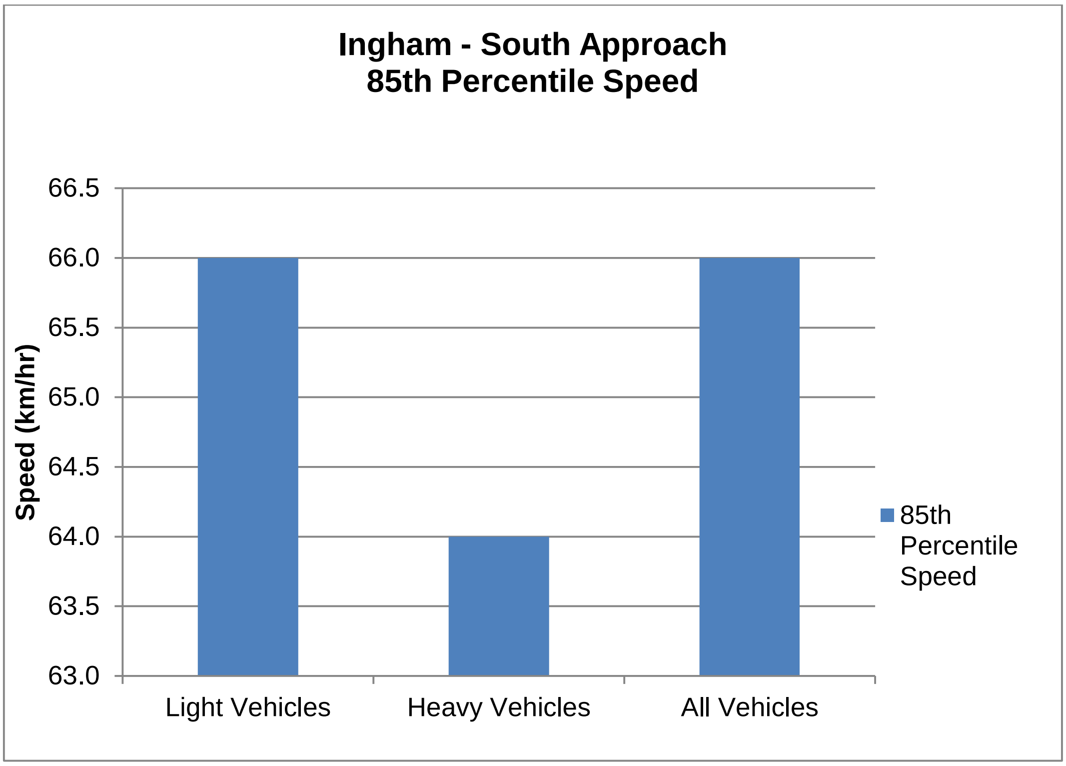

Figure 6.21: Ingham south approach – 85th Percentile speed graph

The results for the Ingham – Bruce Highway (South approach) suggests that there is currently average compliance for both light and heavy vehicles to the posted speed limit. The surveyed 85th percentile speed for light vehicles in this location exceeded the posted speed limit by 6km/hr or 10%. The 85th percentile speed for heavy vehicles exceeded the posted speed limit by 4km/hr or 7%.

6.3 Pentland – Flinders Highway (West Approach)

Pentland is a small town adjoining a section of the Flinders Highway approximately 250km west of Townsville. Pentland has a high population of elderly residents with minimal amenities available. A basic shop, service station, pub, caravan park and hotel motel are located in Pentland. Cattle trucks, mine related freight and tourist with caravans in tow frequently pass through this remote township.

The Pentland - Flinders Highway (West Approach) is a two-lane highway connecting Pentland to the west. The roadway is surfaced with bitumen sealing and adequate line marking. The low speed environment commences at a 60km/hr posted speed sign which is installed on the north side of the roadway. Similar to the Charters Towers (East Approach) the longitudinal grade slopes downwards as you approach and enter the low-speed environment which increases the difficulty to reduce vehicle speed.

Figure 6.22: Pentland west approach (facing east)

Roadside environment prior to the 60km/hr sign consists of vast vegetated bushland with a single gravel driveway located on the northern side of the roadway which links to a basic airstrip. There is no street lighting present on the approach however a single street light is positioned approximately 100m downstream of the 60km/hr sign. Roadside development after the 60km/hr speed limit sign consists of a rail line and vegetation on the south side of the road and residential properties, basic shopping amenities, rural intersections and power lines on the north side of the roadway. Similar to the Ingham – Bruce Highway north approach the 80km/hr speed environment preceding the 60km/hr low speed environment has an approximate length of 350m.

Figure 6.23: Pentland west approach (facing west)

An aerial layout of speed sampling at this location is depicted below.

Figure 6.24: Pentland west approach – speed sample survey layout

The raw speed samples, angle adjusted data and output spreadsheet from the testing undertaken on the 6th July 2015 have been provided in Appendix B.

The following graph tabulates the number of light vehicle samples attained for each speed at this location.

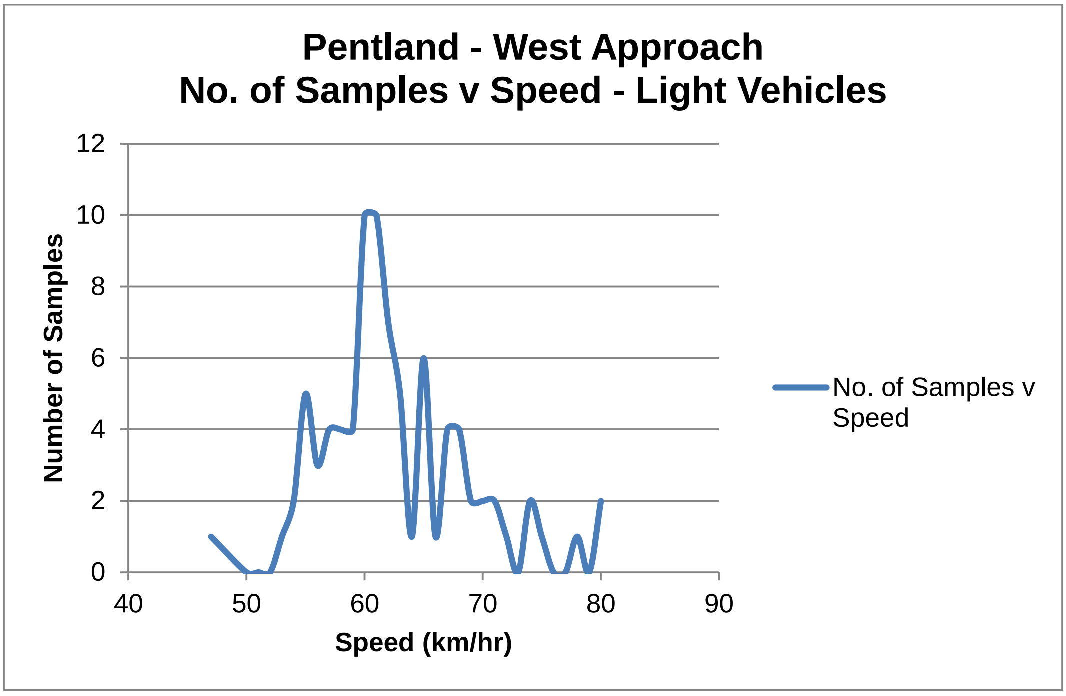

Figure 6.25: Ingham south approach – light vehicle sampling graph

The number of samples attained at each speed for the heavy vehicles is provided below.

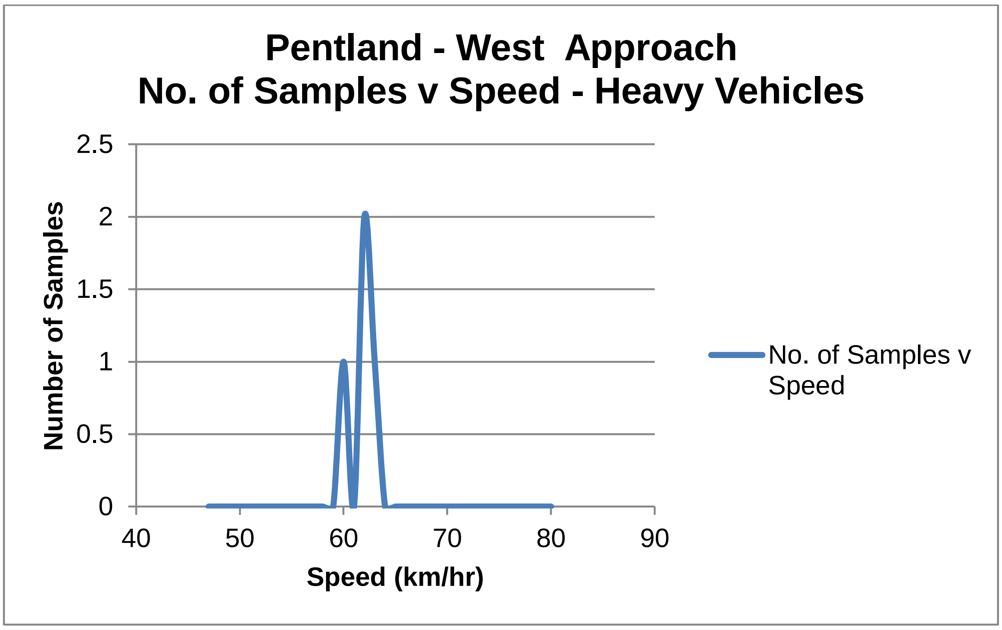

Figure 6.26: Pentland west approach – heavy vehicle sampling graph

Additionally the number of samples attained at each speed for the combined case, including both light and heavy vehicles is provided below.

