University of Southern Queensland

Faculty of Engineering & Surveying

Using GIS to explore the relationship between road grade and accidents

A dissertation submitted by

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Abstract

This project aims to determine the relationship between road grades and road accident using GIS. Over the years, there had been numerous researches focus on improving the safety of road intersection, however there is a lack of research on the straight section of the road, especially on the grade of the road. Therefore this project will focus on the safeness of steep road grade on straight roads.

The objective of this project was to determine if there is a relationship between road accidents and road grades using GIS.

This project is conducted under a GIS environment where sources data are spatially referenced in the projection of GDA94. Data such as study area boundary, height of a location and the number of accidents are obtained in this GIS environment. These information are then used to perform correlation coefficient to determine the relationship between road grade and road accidents.

The result from the correlation indicates that a relationship does exist between road grade and road accident. In conclusion this project showed that road with steeper grade do caused greater number of road crashes when compared to flat or levelled road.

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ENG 4111 / 4112 *Research Project*

Limitations of Use

Certification

I certify that the ideas, designs and experimental work\, results, and 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.

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Student Number: Q97229162

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Signature

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Date

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Firstly, I would like to take this opportunity to sincerely thank Dr Armando Apan for his continuous advice and suggestion on the challenging analysis that lies behind this project.

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GLOSSARY

AADT stands for Annual Average Daily Traffic

ARMIS stands for A Road Management Information System

BTCE stands for Bureau of Transport Communications Economics

Data Set refer, in this context to the complete set of values input into the GIS Software MapInfo

DMR stands for Department of Main Roads

DNR stands for Department of Natural Resources

DOP stands for Department of Police

FSCR stands for Future State Control Road

NAASRA stands for Association of Australian State Road Authorities

Chapter 1

Introduction

Australia's urban areas are continuously expanding as population increases. This increasing population has an impact on transportation needs and creates traffic congestions especially in major cities.

The construction and upgrade of roads, is to provide a safe, convenient and effective way of transporting people and goods. To ensure this safety, road designs are based on the requirements and usage of all road users, this includes pedestrians, cyclist and physical characteristics of vehicles, such as heavy trucks.

Most road crashes occurred when a number of adverse factors combined to cause a failure of the overall transport system. A number of studies has been attempted to identify the main contributing factors (NAASRA Part4 – Road Crashes, 1988, page 11). It is somewhat unfortunate that these studies show the dominant factor in road crash causation is the driver and this factor is accepted to be the most difficult to improve.

In considering the results of the US study, Swan (1982) it suggested that the most common factor is the combination of human and road environment, this is because of the difficulties of processing driver information combined with road environment problems.

1.1 Statement of the Problem

The populations of Brisbane had increased dramatically during the recent years, people are slowly moving and living outside the city centre. This could due to the low availability of vacant block of land and prices increase in house and land in the surrounding city suburbs. There is currently a need for new roads and upgrades to help in providing a transit network for people who is living outside the city centre to commute to the city and back to their surrounding suburbs

The natural terrain plays a part in road grade design of the road vertical alignment. The steepness of the road has always been referred as being unsafe and open to accidents. This project will try to address this problem by looking at whether or not there is a relationship between the road grade and road accidents.

1.2 Significance of The Study

It was identified that the causation of the road / environment aspect of road crash contributory factors are Sabey (1980):

- Adverse road design
- Adverse environment
- Inadequate furniture and markings
- Obstacles

In the construction of roads, the final design location of the vertical alignments is to principally fit to the natural terrain, but considerations also need to be given to the maximum allowable grades, the minimum radius, economical balancing of the earth work, appearance, property acquisition, environmental impacts and the co-ordination with the horizontal alignment (Road Planning and Design Manual, DMR, Chapter 12, 12 –1).

The natural terrain can be considered as an adverse environment due to its irregular steepness. As indicated within the Road Planning and Design Manual, the natural terrain can influence hugely toward the design of a road, hence this can cause a problem with adverse road design. The natural terrain causes two of the four contributing factors in road accidents.

This project will look at identifying the relationship between road accident and road grade using GIS. This project will also analyse a chosen case study, this will give a better understanding of the project and also give an insight to current road grade standards.

1.3 Objective

The objective of this project was to determine if there is a relationship between road accidents and road grades. This study evaluated and analyzed the data in a GIS environment, as both road accident information and spatial locations are contained within a GIS database. The study also provided recommendations for improvements and evaluated the safety of road usage on road grades.

1.4 Scope

The aim of this study was to develop a comprehensive understanding of our current road grade standards and design methodologies for an ideal road. The report examined a case study, in providing a better understanding and insight on the current standards of road grade, and indicated changes that can be applied to improve the safety aspect of road design. The report's main focus was in determining whether locations with high changes in road grade do tend to cause an increase in road accidents.

1.5 Dissertation Overview

Chapter 1 is made up of the introduction, statement of the problems, significant of the study, objective and the aim of this project. The chapter will discuss about how road grade are recognize to cause accident and how this project will justify if there is a relationship between the two. The chapter will also state the objective and aim of this project

Chapter 2 This chapter contains the literature review. It provide reader with background information and statistics data on Australia, these information include Australia's population, road crashes comparison, crashes related cost and road users distribution. The literature review research on what is the current road grade design standard, and black spot identification method.

Chapter 3 The chapter started off with determining the type of road and geographic feature required in the study area. It then goes on to the project study area 'Kessels Road' and how it fit the project selection criteria. The chapter then step by step run down the process of data acquisition, data processing and analysis.

Chapter 4 This chapter provided the result from the project analysis, it includes the correlation result and scatter plot.

Chapter 5 This chapter looks at the result from the analysis and stated the finding from the project. The chapter then discussed the different type of problem faced during the interpretation of the result, and whether or not the result was as expected.

Chapter 6 This chapter conclude the project and give recommendation on what possible future research could be expanded in this topic.

Chapter 2

Literature review

2.1 Chapter overview

This chapter aims to provide a comprehensive in-depth review of key works related to road grades and accident. The chapter began with a literature review on statistic data related to Australia and Australia's City. The next section looked at the current Australia road grade safety standard and the way accident data are collected and stored.

The chapter then reviewed on the topic traffic volume and how it is collected and used in road design. The chapter followed with an in depth reviewed on the current road grade design standard. The reviewed include design specification on maximum and minium grade used in road design.

The next topics in the literature review are on the identification of road black spot. This section will introduce three method of identification of black spot using traffic volume, road severity and accident cost.

The last topic in the literature review is on the potential of GIS and the software that are going to be used in the project analysis.

2.2 Population of Australia

Australia current population is 20,090,437 and is the 52nd most populated country in the world as at 2005. (http://www.census.gov/cgi-bin/ipc/idbrank.pl) The population density of Australia was 2.6 per square kilometre as at the 30 June 2003, compare with 2.4 people per square kilometre in 1998 (AusStats, 2003). At June 2003, about 64% of the Australia's population live in major cities

2.2.1 Population of Australia's major cities

Queensland had the fastest population growth out of all states and territories in Australia during 2002 – 2003 with an increased of 2.3% (AusStats, 2003). In 1998, Brisbane had a population of 1.56 million people in 1998 and increase to 1.73 million people in 2003.

The rapid increase of population in Brisbane had caused road use and traffic pattern to change. The increase in traffic density had been known as the main reason of road crash (see table 1).

Table 1 – Population comparison of Australia Capital Cities

City	30/06/1998	30/06/2003	changes 1998 - 2003 (no)	1998 - 2003 (%)
Sydney	3,969,649	4,201,493	46,369	1.14
Melbourne	3,342,230	3,559,654	43,485	1.27
Brisbane	1,567,996	1,733,227	33,046	2.02
Adelaide	1,090,526	1,119,920	5,879	0.53
Perth	1,334,992	1,433,217	19,645	1.43
Greater Hobart	195,913	199,886	795	0.4
Darwin	101,165	107,922	1,351	1.3
Canberra	309,539	322,492	2,591	0.82

Source: 2001 Census and 2003 Australia Standard Geographical Classification boundaries.

2.3 Road Crash

In the past, vehicle collisions and other traffic incidents on the road system, which result in death, injury or property damages have been referred to as traffic accidents.

Over time, authority and recent trends in publications referring to these matters acknowledge the fact that many of these incidents are not accidental occurrences. Therefore the term road crash had been adopted (NAASRA, Part 4, 1998).

A study conducted almost a quarter of a century ago (Fouracre and Jacobs, 1977) estimated road crashes to cost on average 1 per cent of a country's gross national product (GNP). In Australia, road crashes lead to around 1800 people killed and 22, 000 people seriously injured. It was estimated that they cost Australians a staggering $15 billion each year (http://www.atsb.gov.au/road/road.aspx).

2.3.1 World's Road Fatality Comparison

In 1997 the world's best safety performer was Sweden with 6.1 deaths per 100 000 persons and 1.2 deaths per 10 000 vehicle. The UK and Norway were close behind. The Australian state of Victoria was also among the best road safety performers (see figure 1).

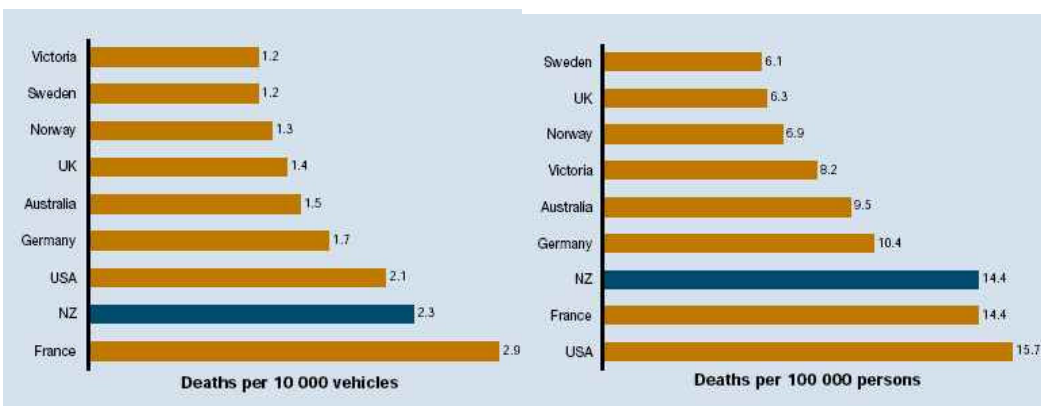


Figure 1 – top nine safety performing country *(Adapted from data submitted to the OECD's International Road and Traffic Accident Database.*

2.3.2 Distribution of Road Crashes by Road User Groups

For road crash analysis, road user / persons can be grouped as followed:

- Drivers
- Passengers
- Pedestrians
- Motor cyclists
- Pedal cyclists
- Others (include occupants of non motorised vehicles tram etc)

Over the last 20 years, with the exception of significant increase in the involvement of motorcycle riders, there has been little variation in the relative involvement of various road users in road crash fatalities (NAASRA, Part 4, 1998). The general proportions of the various road users may be stated as:

- Driver 40%
- Passengers 26%
- Pedestrians 18%
- Motor cyclist 13%
- Bicyclist 3%
- Other represent less than 5%

The driver and passenger's users account for at least half of the total fatality. (Drummond and Healy, 1986) investigated the involvement of drivers in road crashes in Victoria 1981 – 1983 and confirmed the high risk associated with younger driver age group but showed that when the relative exposure of both young male and female drivers is consider there little difference between these group in their involvement in road crashes.

2.3.3 Human Factors

In almost all road crashes, there are human factors derived from the physical and mental condition, experience and ages of the driver, which may contribute to a particular crash. It is widely accepted that human factors are a main contribution to accident (Sabey, 1991; Sabey & Taylor, 1980) and studies show the dominant factor in road crash causation is the driver and this factor is accepted to be the most difficult to improve (NAASRA, part4, 1998, page 11)

2.4 Road accident data

There are several sources of original road crash data each having particular objectives which influence the extent and nature of the information collection. The most common source are (NAASRA, part 4, 1998, page 13):

- Police Department accident reports
- Coronial inquest report
- Road authority reports on fatal and other road crashes
- Insurance company record
- Tow-truck operators
- Special Research Studies such as in depth road crash studies

In general a little use is made of data from sources such as coronial inquests, insurance company record and tow truck operators. Of these, the records of motor car insurance companies and tow truck operators are a largely untapped source of data – particularly with respect to the "non-reported" property damage type road crashes.

The Department of Main Roads supplies the road crash dataset that are used in the project analysis. This road crash dataset is originally collect by the Queensland police. The road crash dataset are updated daily, but only supplied to the Department once every three months, hence the data used in the project analysis are three month old.