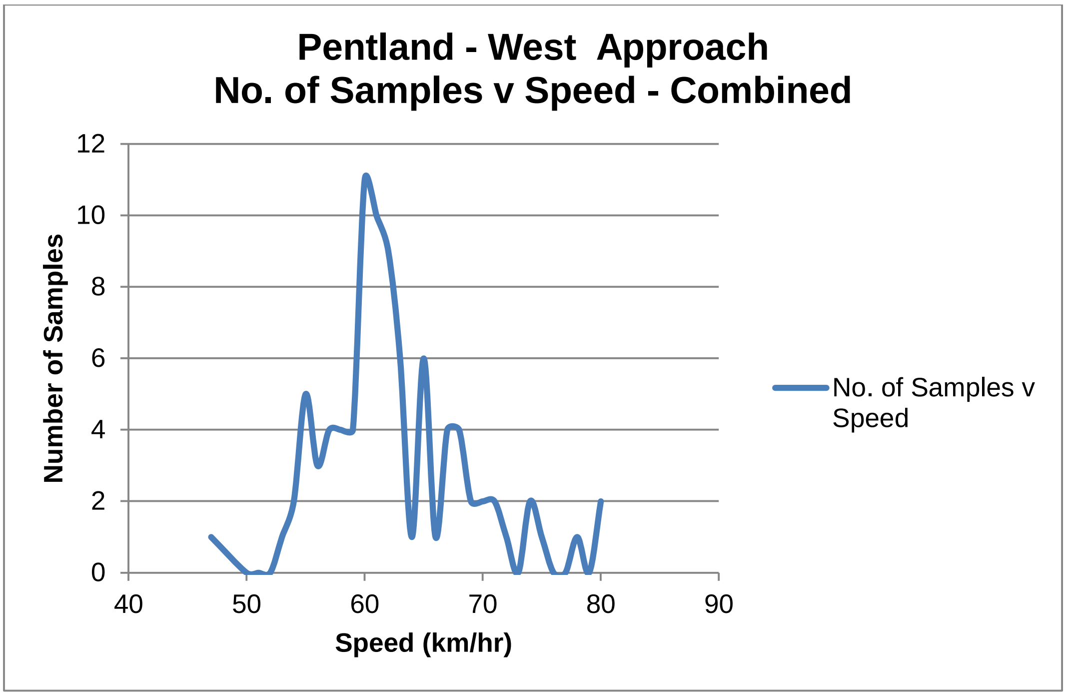

Figure 6.27: Pentland west approach – combined vehicles sampling graph

From this data we are able to calculate the 85th percentile speeds for each vehicle type to gain a further understanding of current compliance to the posted 60km/hr speed limit.

- 85th Percentile (Light Vehicles) – 68km/hr
- 85th Percentile (Heavy Vehicles) – 63km/hr
- 85th Percentile (All Vehicles) – 68km/hr

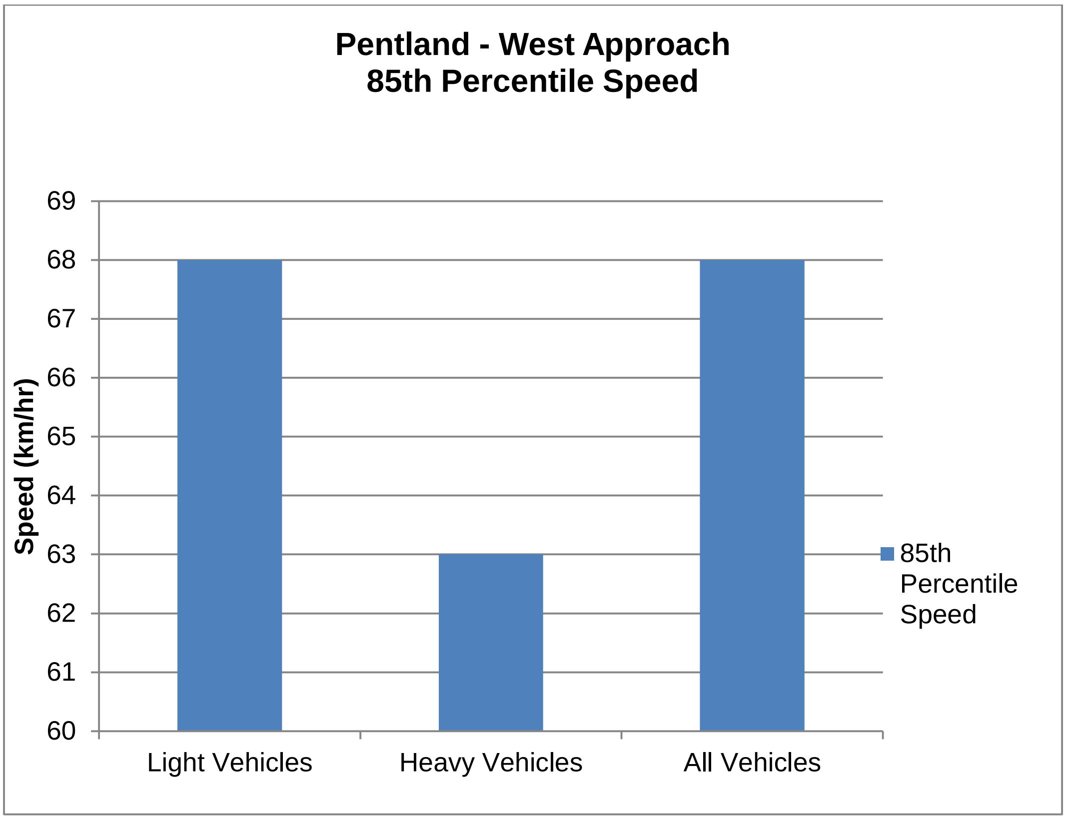

Figure 6.28: Pentland west approach – 85th Percentile speed graph

The analysed results for the Pentland – Flinders Highway (West approach) suggests that there is currently poor compliance for light vehicles and average compliance for heavy vehicles to the posted speed limit. The surveyed 85th percentile speed for light vehicles in this location exceeded the posted speed limit by 8km/hr or 13%. The 85th percentile speed for heavy vehicles exceeded the posted speed limit by 3km/hr or 5%.

6.4 Ayr – Bruce Highway (North Approach)

Ayr is a town located approximately 90km's south of Townsville with a population of around 8,000 people. Ayr is part of the Burdekin shire which boasts the most sugarcane per square kilometre in Australia. Ayr has several schools and a hospital along with many other services common to larger Queensland towns. The Bruce highway passes through the heart of Ayr and forms Ayr's main street, Queen Street. In order to reduce the presence of heavy vehicles through the main street a heavy vehicle bypass route traverses along Jones, Railway and Bower Street. The heavy vehicle bypass conveys a large contingency of tourists and large vehicles around the southern edges of Ayr.

The Ayr - Bruce Highway (North Approach) is a two-lane highway which connects the township of Ayr to the north. The road has a nice riding asphalt surfacing and clearly visible line marking. The low speed environment commences at a single 60km/hr posted speed sign which is installed on the east side of the roadway. The longitudinal grade is relatively flat when entering the low-speed environment. The roadside environment prior to the 60km/hr sign consists of a line of street lights and trees on the east side and a retaining wall, powerlines and several trees on the west side of the roadway. A centre of the road is dedicated to turning lanes and painted medians. Immediately downstream of the low speed environment is a four way intersection, along the east side of the road is a combination of residential properties, a motel and a church. A single residential property exists on the west side of the road along with sugarcane plantation. Further downstream additional 60km/hr posted speed signs are positioned on both sides of the road to reinforce the speed environment requirements. The 80km/hr speed environment preceding the 60km/hr low speed environment is approximately 1.5km.

Figure 6.29: Ayr north approach (facing south)

An aerial layout of speed sampling at this location is depicted below.

Figure 6.30: Ayr north approach – speed sample survey layout

The raw speed samples, angle adjusted data and output spreadsheet from the testing undertaken on the 27th July 2015 have been provided in Appendix B.

The following graph tabulates the number of light vehicle samples attained for each speed at this location.

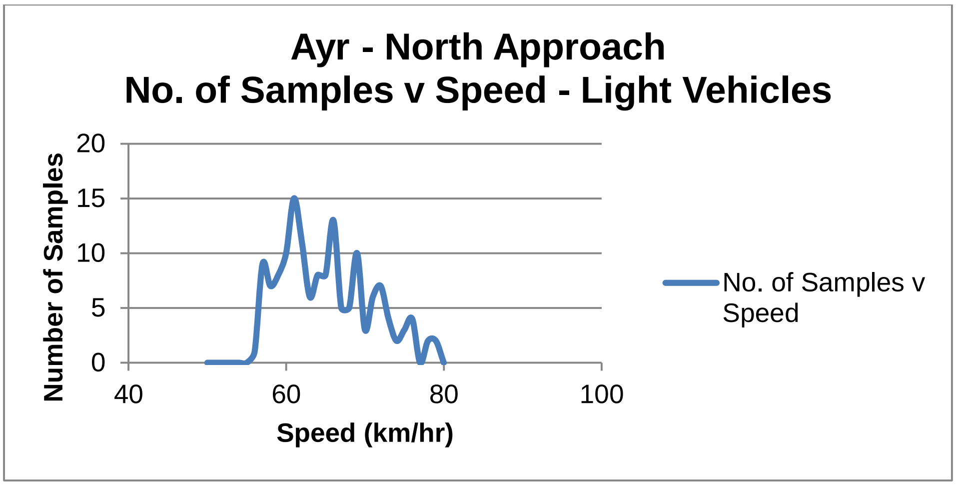

Figure 6.31: Ayr north approach – light vehicle sampling graph

The number of samples attained at each speed for the heavy vehicles is provided below.

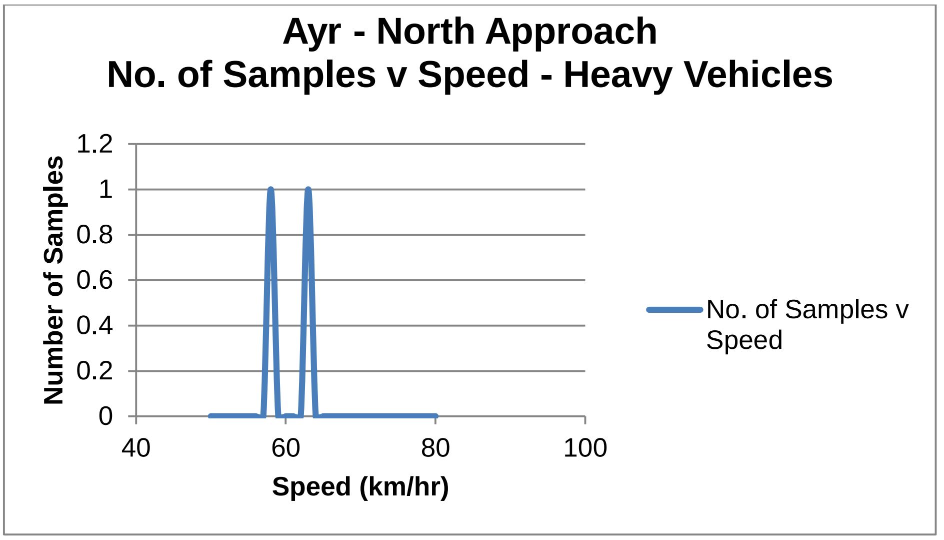

Figure 6.32: Ayr north approach – heavy vehicle sampling graph

It is evident that minimal heavy vehicles were sampled during the survey which is a direct result of the heavy vehicle bypass. Additionally the number of samples attained at each speed for the combined case, including both light and heavy vehicles is provided below.

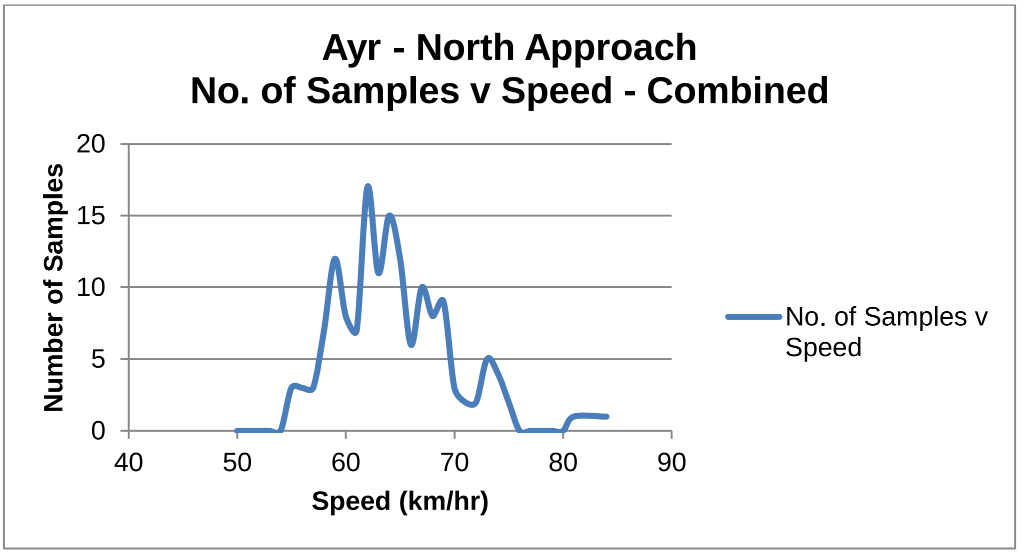

Figure 6.33: Ayr north approach – combined vehicles sampling graph

From this data we are able to calculate the 85th percentile speeds for each vehicle type to gain a further understanding of current compliance to the posted 60km/hr speed limit.

- 85th Percentile (Light Vehicles) – 68km/hr
- 85th Percentile (Heavy Vehicles) – 63km/hr
- 85th Percentile (All Vehicles) – 68km/hr

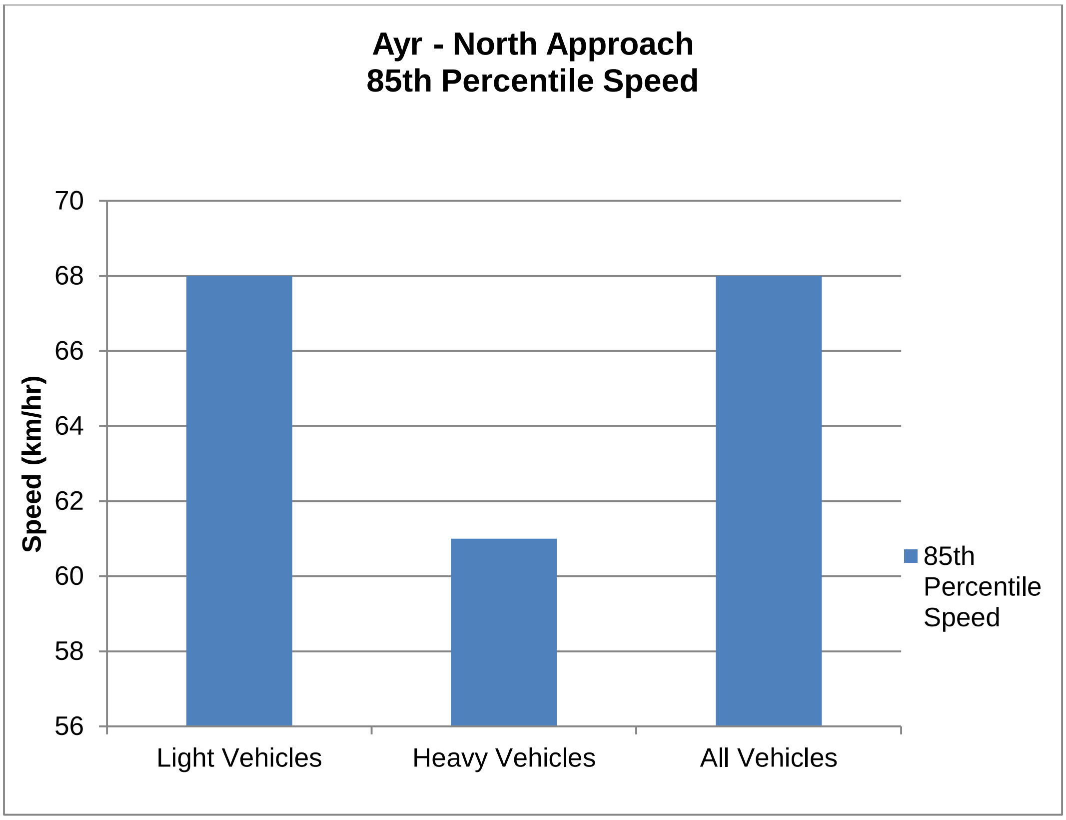

Figure 6.34: Ayr north approach – 85th Percentile speed graph

The analysed results for the Ayr – Bruce Highway (North approach) suggests that there is currently poor compliance for light vehicles to the posted speed limit. The surveyed 85th percentile speed for light vehicles in this location exceeded the posted speed limit by 8km/hr or 13%. The 85th percentile speed for heavy vehicles exceeded the posted speed limit by 1km/hr or 1.6% which reflects exceptional compliance. However the lack of samples which resulted from trucks using another route may not provide a true representation of current heavy vehicle compliance.

6.5 Sample Site Comparison

The 85th percentile speeds for all locations are compared in the graph below to assist in identifying compliance issues for each location.