2.4.1 Collection of Road Accident Data

The evaluation of a black spot relied heavily on the accuracy and quality of the data. It is important that crash data are recorded in a way that it benefited toward the analysis and evaluation of a road black spot.

Currently, all States and Territories maintain crash databases based on information contained in police crash reports. These reports are compiled after police attendance at crash sites or as a result of individuals involves in crashes reporting them at police stations.

The accident database that are gathered are of good qualities, however quantity wise it only represent perhaps half of the number accident that occurs. This is because the traffic police may not be able to collect all the necessary data required to carry out the analysis using the accident data (Kalga and Silanda 2002). This can be because

1. By law, Qld police do not have to attend or take down accident report if there is less than $2500 worth of part damage done to the property. (different depending on state)
2. Driver consider accident damage as minor, or not worth claiming insurance therefore didn't want to report it to the police
3. There are no other party involve, so police was not called

The current road accident collection process are selective, it reduces minor accident and greatly obscure the true representation of accident occurring in Australia.

The quantity of the road accident database can greatly affect the analysis of road black spot. This is because therefore could be a location, where it causes a lot of minor damage. But because the road accident database does not have these accident data, it became impossible to identify these black spot that causes minor damages.

2.4.2 Storage of Road Accident Data

When analysis for road black spot, sometime there is a need to analysis by looking at accident history on that particular black spot. Most jurisdictions keep crash site records for at least 20 years. Some jurisdictions have records going back much further, for example South Australia's road crash database goes back to 1968. The road crashed dataset that are being used in this project analysis contained road accident from 1992 to 2004.

2.5 Traffic Volume

Traffic volume is one of the most basic considerations in the design of roads. The traffic volumes influence the need and justification for works, the selection of roads and intersection types, and the selection and application of design standards.

The traffic volume can also be regarding as the traffic flow. It is defined as the number of vehicles, cyclists or pedestrians passing a given pint during a specified period of time. Traffic volume can varies from hour to hour and day to day and even season to season. The variations on traffic volume can be caused by factors such as function of the road, the nature of the traffic on it, whether rural or an urban area and so on.

Traffic recorder of various kinds is used for colleting traffic counts. The traffic data for a District can be collected at road section, carriageway or lane level. Traffic counting can be done automatically or manually.

2.5.1 Automatic Counts

The traffic can be counted automatically by mounting the automatic traffic recorder devices on to a fixture. This type of recorder is suitable for location where there is high volume of traffic or in area where it is hazardous to perform manual counting. Automatic counts are data that is collected automatically by traffic recorders. There are various different types of automatic counts (ARMIS Help file, Department of Mains Road) (see table 2).

Table 2 – Automatic traffic volume counter

Vehicle counters	Record traffic volume per interval.
Classifiers	Record traffic volume by vehicle class per interval. Includes data such as mean speed, 85% speed, and speed distribution.
WIM (Weigh In Motion)	Record: • Traffic volume by vehicle class per interval • Mass Includes data such as mean speed, 85% speed, speed distribution, gross vehicle mass, axle group mass, ESAs by vehicle class, ESAs by axle group type.
Streams	Manage freeways and signalised intersections Provide incident management Provide traveller information services Record traffic volume per interval

Source: ARMIS, DMR in house Software help file, 2005

2.5.2 Manual Counts

Manual counts are collected by people who manually record the information by observing traffic. Manual information is usually collected at intersections. There are two types of manual counts (ARMIS, Department of Mains Road) (See table3):

Table 3 – Manual traffic volume counter

Axle counts	Record the number of axles per day.
Intersection counts	Record: • Traffic volume by turning movement (left hand turn, right hand turn, straight, U-turn) • Traffic volume by vehicle classification • Pedestrian volume

Source: ARMIS, DMR in house Software help file, 2005

2.5.3 Annual Average Daily Traffic

The annual average daily traffic volume (AADT) is calculated by counting the number of vehicles passing a roadside or observation point in a year and dividing this number by 365. It is thus an average 24-hour daily traffic volume. The AADT volume is often suitable as a basis for planning and investigation to do with economic studies.

The ratio of No of accident / AADT can also be a good indication of whether an intersection is a possible high risk black spot or not. This Accident vs traffic volume ratio can be calculated by

Accident ratio = No of accident in an given point / AADT

For example a section of road had two intersections. Intersection one had 23 accident with an AADT of 37000, while intersection two had 12 accidents with an AADT of 14000. By calculating the Accidents ratio we found that intersection had an ratio of 1 : 1608 while intersection two had an ratio of 1 : 1166. This clearly show that even thou intersection one had more accident than intersection two, it proof that intersection two is highest risk.

2.5.4 Major Urban Roads

Urban areas can be defined as developed site within boundaries set by responsible state and local Authorities. Urban areas have fundamentally different characteristics from rural area with regard to land use, density of road network, nature of travel patterns and the way in which these elements are related. The Department of Main Roads consider the whole South East Queensland road to be urban road when calculating accident costing (See figure 2).

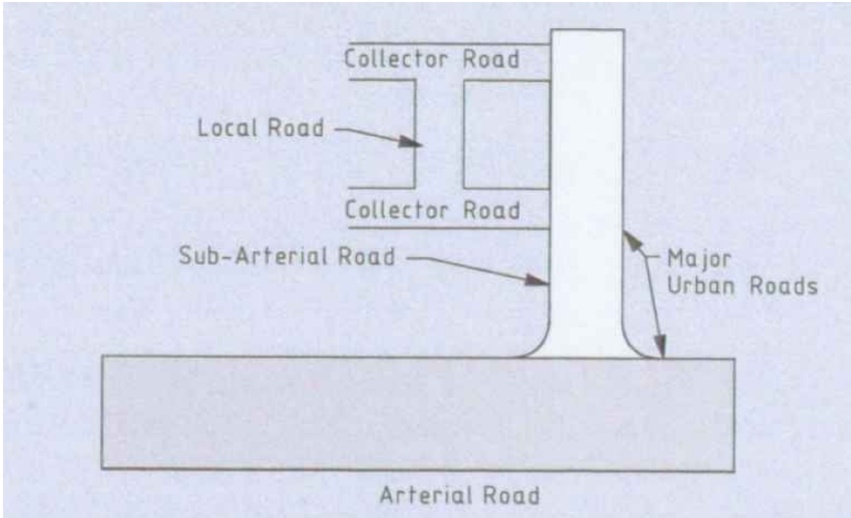


Figure 2 A schematic road network (adapted from AUSTROAD)

Major Urban roads are roads through urban areas serving the major centres of urban activity. They generally have intersections at grade, provide access to abutting properties and carry traffic of which the greater part has neither origin nor destination at the abutting property. The term Major urban road excludes streets, collector/distributor roads, freeways, motorways and expressway. (Urban Road Design AUSTROADS)

There are two categories of major urban roads:

- Urban arterial road is a road that carries high volumes of through traffic and links the larger urban activity centres (may be divided or undivided)
- Urban sub – arterial road is a road that connect arterial road to areas of urban development (may be divided or undivided).