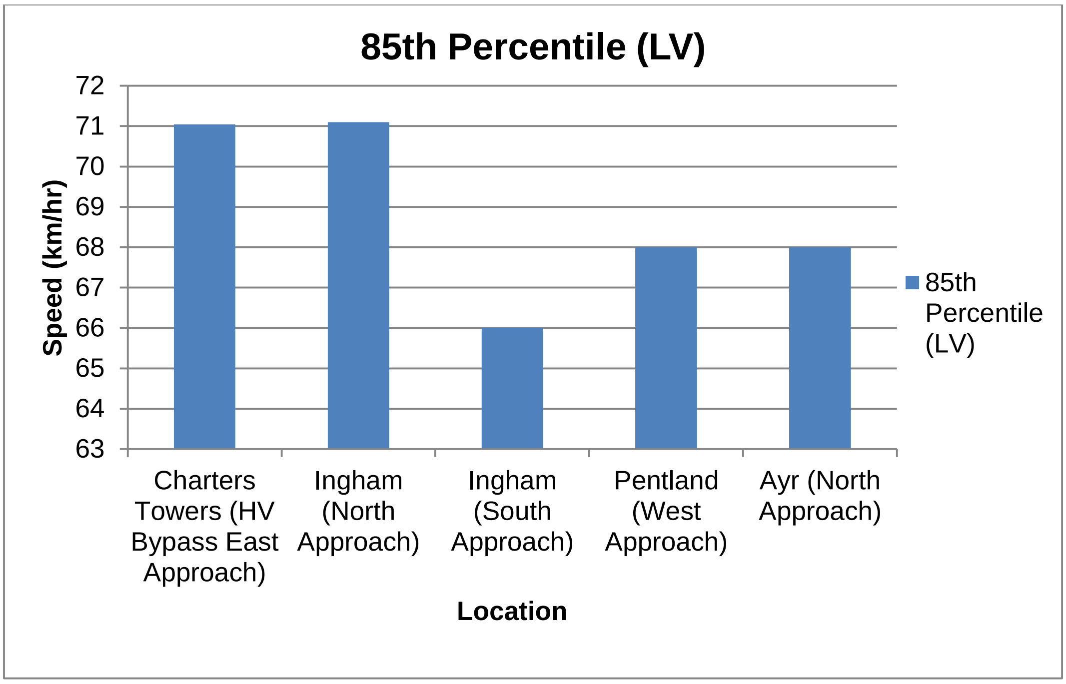

Figure 6.35: All sites – 85th Percentile speed graph (light vehicles)

It is clear that there is currently a significant variance between compliance between each of the approaches to Ingham. The variance appears to be a result of the considerable difference between each approaches roadside development. Both Charters Towers – Flinders Highway (East Approach) and Ingham – Bruce Highway (North Approach) resulted in light vehicles 85th Percentile speeds exceeding the posted limit by 11km/hr / 18%. The Pentland – Flinders Highway (West Approach) and the Ayr – Bruce Highway (North Approach) displayed similar compliance with light vehicle 85th Percentile speeds exceeding the posted speed limit by 8km/hr / 13%. The most speed limit compliant location for light vehicles was the Ingham – Bruce Highway (South Approach) with an 85th Percentile speed of 66km/h, exceeding the posted speed limit by 6km/hr / 10%.

The following two graphs incorporate the heavy vehicles results for comparison.

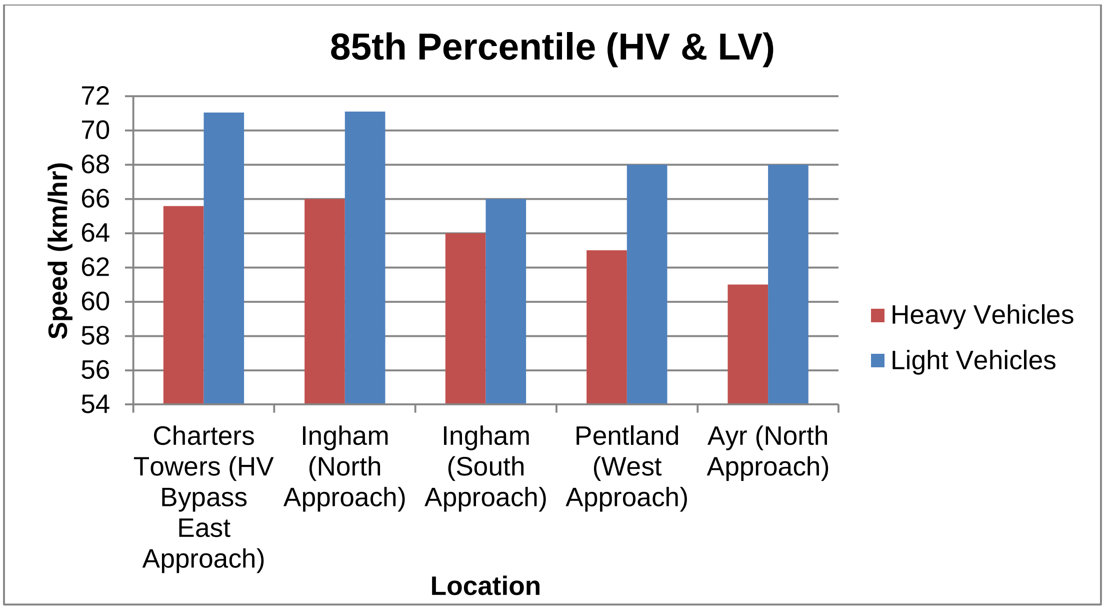

Figure 6.36: All sites – 85th Percentile speed graph (light & heavy vehicles)

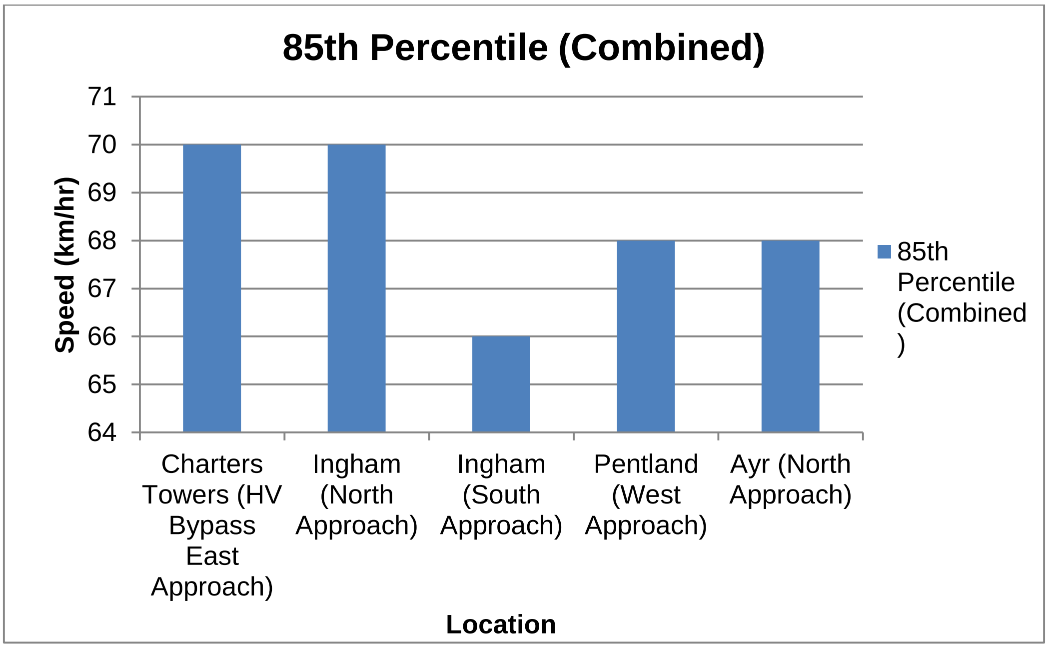

Figure 6.37: All sites – 85th Percentile speed graph (combined vehicles)

Chapter 7

Crash Data Analysis

A detailed crash analysis was undertaken for each of the five field speed survey locations.

7.1 Pentland – Flinders Highway (West Approach)

No incidents found in community or transition zone.

7.2 Charters Towers – Flinders Highway (East Approach)

Figure 7.1: Charters Towers east approach – crash location overlay

Crash ID 8011 (MedT, 2008, 800)

In April 2008 a utility travelling west was involved in a single vehicle accident. The occupant required medical treatment and the utility had extensive unrepairable damage. The vehicle left the road very close to the 60km/hr posted speed sign.

Crash ID 5897 (Minor, 2007, 804)

Crash not applicable to this project as the vehicle was heading north and transitioning speed not relevant.

7.3 Ingham – Bruce Highway (North Approach)

Figure 7.2: Ingham north east approach – crash location overlay

Crash ID 5751 (PDO, 2007, 703)

Single vehicle crash not applicable to this project as the vehicle was heading north and transitioning speed not relevant.

Crash ID 9116 (Minor, 2009, 104)

In March 2009 two light vehicles collided after a vehicle attempted to exit Halifax Road and enter the Bruce Highway. The incident occurred during the day on a dry, clear road. Both vehicles received moderate damage and needed to be towed away. Incident location was within the 60km/hr low speed environment, excess speed may have played a factor.

Crash ID 2569 (Minor, 2010, 301)

Crash not applicable to this project as the vehicle was heading north and transitioning speed not relevant.

Crash ID 2450 (Minor, 2010, 400)

Crash is not applicable to the project, incident occurred whilst trying to park within a carpark set away from the Bruce Highway.

Crash ID 463 (Fatal, 2012, 003)

Crash not applicable to this project as the vehicle was heading north and transitioning speed not relevant.

Crash ID 12171 (Hosp, 2013, 303)

Crash not applicable to this project as the vehicle was heading north and transitioning speed not relevant.

Crash ID 402 (Fatal, 2008, 804)

Crash not applicable to this project as the vehicle was heading north and transitioning speed not relevant.

Crash ID 7979 (PDO, 2009, 708)

A single vehicle property damage only incident occurred in January 2009 approximately 500m downstream of the start of the 60km/hr low speed environment. The incident occurred on a rainy night whilst the road was wet, horizontal alignment was straight. The vehicle left the travel lane and mounted a traffic island resulting in moderate damage and being towed away.

7.4 Ingham – Bruce Highway (South Approach)

Figure 7.3: Ayr south approach – crash location overlay

Crash ID 686 (PDO, 2010, 301)

In April 2010 a multiple vehicle property damage only incident occurred approximately 350m downstream of the 60km/hr low speed environment. Whilst two vehicles were stationary a third vehicle was unable to stop and rear ended the stationary vehicles. The incident occurred during the day on a clear, dry, straight road. Speed or driver inattention may have contributed.

Crash ID 9274 (PDO, 2009, 101)

Crash not applicable to this project as the vehicle was heading north and transitioning speed not relevant.

Crash ID 3317 (MedT, 2011, 104)

Crash not applicable to this project as the vehicle was heading north and transitioning speed not relevant.

7.5 Ayr – Bruce Highway (North Approach)

Figure 7.4: Ayr north approach – crash location overlay

Crash ID 5607 (PDO, 2007, 301)

In April 2010 a multiple vehicle property damage only incident occurred approximately 250m downstream of the 60km/hr low speed environment. Whilst a vehicle was stationary two trailing vehicles were unable to stop and rear ended the stationary vehicle. The incident occurred during the day on a clear, dry, straight road. Speed or driver inattention may have contributed. The stationary light vehicle received minor damage whilst the two trailing light vehicles incurred moderate damage and were towed away.

Crash ID 1038 (Hosp, 2010, 301)

In October 2010 a hospitalisation incident involving multiple vehicles occurred approximately 400m downstream of the 60km/hr low speed environment. The incident involved two light vehicles stopped at a cane rail crossing whilst a trailing light vehicle rear ended the stationary vehicles. The incident occurred during the day on a clear, dry, straight road. Speed or driver inattention may have contributed. The platoon stationary vehicle received minor damage, the trailing stationary vehicle received major damage (towed away) and the third vehicle whom did not comply with the stopping requirement received moderate damage (towed away).

Crash ID 6517 (PDO, 2007, 303)

Crash not applicable to this project as the vehicle was heading north and transitioning speed not relevant.

Crash ID 9609 (PDO, 2009, 301)

In July 2009 a multiple vehicle property damage only incident occurred approximately 800m downstream of the 60km/hr low speed environment. Whilst three vehicles were slowing or stationary a fourth vehicle failed to comply with the stopping requirement and rear ended the other three vehicles. Platoon and second vehicle received minor damage, whilst the third and fourth vehicle received moderate damage and were towed away. The incident occurred during the day on a clear, dry, straight road. Speed or driver inattention may have contributed.

Crash data analysis for all five locations within the time period stated above suggests that there is currently no major detrimental impact on public health throughout the focus area transition zones. Summary of crashes includes one medical treatment injury, one minor incident, one hospitalisation incident and four property damage only incidents have occurred within the focus area. By far the majority of crashes within these areas is the rear ending of stationary or slowing vehicles. Whilst there have been no fatalities recorded during the time period studied it is clear that the multiple minor, property damage and single hospitalisation incident are a cause of concern and it is clear improvements can be made.

The Australian Government's Black Spot Programme is committed to reducing crashes throughout the country. The Government's funding commitment to support the programme is reported to be $500 million between 2014-2015 and 2018-2019. Nominations are invited by all road stakeholders to identify potential Black spot locations. The current eligibility criteria states a minimum Benefit Cost Ratio of 1:1 and a minimum site crash history of 2 casualty crashes over a five year period or 0.13 crash casualties per km per year over five years.

Chapter 8

Environmental Factors

The weather throughout North Queensland can be variable depending on the season. Rainfall is quite significant within Ingham and Ayr due to their coastal location. Within these areas the speed transition approaches are surfaced with asphalt surfacing. Due consideration to the use of transverse pavement markings is required in these tropical areas as general line marking paint will reduce the friction between the vehicle and the roadway. This loss of friction is not desirable in an area where the objective is to get vehicles to transition to lower more suitable speeds as they approach low speed environments. Road surface condition throughout all five focus areas was satisfactory. There were no signs of pavement failures, pot holes or surface unevenness at any of the sites investigated.

While there was no evidence of animals close to the road during the speed survey it is expected that they would commonly make their way across and along the roadway. After discussion with locals at all four regional centres it was apparent that the animals were most predominant in the inland centres Pentland and Charters Towers. Kangaroos are frequently witnessed to cross roads in these areas and are a significant problem for road users.

Another important environmental factor of particular relevance is the rising and setting of the sun. The sun rises within a range northward or southward of exact east. Similarly the sun sets within a range northward or southward of exact east depending on the time of year. Throughout North Queensland during mornings and afternoons many transition zones require the driver to cope with a direct view of the sun. Modern cars are fitted with adjustable sun visors to aid the driver in reducing or removing the direct view of the sun which when in use subsequently reduces the amount of vision through the vehicles windscreen. In areas where this is identified as significant it would be appropriate to provide the driver with alternative communication methods. These methods could include audio or physical methods such as rumble grids or raised pavement markings.

During nightfall some regional areas do not have street lighting illumination as is the case on the western approach to Pentland. In areas such as this it is critical that the regulatory speed sign installed consists of retroreflective materials complying with AS / NZS 1906.1. Reflectorisation is a standard requirement for regulatory speed signs roads throughout Queensland, however periodic inspection should be undertaken to ensure the regulatory sign is providing sufficient reflectorisation. Where possible good practice is to ensure that the “welcome to town” sign is well illuminated to reinforce the upcoming change to a low-speed urbanised environment.

Chapter 9

Recommendations for Changes at Sample Sites

Significant reduction or elimination of future incidents within transition zones may be achievable with a strong focus on achieving improved speed compliance and maintaining driver attention during the transition from high-speed to low-speed environments. After consideration of current speed compliance, crash data and environmental factors the following recommendations have been provided for each approach within the project's focus area.

9.1 Site Specific Recommendations

The Charters Towers – Flinders Highway east approach currently has poor compliance to the posted speed limit and was among the least two speed compliant areas sampled. The combined 85th percentile speed for this approach exceeded the posted speed limit by 10km/hr. Despite this only one single vehicle incident has occurred within the assessed period of crash data. The lack of urban roadside development at the beginning of the 60km/hr and the declining vertical geometry appear to be significantly contributing to road users exceeding the posted speed. It is recommended that a rumble grid be installed upstream of the 60km/hr sign to assist in alerting drivers of the upcoming low speed environment. This location is suitable for the installation of a grooved rumble grid as it has been surfaced with asphalt.

A similar lack of compliance to the posted speed limit was also noted in the Ingham – Bruce Highway North Approach. Survey results for this area are similar to the Charters Towers approach where the combined 85th percentile speed exceeds the posted speed limit by 10km/hr. The crash data presented two incidents of interest to this focus area. The first incident involved the collision of two light vehicles after one vehicle attempted to enter the highway from an adjoining road. The second incident involved a vehicle leaving the road and mounting a traffic island during a rainy night.

Without being presented with a list of the contributing driver factors it is difficult to ascertain the cause of the incident. The approach had a preceding 80km/hr speed environment amongst the shortest of the approaches investigated with a total length of approximately 350m. Recommendations for improving speed compliance for this approach include installing an additional 60km/hr regulatory speed sign on the right hand side of the road, parallel to the existing sign. Installation of a trial grooved rumble grid is also recommended at this approach to assist in alerting the driver of the upcoming urbanised environment. This treatment device is recommended due to the long stretch of high-speed environment on the roadway upstream of this approach.

The Ingham – Bruce Highway south approach was identified as the most speed compliant approach of all five focus areas. The combined 85^{th} percentile speed only exceeded the posted speed limit by 6km/hr. A single property damage only report recorded within the crash data findings reinforces a link between speed compliance and crash rates. The length of the 80km/hr approach preceding the low speed environment is in excess of 750m. Whilst this transition zone is performing well, further improvement could be achieved with the installation of an electronic speed feedback sign. The Ingham south approach has sufficient traffic volumes to warrant the installation whilst minimising the risk of vandalism to the device.

Speed sample results for the Pentland – Flinders highway show the combined 85^{th} percentile speed exceeding the posted speed limit by 8km/hr. Upon reviewing the crash data it was revealed that no incidents had been recorded for the approach. Out of the five focus areas this approach was the only one to have nil recorded incidents. It is suspected that the omission of incidents is strongly related to the low traffic volumes present. In order to improve speed compliance in this area it is recommended to trial the installation of either transverse or converging pavement markings with decreasing longitudinal spacings prior to the low speed environment. Alternative treatments such as rumble grids or electronic speed feedback signs are not recommended for this approach due to its two coat bitumen seal and remoteness.

Combined 85^{th} percentile speed sample results for the Ayr – Bruce Highway north approach exceeded the posted speed limit by 8km/hr. The traffic composition of this approach consists of primarily light vehicles as a result of an upstream heavy vehicle bypass route. Crash data indicates that this approach has recorded the most significant number and severity of incidents within the five focus areas. Three multiple vehicle incidents have occurred downstream of the 60km/hr low speed environment resulting in property damage and in one case hospitalisation. It is apparent that there is a need to improve speed compliance and driver alertness throughout the initial passage of this low speed environment. The installation of an electronic speed feedback sign is recommended for this approach to significantly influence positive driver behaviour, alertness and speed compliance.

Chapter 10

Conclusions and Recommendations for Further Work

Through an extensive literature review, site based speed sampling and crash data analysis the project has provided meaningful insight into the performance of transitioning roadways from high-speed to low-speed environments in regional North Queensland.