2.6 Vertical Alignment

Vertical alignment (referred to as, and geometrically represent by the grade line or longitudinal section) consists of straight grades joined by vertical curves. The final design location of the vertical alignment is principally the fit to the natural terrain but consideration also need to be given to the maximum allowable grades, the minium radius vertical curve the economical balance of the earthworks, the appearance, property acquisition, environmental impact and the co-ordination with the horizontal alignment.

2.6.1 Road Grades

Generally, grade should be as flat as possible consistent with economy. Flat grades allow vehicle to operate and travel at the same speed. Steeper road grade can produce a variation in speeds between lighter vehicles and the heavier vehicles both in uphill and downhill directions. This speed variation leads to higher relative speeds of vehicle producing the potential for higher rear-end and head on vehicle accident rates (Road Planning and design manual, chapter 12 vertical alignment, 12-1). This speed variation also results in increased queuing and overtaking requirements, which give rise to further safety problems particularly at higher traffic volumes. In addition, freight costs are increased due to the slow speed of heavy vehicles (See table 4).

Table 4: Effect of grade on vehicle performance, and its suitability

Grade	Reduction in Vehicle Speed as compared to Flat Grade				Road Type Suitability
	Uphill		Downhill		
	Light Vehicle	Heavy Vehicle	Light Vehicle	Heavy Vehicle	
0-3	Minimal	Minimal	Minimal	Minimal	For use on all roads.
3-6	Minimal	Some reduction on high speed roads	Minimal	Minimal	For use on low-moderate speed roads (incl. high traffic volume roads)
6-9	Largely unaffected	Significantly slower	Minimal	Minimal for straight alignment. Substantial for winding alignment	For use on roads in mountainous terrain. Usually need to provide auxiliary lanes if high traffic volumes
9-12	Slower	Much slower	Slower	Significantly slower for straight alignment. Much slower for winding alignment	Need to provide auxiliary lanes for moderate - high traffic volumes. Need to consider run-away vehicle facilities if the number of commercial vehicles is high
12-15	10 -15 km/h slower	15% max. negotiable	10 -15 km/h slower	Extremely slow	Satisfactory on low volume roads (very few or no commercial vehicles)
15-33	Very slow	Not negotiable	Very slow	Not negotiable	Only to be used in extreme cases and be of short lengths (no commercial vehicles)

Note: Grades over 15% should be used only in extreme cases (eg. access to an isolated vantage point) and should be for short lengths where no heavy vehicles are required to use them.

Source: NAASRA, Sydney 1988

2.6.2 Maximum Grade

Criteria for maximum grades are based mainly on studies of the operating characteristics of typical heavy trucks (See table 5). Although design values have been determined and agreed upon for many highway features, few conclusions have been reached on roadway grades in relation to design speed limit. (http://www.sddot.com/pe/roaddesign/docs/rdmanual/rdmch06.pdf)

Table 5: General maximum grades over long lengths of road for a range of typical situation.

Target Speed (km/h)	Terrain					
	Flat	Rolling	Mountainous			
			<2000 AADT	2000-5000 AADT (See Note 1)	5000-10000 AADT (See Note 2)	>10000 AADT (See Note 3)
50	6-8	8-10	12	10	-	-
60	6-8	7-9	10	9	9	-
80	4-6	5-7	9	8	7	7
100	4	4-6	-	-	6	6
120	3	3-5	-	-	-	5

NOTES:

1. Overtaking lanes may be required depending on overtaking opportunities and percentage commercial vehicles.
2. Overtaking lanes would be recommended where overtaking opportunities are occasional and the component of commercial vehicles is greater than or equal to 5%.
3. Four lanes divided or undivided should be investigated.
4. The maximum design grade should be used infrequently, rather than as a value to be adopted in most cases.

Source: NAASRA, Sydney 1988

The following situations may justify the adoption of grades steeper than the general maximum (Road Planning and design manual, chapter 12 vertical alignment, 12-1):

- Comparatively short sections of steeper grade which can lead to significant cost saving
- Difficult terrain in which grades below the general maximum grades are not practical
- Absolute number of heavy vehicles are generally low
- Less important local road where the costs of achieving high standards are less able to be justify.

The first three conditions applied even on major roads.

2.6.3 General Maximum Length of Steep Grade

It is undesirable to have a very long length of steep grade. On both the upgrade and downgrade. The lower operating speed of trucks may cause inconvenience to other traffic. When it is impracticable to reduce the length of grad to the desirable length, consideration should be given to providing an auxiliary lane both in the uphill and downhill directions.

Current vehicle standards require multi-combination vehicles to be able to maintain a speed of 70 km/h on a 1% grade. The length of grade plays an important in the performance of those vehicles (Road Planning and design manual, chapter 12 vertical alignment, 12-1) (See table 6).

Table 6: Desirable maximum lengths of grades not requiring special consideration.

Grade (%)	Length (m)
2-3	1800
3-4	900
4-5	600
5-6	450
>6	300

Source: NAASRA, Sydney 1988

It is a worthwhile to design feature to avoid horizontal curves, or at least sharp curves at the bottom of steep grades, where speeds may develop to the point of difficult vehicle control. This is likely only in the case of 85^{th} percentile speeds greater than 60km /h (Road design Planning and Design Manual, Chapter 12, page 12 – 3).