The project has identified that crash rates within the focus areas do not meet or exceed the Australian Government's Black Spot Programme minimum crash history eligibility criteria. Consequently these areas would not be considered as high priority based on the black spot criteria. The review of crash data has identified that current traffic control devices are effective in limiting 'casualty crashes' but are ineffective in achieving acceptable speed compliance. The speed sample results in all locations support this position with 85^{th} percentile speeds significantly in excess of the posted speed limit. The project was unable to establish a clear link between speed and crash data within the focus areas.

While speed is a significant issue it is considered a low priority from an expenditure perspective and is recommended that the lack of compliance is addressed through the road authority's maintenance budget. Recommendations for site specific treatments have been provided in section 9.1 and include additional signage, rumble grids, electronic speed feedback signs and pavement markings. Future changes to traffic composition, traffic volumes and community expectations will require sagacity to ensure standards; controls and procedures are effective, relevant and constantly improve.

10.1 Accomplishment of Project Objectives

The project objectives outlined in Appendix A have been addressed as follows:

1. The project has developed a clear understanding of problems associated with transitioning from high-speed to low-speed environments and the current design standards, treatments and management strategies that exist globally.

2. The study area was defined and incorporated five sites within Charters Towers, Ingham, Pentland and Ayr.

3. A successful pilot field survey was undertaken in Charters Towers and lessons learnt contributed to succeeding speed surveys.

4. Discussion with the project supervisor Professor Ron Ayers regarding data quality and quantity was undertaken.

5. The data was used to develop 85th percentile speed results and compared between sites whilst developing an appreciation for the site characteristics and controls.

6. Environmental factors relevant to North Queensland were investigated and consideration was given to determine appropriateness of current management strategies.

7. Objectives seven and eight were aligned and recommendations on additional control devices to be retrofitted to improve speed compliance and public safety were provided.

10.2 Further Research

The following further research has been identified as a result of this project:

- Investigate the most suitable length of the 80km/hr speed environment upstream of the low-speed environment. This investigation would require experimentation on the length of the 80km/hr zone with speed sampling undertaken to find the optimal upstream length.

- Speed sampling of the focus area transition zones continuously for a one week period. It would be preferable that a vehicle speed counter be installed to facilitate continuous sampling. This method would provide a more complete understanding of driver behaviour and the impact of environmental factors in the focus areas. It would be of interest to assess transition zone speed compliance under night conditions.

- Trialling the treatments presented in this project whilst monitoring and assessing the impact at focus sites over a 12 month period. These experiments would provide valuable contributions to improve the understanding of transitioning vehicles from high-speed to low-speed environments in the local context.

- Further sites could be examined within North Queensland to provide a more complete understanding of the performance of speed transitioning in regional approaches. Additional sites recommended for experimentation and analysis includes Ayr’s southern approach, Charters Towers western approach and Pentland’s eastern approach.

References

American Association of State Highway and Transportation Officials (AASHTO), *A policy on geometric design of highways and streets*, AASHTO, Washington DC, 2001

Australian Transport Council (ATC), *National Road Safety Action Plan 2007 and 2008*, Australian Transport Safety Bureau, Australian Government Department of Transport and Regional Services, Canberra, 2006

Austroads, *Guide to Road Design*, Part 2: Design Considerations, Austroads Incorporated, Sydney, 2006

Austroads, *Guide to Road Design*, Part 3: Geometric Design, Austroads Limited, Sydney, 2010a

Austroads, *Guide to Road Design*, Part 6: Roadside Design, Safety and Barriers, Austroads Limited, Sydney, 2010b

Austroads, *Guide to Road Design*, Part 6B: Roadside Environment, Austroads Incorporated, Sydney, 2009a

Austroads, *Guide to Road Safety*, Part 3: Speed Limits and Speed Management, Austroads Incorporated, Sydney, 2008

Austroads, *Guide to Traffic Management*, Part 10: Traffic Control and Communication Devices, Austroads Incorporated, Sydney, 2009b

Barker, J., Helliar-Symons, R.D., *Countdown Signs and Roundel Markings Trails*, TRL Report 201, Transport Research Laboratory, Crowthorne U.K. 1997

Center for Transportation Research and Education, *Handbook of Simplified Practice for Traffic Studies*, Iowa State University, 2002

Charlton, S., Baas, P., *Speed change management for New Zealand roads*, Land Transport New Zealand Research Report 300, 2006

Corkle, J., Marti, M., Montebello, D., *Synthesis on the Effectiveness of Rumble Strips*, SRF Consulting Group Incorporated, October 2001

Cruzado, I., Donnell, E., *Effectiveness of Speed Minders in Reducing Speeds on Rural Highways in Pennsylvania, Final Report*, The Thomas D. Larson Pennsylvania Transportation Institute, Pennsylvania State University, 2008

Cruzado, I., Donnell, E., *Factors Affecting Driver Speed Choice along Two-Lane Rural Highway Transition Zones*, Journal of Transportation Engineering, August 2010

Department of Infrastructure and Regional Development 2015, Australian Government, viewed 17 October 2015, <http://investment.infrastructure.gov.au/funding/blackspots/index.aspx>

Department of Transport and Main Roads, *Queensland Transport and Roads Investment Program 2014-15 to 2017-18*, Queensland Government, 2014

Department of Main Roads, *Road Planning and Design Manual, Chapter 5: Traffic Parameters and Human Factors*, Queensland Government, 2004

Elvik, R., Christensen, P., Amundsen, AH., *Speed and road accidents: an evaluation of the power model*, TOI report 740/2004, Institute of Transport Economics TOI, Oslo, Norway, 2004

Federal Highway Administration, *Traffic Calming on Main Roads Through Rural Communities*, US Department of Transportation, February 2009

Fildes, B., Lee, S., *THE SPEED REVIEW: ROAD ENVIRONMENT, BEHAVIOUR, SPEED LIMITS, ENFORCEMENT AND CRASHES,* Monash University Accident Research Centre, September 1993

Hildebrand, E.D., Ross, A., Robichaud, K., *The Effectiveness of Transitional Speed Zones,* ITE Journal, Vol. 7, No.10, Institute of Transportation Engineers, Washington, D.C, 2004

Makwasha, T., Turner, B., *Evaluating the use of rural-urban gateway treatments in New Zealand*, Transport Policy, Planning and Management, ARRB Group Ltd, 2013

Manual of Uniform Traffic Control Devices, *Part 4 Speed Controls*, Queensland Government, 2003

Manual of Uniform Traffic Control Devices, *Supplement Part 4 Speed Controls*, Queensland Government, 2015

NCHRP Synthesis 412 Transportation Research Board, *Speed Reduction Techniques for Rural High-to-Low Speed Transitions*, National Cooperative Highway Research Program, 2011

NCHRP Report 737 Transportation Research Board, *Design Guidance for High-Speed to Low-Speed Transition Zones for Rural Highways,* National Cooperative Highway Research Program, 2012

Winnett, M.A., Wheeler, A.H., *Vehicle-Activated Signs: A Large Scale Evaluation, TRL Report 549*, Transport Research Laboratory, Crowthorne, U.K, 2002

Appendix A – Project Specification

University of Southern Queensland

ENG4111/ENG4112 Research Project

Project Specification

FOR: Jared West

TOPIC: ***Transitioning roadways from high-speed to low-speed environments when approaching Regional Towns in North Queensland***

SUPERVISORS: Prof. Ron Ayers

PROJECT AIM: This project seeks to analyse the effectiveness of traffic control devices currently in place to transition motorists from high-speed to low-speed environments, and to recommend improvements to current standards and procedures. The specific geographical focus will be on approaches to Rural Townships within North Queensland.

PROGRAMME:

1. Develop a clear understanding of the problems associated with transitioning from high-speed to low-speed environments, and the current design standards, treatments and management strategies that are utilised both in Australia and overseas.

2. Define a study area consisting of a minimum three sites in North Queensland, and obtain relevant crash and other data associated with transition speed zones in the geographical study area (e.g. Burdekin, Bowen, Charters Toweprs, Collinsville, Ingham and Innisfail).

3. Plan and undertake a pilot field survey at three sites to measure compliance to the posted speed limits in speed transition zones, and to observe motorist behaviour. The field surveys will require speed samples of motorists to be recorded with the use of a speed measurement device. Adjust the survey methodology as needed.

4. Review survey data quality and quantity outcomes from pilot surveys with Supervisor and ascertain whether further analysis on pilot sites is required or whether survey at additional sites would be more beneficial to the project.

5. Analyse data in depth to develop an understanding of public compliance to current measures in place and to discern the effectiveness of current standards.

6. Analyse environmental and other factors relevant to the region and determine whether these have an effect on the appropriateness of the strategies in place.

7. Prepare and justify recommendations for changes to existing standards and procedures.

As time permits:

8. Determine if innovative retrofit improvements can be applied at any of the sites investigated in this study.

AGREED ___________________ (student) ___________________ (supervisor)

Date: / / 2015 Date: / / 2015

Examiner: ____________________________

Appendix B – Field Speed Sample Data

Charters Towers - East Approach
RAW DATA (SAMPLES)

Light Vehicles					
62	75	51	65	71	74
60	59	72	58	62	60
65	77	65	69	63	61
69	59	65	56	51	62
65	68	56	72	63	63
70	65	59	57	66	57
63	54	66	58	60	60
64	70	65	62	76	59
60	63	67	67	69	57
63	59	62	66	58	72
78	64	58	67	59	75
52	61	58	72	69	73
66	62	76	55	62	60
75	67	72	63	69	
67	62	55	72	58	
57	57	61	65	63	
62	64	66	55	70	
65	59	75	61	71	
67	59	58	58	68	
63	72	73	64	61	
65	57	71	63	58	
62	61	71	67	71	
69	63	57	64	68	
56	62	61	60	55	
66	60	58	59	67	

HV
57
63
52
69
61
62
54
66
74
62
59
63
60
62
69
59
62
58
60
57
60
59

Charters Towers - East Approach
Adjusted (angle between vehicle and radar)

		degrees	radians	Cos			
	Angle	2	0.035	0.999			
LV	LV	LV	LV	LV	LV		HV
62	75	51	65	71	74		57
60	59	72	58	62	60		63
65	77	65	69	63	61		52
69	59	65	56	51	62		69
65	68	56	72	63	63		61
70	65	59	57	66	57		62
63	54	66	58	60	60		54
64	70	65	62	76	59		66
60	63	67	67	69	57		74
63	59	62	66	58	72		62
78	64	58	67	59	75		59
52	61	58	72	69	73		63
66	62	76	55	62	60		60
75	67	72	63	69			62
67	62	55	72	58			69
57	57	61	65	63			59
62	64	66	55	70			62
65	59	75	61	71			58
67	59	58	58	68			60
63	72	73	64	61			57
65	57	71	63	58			60
62	61	71	67	71			59
69	63	57	64	68			
56	62	61	60	55			
66	60	58	59	67			

Date:	25/06/2015	Start Time:	2:00pm
Site Location:	**Charters Towers East Approach**	End Time:	5:15pm
Speed Limit:	60	Anything out of Ordinary:	no
Flow Direction:	West Bound	Weather:	fine

Speed	**Passenger Vehicle**		**Heavy Vehicles (Trucks, Bus etc)**		**Total**
	Record	**No**	**Record**	**No**	
<50	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
50	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
51	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
52	*Refer converted data field*	**1**	*Refer converted data field*	**1**	**2**
53	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
54	*Refer converted data field*	**1**	*Refer converted data field*	**1**	**2**
55	*Refer converted data field*	**4**	*Refer converted data field*	**0**	**4**
56	*Refer converted data field*	**3**	*Refer converted data field*	**0**	**3**
57	*Refer converted data field*	**7**	*Refer converted data field*	**2**	**9**
58	*Refer converted data field*	**10**	*Refer converted data field*	**1**	**11**
59	*Refer converted data field*	**9**	*Refer converted data field*	**3**	**12**
60	*Refer converted data field*	**8**	*Refer converted data field*	**3**	**11**
61	*Refer converted data field*	**7**	*Refer converted data field*	**1**	**8**
62	*Refer converted data field*	**11**	*Refer converted data field*	**4**	**15**
63	*Refer converted data field*	**11**	*Refer converted data field*	**2**	**13**
64	*Refer converted data field*	**5**	*Refer converted data field*	**0**	**5**
65	*Refer converted data field*	**10**	*Refer converted data field*	**0**	**10**
66	*Refer converted data field*	**6**	*Refer converted data field*	**1**	**7**
67	*Refer converted data field*	**8**	*Refer converted data field*	**0**	**8**
68	*Refer converted data field*	**3**	*Refer converted data field*	**0**	**3**
69	*Refer converted data field*	**6**	*Refer converted data field*	**2**	**8**
70	*Refer converted data field*	**3**	*Refer converted data field*	**0**	**3**
71	*Refer converted data field*	**5**	*Refer converted data field*	**0**	**5**
72	*Refer converted data field*	**7**	*Refer converted data field*	**0**	**7**
73	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
74	*Refer converted data field*	**1**	*Refer converted data field*	**1**	**2**
75	*Refer converted data field*	**4**	*Refer converted data field*	**0**	**4**
76	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
77	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
78	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
79	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
80	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
>80	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
Total					**160**

Ingham - North Approach
RAW DATA (SAMPLES)

Light Vehicles					
61	69	67	59	62	64
60	57	61	66	65	65
80	58	63	57	60	68
59	75	66	55	61	64
60	60	70	65	59	68
56	64	68	70	59	59
58	68	65	75	63	58
60	61	58	78	71	78
61	67	71	60	77	69
59	73	62	63	64	63
56	60	61	56	56	60
56	61	57	67	59	64
77	60	56	72	66	74
56	57	71	58	62	65
61	60	65	60	58	68
68	71	57	72	56	72
65	65	68	73	75	65
71	66	63	65	57	70
58	74	68	70	59	61
66	59	71	74	63	64
60	65	58	56	59	60
64	60	69	75	61	62
68	57	67	60	62	70
67	68	61	71	62	63
65	63	70	64	65	72

HV
69
56
58
60
66
62
64

Ingham - North Approach
Adjusted (angle between vehicle and radar)

	degrees	radians	Cos
Angle	3	0.052	0.999

LV	LV	LV	LV	LV	LV	HV
61	69	67	59	62	64	69
60	57	61	66	65	65	56
80	58	63	57	60	68	58
59	75	66	55	61	64	60
60	60	70	65	59	68	66
56	64	68	70	59	59	62
58	68	65	75	63	58	64
60	61	58	78	71	78	
61	67	71	60	77	69	
59	73	62	63	64	63	
56	60	61	56	56	60	
56	61	57	67	59	64	
77	60	56	72	66	74	
56	57	71	58	62	65	
61	60	65	60	58	68	
68	71	57	72	56	72	
65	65	68	73	75	65	
71	66	63	65	57	70	
58	74	68	70	59	61	
66	59	71	74	63	64	
60	65	58	56	59	60	
64	60	69	75	61	62	
68	57	67	60	62	70	
67	68	61	71	62	63	
65	63	70	64	65	72	

Date:	3/07/2015		Start Time:	12:00pm	
Site Location:	**Ingham North Approach - Bruce Highway**		End Time:	2:50pm	
Speed Limit:	60km/hr		Anything out of Ordinary:	no	
Flow Direction:	South Bound		Weather:	fine	

Speed	**Passenger Vehicle**		**Heavy Vehicles (Trucks, Bus etc)**		**Total**
	Record	**No**	**Record**	**No**	
<50	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
50	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
51	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
52	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
53	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
54	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
55	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
56	*Refer converted data field*	**9**	*Refer converted data field*	**1**	**10**
57	*Refer converted data field*	**7**	*Refer converted data field*	**0**	**7**
58	*Refer converted data field*	**8**	*Refer converted data field*	**1**	**9**
59	*Refer converted data field*	**10**	*Refer converted data field*	**0**	**10**
60	*Refer converted data field*	**15**	*Refer converted data field*	**1**	**16**
61	*Refer converted data field*	**11**	*Refer converted data field*	**0**	**11**
62	*Refer converted data field*	**6**	*Refer converted data field*	**1**	**7**
63	*Refer converted data field*	**8**	*Refer converted data field*	**0**	**8**
64	*Refer converted data field*	**8**	*Refer converted data field*	**1**	**9**
65	*Refer converted data field*	**13**	*Refer converted data field*	**0**	**13**
66	*Refer converted data field*	**5**	*Refer converted data field*	**1**	**6**
67	*Refer converted data field*	**5**	*Refer converted data field*	**0**	**5**
68	*Refer converted data field*	**10**	*Refer converted data field*	**0**	**10**
69	*Refer converted data field*	**3**	*Refer converted data field*	**1**	**4**
70	*Refer converted data field*	**6**	*Refer converted data field*	**0**	**6**
71	*Refer converted data field*	**7**	*Refer converted data field*	**0**	**7**
72	*Refer converted data field*	**4**	*Refer converted data field*	**0**	**4**
73	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
74	*Refer converted data field*	**3**	*Refer converted data field*	**0**	**3**
75	*Refer converted data field*	**4**	*Refer converted data field*	**0**	**4**
76	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
77	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
78	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
79	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
80	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
>80	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
Total					**157**

Ingham - South Approach
RAW DATA (SAMPLES)

Light Vehicles					
61	56	61	59	64	63
61	55	59	56	62	62
58	56	60	60	65	67
60	57	64	58	64	59
65	59	61	61	62	58
62	61	63	62	58	58
63	58	62	60	56	62
56	64	64	72	68	61
58	61	71	59	62	71
60	59	59	63	58	58
61	77	66	58	65	68
57	62	61	66	66	61
67	65	58	64	57	59
73	66	67	63	57	63
59	60	62	62	55	58
60	59	59	65	70	67
57	63	66	65	57	64
62	59	61	62	58	65
57	58	58	60	56	
61	62	67	58	61	
67	56	62	62	62	
55	63	59	57	65	
58	54	68	68	64	
59	63	60	68	59	
69	68	59	66	65	