Computer simulation (VEHSIM) may be used to access truck performance on grades. It should be noted that trucks could reach excessive speeds on long downhill grades as low as 3% when out of control (NRTC, 1997). Providing escape facilities may be required for these cases, an example is the downhill on Toowoomba, QLD range, where emergency ramp are in place on the bent of curve)

2.6.4 Steep Grade Considerations

Although speeds of cars may be reduced slightly on steep upgrades, large differences between speeds of light and heavy vehicles can occur and speed of the latter can be quite slow. It is important, therefore to provide adequate horizontal sight distance to enable faster vehicle operator to recognise when they are catching up to a slow vehicle and to adjust their speed accordingly.

On any generally rising or generally falling section of road, adverse grade (grade opposite to the general rise or fall of the section) should be avoided as much as practicable, as they are wasteful of energy. Where possible it is preferable to introduce a flatter grade at the top of a long ascent, particularly on low speed roads, but this must not be forced by such an expedient as steepening the lower portion of the grade (Road Planning and design manual, chapter 12 vertical alignment, 12-3).

On steep downgrades, it is desirable to increase the design speed of the individual geometric elements progressively toward the foot of the steep grade. Where this cannot be achieved and where percentages of heavy vehicles are high, consideration should be given to construction of runaway vehicle facilities. These usually take the form of an upward sloping escape ramp or an arrestor bed of sand or gravel.

2.6.5 Minimum Grade

Very flat grades may make it difficult to provide longitudinal drainage in table drains, kerb and channel and medians, where these parallel the road grade. As far as possible, these drainage requirements should not dictate the road grade rather the drainage facility should be design to accommodate road grade (Road Planning and design manual, chapter 12 vertical alignment, 12-3). This may require greater recourse to sub surface drains with closely spaced inlets, or independently graded table drains, or other solution to suit the circumstances. Care should be taken in cases where flat grade is combined with horizontal curvature. The rotation of the pavement may create a situation where the flow path crosses from one side of a lane to the other, resulting in undesirable depths of water on the pavement surface. Worst condition can occur on steep grades combined with successive curves in opposite direction. The combination of grade and pavement rotation can create a situation where the flow path meanders from one side of the road to the other with the depth of flow becoming excessive (Road Planning and design manual, chapter 12 vertical alignment, 12-3).

2.7 Definition of Road Black Spot

The Greater London Council's definition of an Accident Black Spot Location is based on the following criteria:

- Sufficient accidents to identify a pattern, a rising trend, sufficient accident of the same type
- The remedial measure will give a good rate of return
- The measure can be implemented quickly

A location may be:

- A single site
- A road link
- A local traffic area

2.7.1 Black Spot Identification

The identification of accident black spot location for road safety treatments has been one of the most controversial topics in road safety literature (Nguyln, T, N, 1991: P1) road. Researched indicate that there had been many methods and approaches in black spot identification. However, only a few of these methods had been taken on by road safety organization, this could be because of the high cost and time or effectiveness of the methods. The black spot identifying method can be grouped into four categories (Nguyln, T, N, 1991: P1):

- Identification based on mathematical models
- Identification based on accident proxy / surrogate measures
- Identification based on accident experience
- Identification based on hazardous roadway feature inventory

The black spot identification method was reviewed because it can help identify element that had a strong link with road accident. These elements can be identified and used to manipulate the accident data so that it can better reflect the number of accident in the study area.

2.7.2 Method Based on Accident Experience

This is probably the most common, simplest and most adopted method by most road organization. This method relied principally on existing road accident data.

Using the road accident data as the most dataset, the following are some of the method commonly used in identifying accident black spot location.

- Accident frequency Method
- Accident Rate method
- Accident severity method

2.7.3 Accident Rate Method

The difference between the accident frequency method and the accident rate method is that, the accident rate method also takes the traffic volume into account. The accident rate method compares the number of accidents at a location with the number of vehicle (traffic volumes) throughout the road or street system. This comparison result is known as an accident rate. The accident is stated in terms of "accidents per million vehicles" for intersections, while the term "accidents per million vehicle mile of travel" is used for segment or section of roads. There are two major problems with the accident rate methods. As pointed out by the Greater London Council, who had given up on using the accident rate method, these are as follows.

1. The collecting of traffic volume on a regular basis for 4500 intersection and 6500 road section is very time consuming and very costly
2. The results apparently show that similar roads with very different accident rate, so that norms could not be established. (Kelly et al, 1976)

2.7.4 Accident Severity Method

The fundamental principle behind the accident severity method is that each accident can and should be assigned a weight according to its severity or the cost of damage (Nguyln, T, N, 1991: P3). The method aims at differentiate accident by various index or severity. This index or severity have been proposed and are used to identify and rank accident black spot location for treatment; so far there still have not been a general agreement (Nguyln, T, N, 1991: P3).

Discussed below are the three most common indices to weight an accident:

- Weighted by most serious injury
- Weighted by accidents cost

2.7.4.1 Weighted by Most Serious Injury

This weighted method uses the severity as a measure to how bad or hazardous a road location is. The accident severity measure can be used to weights the number of accident and this is done by assigning a score to different levels of severity (Nguyln, T, N, 1991: P3). The score of all the accidents that happen at the road accident during a certain time period are added up: the higher the scores are, the more hazardous the location is.

2.7.4.2 Weighting by Accident Cost

This weighted method estimates the cost of the accident at the road location using either an average accident cost, or accident cost by accident type. As of 2005, the Department of Mains Road had adopted the Department of Transport and Regional Services black spot programs and using the following severity crash cost: (DMR, Christine Pringle, Traffic Administration Officer) (See table 7):

Table 7: DMR severity cost

Urban Fatal	A$	920, 072
Urban Casualty	A$	66, 384
Urban Property	A$	17, 302
Rural Fatal	A$	1, 008, 978
Rural Casualty	A$	92, 617
Rural Property	A$	15, 850

Source: ARMIS Manual, DMR , 2005

The cost of all the accidents that happen at the road accident during a certain time period are added up, the higher the costs are the more hazardous the location is.

2.8 GIS Potentiality

GIS stands for Geographic information system. It supports the display and analysis of spatial data. A powerful aspect of GIS is it had flexibility when modelling spatial objects to suit particular application requirement. GIS can provide the ability to model the physical proximity of spatial features and allow road accident data to be placed in a spatial environment. This allows the identification of pattern and clustering form by road accident through GIS. The GIS environment also allow for the measuring of distance between points, hence this is a greatly useful for our analysis. Through technology and development, GIS are capable of performing faster, large volume and more complicated spatial analysis. This is beneficial as it allow the analysis of road black spot in larger area and much quicker.