HV
68
64
62
61
58
62
60
59
62

Ingham - South Approach
Adjusted (angle between vehicle and radar)

		degrees	radians	Cos
	Angle	5	0.087	0.996

LV	LV	LV	LV	LV	LV		HV
61	56	61	59	64	63		
61	55	59	56	62	62		68
58	56	60	60	65	67		64
60	57	64	58	64	59		62
65	59	61	61	62	58		61
62	61	63	62	58	58		58
63	58	62	60	56	62		62
56	64	64	72	68	61		60
58	61	71	59	62	71		59
60	59	59	63	58	58		62
61	77	66	58	65	68		
57	62	61	66	66	61		
67	65	58	64	57	59		
73	66	67	63	57	63		
59	60	62	62	55	58		
60	59	59	65	70	67		
57	63	66	65	57	64		
62	59	61	62	58	65		
57	58	58	60	56	0		
61	62	67	58	61	0		
67	56	62	62	62	0		
55	63	59	57	65	0		
58	54	68	68	64	0		
59	63	60	68	59	0		
69	68	59	66	65	0		

Date:	3/07/2015	Start Time:	3:00pm
Site Location:	**Ingham South Approach - Bruce Highway**	End Time:	5:40pm
Speed Limit:	60km/hr	Anything out of Ordinary:	no
Flow Direction:	North Bound	Weather:	fine

Speed	**Passenger Vehicle**		**Heavy Vehicles (Trucks, Bus etc)**		**Total**
	Record	**No**	**Record**	**No**	
<50	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
50	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
51	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
52	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
53	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
54	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
55	*Refer converted data field*	**3**	*Refer converted data field*	**0**	**3**
56	*Refer converted data field*	**7**	*Refer converted data field*	**0**	**7**
57	*Refer converted data field*	**8**	*Refer converted data field*	**0**	**8**
58	*Refer converted data field*	**17**	*Refer converted data field*	**1**	**18**
59	*Refer converted data field*	**16**	*Refer converted data field*	**1**	**17**
60	*Refer converted data field*	**9**	*Refer converted data field*	**1**	**10**
61	*Refer converted data field*	**14**	*Refer converted data field*	**1**	**15**
62	*Refer converted data field*	**17**	*Refer converted data field*	**3**	**20**
63	*Refer converted data field*	**9**	*Refer converted data field*	**0**	**9**
64	*Refer converted data field*	**8**	*Refer converted data field*	**1**	**9**
65	*Refer converted data field*	**9**	*Refer converted data field*	**0**	**9**
66	*Refer converted data field*	**6**	*Refer converted data field*	**0**	**6**
67	*Refer converted data field*	**6**	*Refer converted data field*	**0**	**6**
68	*Refer converted data field*	**6**	*Refer converted data field*	**1**	**7**
69	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
70	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
71	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
72	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
73	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
74	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
75	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
76	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
77	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
78	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
79	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
80	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
>80	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
Total					**152**

Pentland - West Approach
RAW DATA (SAMPLES)

Light Vehicles			
71	63	80	56
67	62	61	55
54	60	59	63
59	55	59	65
57	60	62	59
65	71	64	61
63	58	65	65
60	69	62	68
70	60	58	61
60	75	60	63
56	62	58	
68	62	57	
62	74	65	
55	68	55	
61	66	53	
61	58	54	
68	67	57	
61	63	72	
60	70	61	
69	67	60	
55	80	56	
74	67	57	
61	60	47	
61	60	61	
62	78	65	

HV
62
63
60
62

Pentland - West Approach
Adjusted (angle between vehicle and radar)

	degrees	radians	Cos
Angle	2	0.035	0.999

LV	LV	LV	LV		HV
71	63	80	56		62
67	62	61	55		63
54	60	59	63		60
59	55	59	65		62
57	60	62	59		
65	71	64	61		
63	58	65	65		
60	69	62	68		
70	60	58	61		
60	75	60	63		
56	62	58			
68	62	57			
62	74	65			
55	68	55			
61	66	53			
61	58	54			
68	67	57			
61	63	72			
60	70	61			
69	67	60			
55	80	56			
74	67	57			
61	60	47			
61	60	61			
62	78	65			

Date:	6/07/2015		Start Time:	11:10am	
Site Location:	**Pentland West Approach - Flinders Highway**		End Time:	3:00pm	
Speed Limit:	60km/hr		Anything out of Ordinary:	no fine	
Flow Direction:	East Bound		Weather:		

Speed	Passenger Vehicle		Heavy Vehicles (Trucks, Bus etc)		Total
	Record	No	Record	No	
<50	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
50	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
51	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
52	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
53	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
54	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
55	*Refer converted data field*	**5**	*Refer converted data field*	**0**	**5**
56	*Refer converted data field*	**3**	*Refer converted data field*	**0**	**3**
57	*Refer converted data field*	**4**	*Refer converted data field*	**0**	**4**
58	*Refer converted data field*	**4**	*Refer converted data field*	**0**	**4**
59	*Refer converted data field*	**4**	*Refer converted data field*	**0**	**4**
60	*Refer converted data field*	**10**	*Refer converted data field*	**1**	**11**
61	*Refer converted data field*	**10**	*Refer converted data field*	**0**	**10**
62	*Refer converted data field*	**7**	*Refer converted data field*	**2**	**9**
63	*Refer converted data field*	**5**	*Refer converted data field*	**1**	**6**
64	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
65	*Refer converted data field*	**6**	*Refer converted data field*	**0**	**6**
66	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
67	*Refer converted data field*	**4**	*Refer converted data field*	**0**	**4**
68	*Refer converted data field*	**4**	*Refer converted data field*	**0**	**4**
69	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
70	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
71	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
72	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
73	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
74	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
75	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
76	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
77	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
78	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
79	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
80	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
>80	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
Total					**89**

Ayr - North Approach
RAW DATA (SAMPLES)

Light Vehicles					
61	57	62	60	68	64
64	61	58	63	66	58
73	65	59	66	68	66
60	63	60	68	67	72
56	57	69	66	63	64
63	63	61	63	81	66
64	65	63	68	58	62
56	74	64	72	63	63
55	70	67	71	59	54
63	64	66	71	65	68
61	61	54	68	67	58
58	63	61	67	64	72
68	62	64	58	62	65
66	63	58	62	58	61
62	59	68	57	54	57
68	61	74	72	73	58
58	60	69	67	72	63
66	57	58	61	61	61
63	65	59	55	59	64
58	69	73	66	55	61
84	64	62	70	60	73
63	67	59	60	80	65
62	67	61	61	66	62
60	64	57	59	61	64
62	67	61	56	59	61

HV
57
62

Ayr - North Approach
Adjusted (angle between vehicle and radar)

	degrees	radians	Cos
Angle	2	0.035	0.999

LV	LV	LV	LV	LV	LV	HV
61	57	62	60	68	64	
64	61	58	63	66	58	57
73	65	59	66	68	66	62
60	63	60	68	67	72	
56	57	69	66	63	64	
63	63	61	63	81	66	
64	65	63	68	58	62	
56	74	64	72	63	63	
55	70	67	71	59	54	
63	64	66	71	65	68	
61	61	54	68	67	58	
58	63	61	67	64	72	
68	62	64	58	62	65	
66	63	58	62	58	61	
62	59	68	57	54	57	
68	61	74	72	73	58	
58	60	69	67	72	63	
66	57	58	61	61	61	
63	65	59	55	59	64	
58	69	73	66	55	61	
84	64	62	70	60	73	
63	67	59	60	80	65	
62	67	61	61	66	62	
60	64	57	59	61	64	
62	67	61	56	59	61	

Date:	27/07/2015	Start Time:	10:30pm
Site Location:	**Ayr North Approach - Bruce Highway**	End Time:	1:30pm
Speed Limit:	60km/hr	Anything out of Ordinary:	no
Flow Direction:	South Bound	Weather:	fine

Speed	**Passenger Vehicle**		**Heavy Vehicles (Trucks, Bus etc)**		**Total**
	Record	**No**	**Record**	**No**	
<50	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
50	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
51	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
52	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
53	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
54	*Refer converted data field*	**3**	*Refer converted data field*	**0**	**3**
55	*Refer converted data field*	**3**	*Refer converted data field*	**0**	**3**
56	*Refer converted data field*	**3**	*Refer converted data field*	**0**	**3**
57	*Refer converted data field*	**6**	*Refer converted data field*	**1**	**7**
58	*Refer converted data field*	**12**	*Refer converted data field*	**0**	**12**
59	*Refer converted data field*	**8**	*Refer converted data field*	**0**	**8**
60	*Refer converted data field*	**7**	*Refer converted data field*	**0**	**7**
61	*Refer converted data field*	**17**	*Refer converted data field*	**0**	**17**
62	*Refer converted data field*	**10**	*Refer converted data field*	**1**	**11**
63	*Refer converted data field*	**15**	*Refer converted data field*	**0**	**15**
64	*Refer converted data field*	**12**	*Refer converted data field*	**0**	**12**
65	*Refer converted data field*	**6**	*Refer converted data field*	**0**	**6**
66	*Refer converted data field*	**10**	*Refer converted data field*	**0**	**10**
67	*Refer converted data field*	**8**	*Refer converted data field*	**0**	**8**
68	*Refer converted data field*	**9**	*Refer converted data field*	**0**	**9**
69	*Refer converted data field*	**3**	*Refer converted data field*	**0**	**3**
70	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
71	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
72	*Refer converted data field*	**5**	*Refer converted data field*	**0**	**5**
73	*Refer converted data field*	**4**	*Refer converted data field*	**0**	**4**
74	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
75	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
76	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
77	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
78	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
79	*Refer converted data field*	**0**	*Refer converted data field*	**0**	**0**
80	*Refer converted data field*	**1**	*Refer converted data field*	**0**	**1**
>80	*Refer converted data field*	**2**	*Refer converted data field*	**0**	**2**
Total					**152**