2.8.1 MapInfo – GIS Software

MapInfo are widely used and currently many of the state and local government authorities uses MapInfo to manager their GIS data. MapInfo is easy to use and provide powerful programming tools for accomplished users.

The cost of a MapInfo Professional is about $1495. MapInfo can be run under Microsoft window 9X / NT / 2000 / ME / XP. It required a minium of a Pentium, 64MB ram, and about 200 MB for installation.

MapInfo product continues to evolve, it embracing more analytical functionality, wider compatibility with industry data standards, and most notably, it had great enhances its mapping and presentation capabilities over the year. MapInfo professional can also allow thematic data and digital ortho-photo to be combined and simultaneous display.

The reason why MapInfo was chosen over other software

- Most state and local government uses MapInfo
- Majority of the dataset collected are already in MapInfo (tab) software format.
- The measuring tools and SQL query dialogue functionality is easy to use
- MapInfo has enhanced raster and display features
- The software does not have high computer specification requirement

However, there are some weaknesses in MapInfo are the lacks of cartographic control and 3 – D images become degraded under manipulation.

2.9 Summary

The literature review indicates that Brisbane is a fast growing city and there is a need for new road and existing road to be upgraded. From the literature review, it indicates that the natural terrain and traffic volume plays a very important part in the design of vertical alignment road grade.

It is understand that the aim of the project was to identify the relationship between road grade and road accident and not a road accident black spot. But by reviewing the current black spot identification method, it helps to identify three elements that are strongly related to road accident. These three elements are traffic volume, accident severity and accident cost. Therefore in the project analysis, these three element was be used to manipulated the accident data so that the accident data relate and take consideration of these three element. The manipulation of the road accident data, aim to better reflect the number of accident data in the study area.

The literature review shows that there is very little amount of study being done on the relationship of road grade and road accident. Therefore, by using GIS and its advantage of GIS technology in determining road features and accident relationship, the result from this project is fulfilling and significant to road authorities.

CHAPTER 3

Research Methods

3.1 Chapter Overview

This chapter started off by defining the study area and what features the study area must have, such features are the study area's geographical location, high changes of grades, high traffic volume, length and sufficient crash records.

The chapter then follow with what data are required for the project analysis and how these data are captured and acquired. The chapter then go on to discussed about what sort of data pre-processing are required and how these data are analysed. Finally, the chapter finished off with talking about the validation and accuracy assessment.

3.2 Defining the Study Area

The objective of this project was to identify the relationship between road grade and road accidents in a GIS environment. Therefore there are three important things that the chosen project area must include. Firstly the chosen project area must geographically have hilly terrain. Secondly it needs to have sufficient population of historical accident records, so that analysis of the study area can be performed. Finally it should be located in an urban area, so that there is a high traffic volume. A high traffic volume is particularly important because it can be use to represent other urban roads within the city.

3.2.1 Case study – Kessels Road

I have chosen 10.8 Kilometers of roads, make up of Grandard road, Kessels road and Mt Gravatt – Capalaba road in Brisbane, QLD. The road starts at the intersection of Ipswich motorway and Grandard road and end at the intersection of Mt Gravatt – Capalaba road and Broadwater road. From this project onward the 10.8km of roads are referred to as Kessels rd, this is because Kessels road was the longest road out of the three.

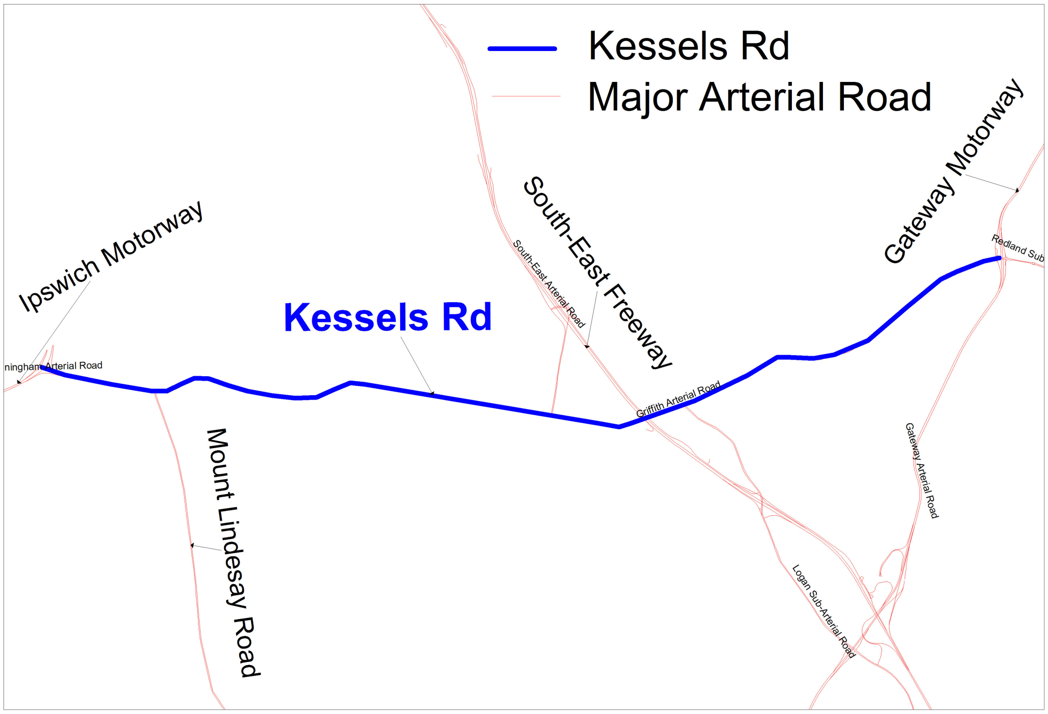


Figure 4: Map of Study Area, Kessels Rd

Kessels road is one of the most important sub arterial roads that service the Brisbane Southern suburbs and had a Annual Average Daily Traffic (AADT) of approximately 19,000 per day for both North and South Bound. The roads are currently 4 – 6 lanes in width. Majority of Kessels road had a speed limited of 60 km/hour with a small section of roads that had a speed limit of 70km/hr. It has divided carriageway with kerbed traffic islands as the divider for most of its length. Kessels rd is regarded as a sub – arterial road. Half of Kessels rd is level and flat, and the other half had steep road grade. In particular two sections of Kessels road had extremely steep grades. Kessels road is an ideal for our analysis as it satisfies the entire requirement that is required in our study area selection section.

3.3 Data Capture and Acquisition

After the project study area is chosen, the next process that follows is to determine the type of dataset that are require to perform the necessary analysis. The data selection is the initial stage, therefore it is the most important stages. This is because it determine what sort of data are used in the analysis are selected in this stage. During the data selection process, there were a lot of little things required consideration, they are:

- What format the data should be in
- What GIS software will be used
- How are the height of an area going to be obtained (through survey or photogrammetry)
- What contour interval data should be use

From research, it was decided that MapInfo would be the GIS software for this project. Another decision made was that since the road in our study area is a state controlled road, data related to accident, AADT, Traffic light location and road alignment would best be obtain from the state government and preferability in MapInfo format.

From the literature these are the dataset that are considered to be essential for this project, they are:

Dataset

- Road crash accident data (DMR)
- Contours (DNRM)

- Annual average Daily Traffic (DMR)
- State Controlled Road (DMR)
- Traffic light location (DMR)
- Digital Video Recorder (DMR)

Imagery

- Ortho – rectify aerial photograph (Webmap Pty Ltd)
- Registered UBD digital Map (UBD)

Software

- Mircrosoft Excel
- MapInfo Professional 7.5
- A road information management system (ARMIS)
- ChartView

3.3.1 Defining Into Smaller Study Area

The project area consists of a stretch of road 10.8 km in length and focuses on the straight sections of road only, hence this does not include road intersections. For example, the images below show part of Kessels road. The length of road that are to be studied are between the two traffic lights, and it is referred to or considered as being one section of road (see Figure 4).

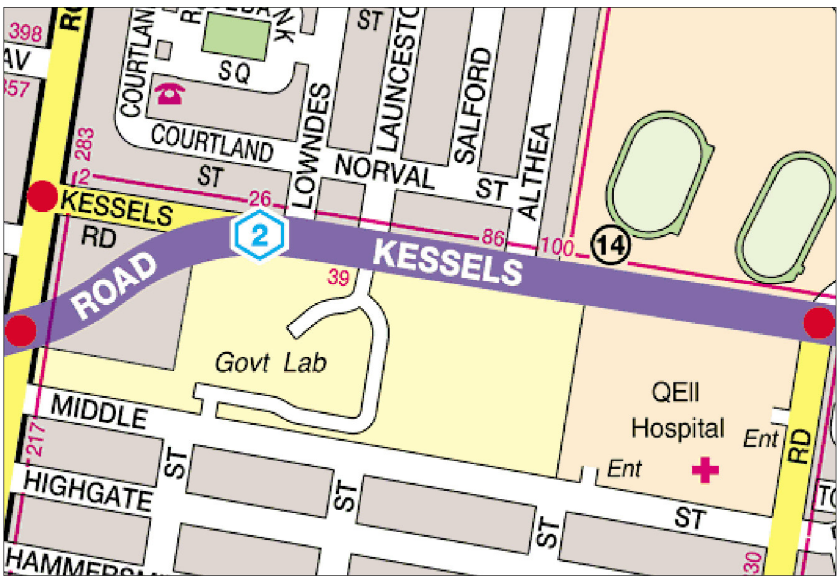


Figure 4: A section of Kessels Road

A buffer boundary was placed across the width of Kessels Rd (see Figure 5). Data such as road accidents location and traffic volume that fall within this white boundary are consider outside of the study area and are not been collected (see Figure 5).

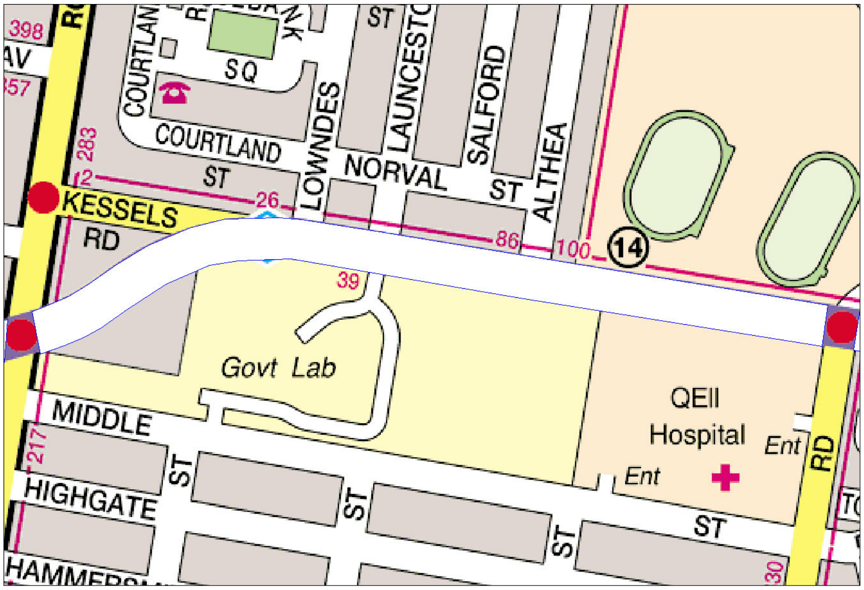


Figure 5: The white boundary, indicated area of interest

In cases where a road consists of a change in road grade direction, meaning uphill to downhill or vice versa. That section of road will be marked and broken into two individual smaller sections of study areas (See Figure 6). This was done so that we can look at the relationship of road grade and road accident in raise, fall and level situation.

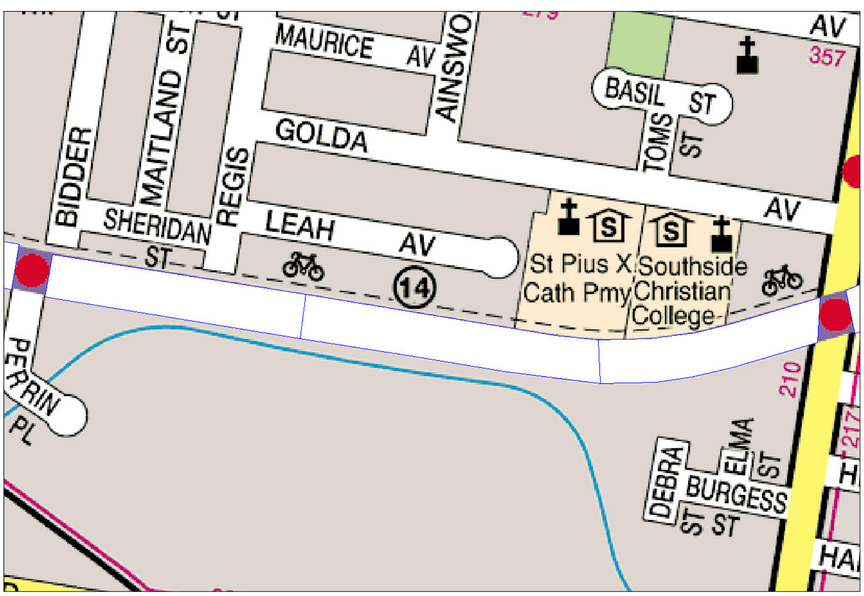


Figure 6: Single stretch of road broken into three parts due to changes in grades direction

3.3.2 Acquisition of Accident Record

After the study area boundary was defined and broken into the three categories, rise, fall and flat. The next thing to do was to collect the number of accident that occurs within these individual road sections. As mention before, the objective of this analysis focus on the straight of the road, therefore no accident data at a traffic light road intersection was collected. Crash dataset that are to be used in this project are supplied by the Department of Main Roads.

Firstly the crash data records in MapInfo counted in each study boundary. After the crash data records are display, a text displaying severity and year are label next to each crash data point for easy counting. This is so that the severity and year of the accident can be acquired manually by hand.

The severity and year of each crash accident are entered into an excel spreadsheet which used for in the analysis. The excel table below, show each section of road, follow by how many of each severity of accident happened at that particular year (See Table 8).

ID			1997						1998					
			1	2	3	4	5	Total	1	2	3	4	5	Total
S14	-	S15_4			2	1	9	12			2	1	1	4
S15_4	-	S16			5			5			5		2	7
S16	-	S17			1			1						0
S17	-	S18					1	1						0

Table 8: Accident manually collected by year and severity

After the accident data table was prepared, it was noticed that there was not enough sample population data to perform an analysis on each individual year. Therefore, it was decided to combine the total number of accident record over the 13 years period to form a larger sample population (See table 9).

ACCIDENT (YEAR)								
1992 - 2004								
ID			1	2	3	4	5	Total
S1	-	S2	1	5	6	1	4	17
S2	-	S2_1		1	3	3	6	13
S2_1	-	S3		1	5	3	6	15
S3	-	S3_1		9	10	6	8	33
S3_1	-	S4		6	6	7	10	29
S4	-	S4_1		3	6	6	12	27

Table 9: Total car crash data over 13 year period in one single table

3.3.3 Acquisition of Road Alignment

The road in our study area is a state controlled road, and is maintain by the Department of Main Roads. The Network Survey vehicle is used to determine the existing road centrelines (including all side roads) via measurement using GPS technology. Simply, this involve a GPS unit to be mounted on the top of the vehicle and driving each state controlled roads at a speed that are necessary to maintain lock onto the GPS satellites. The raw capture GPS road alignment data are then brought into the office for editing and modifying to form the digital road network (DRN) (see Figure 7).

The dataset contains information such as the name of the roads, No of carriageway and District ID. The State controlled road dataset are supplied in MapInfo format and was used to obtain the distance between two points.

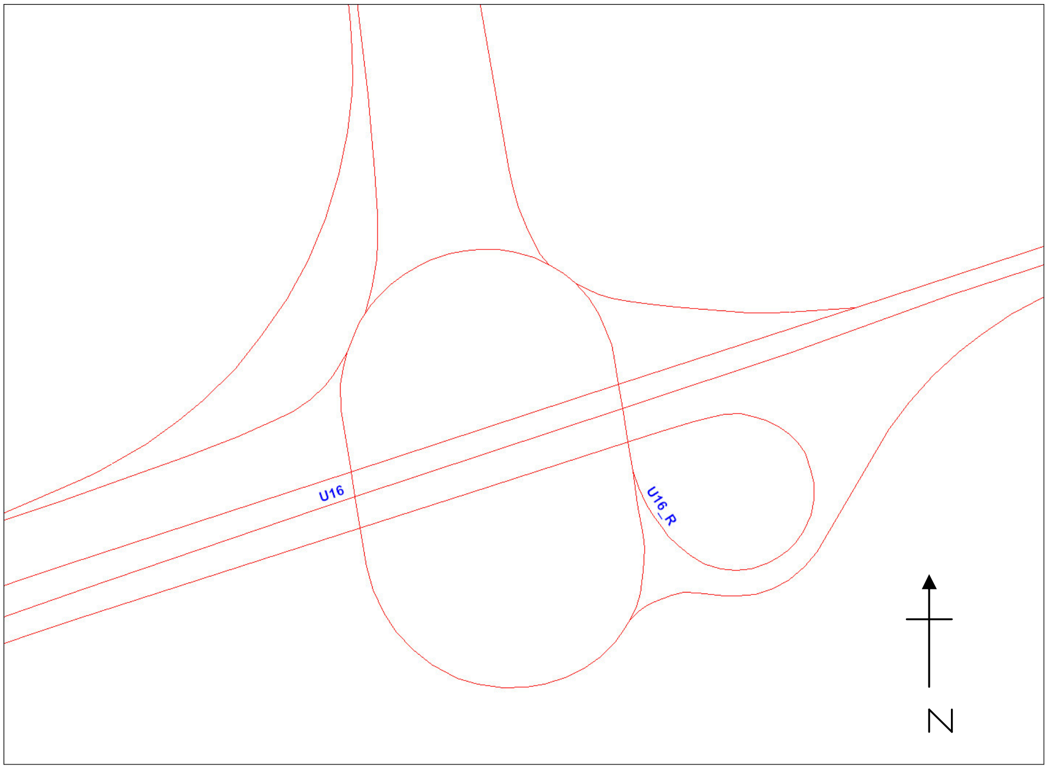


Figure 7: Road alignment captured using GPS unit mounted vehicle

For this project, the distance between two points is measured using MapInfo in a GIS environment. The measuring of distance is one of the most basic map analysis techniques. The GIS environment projection is The Geocentric Datum of Australia 1994 (GDA94) and the unit measurement was set at meters. In MapInfo, a workspace was set up with a registered digital UBD in the background and the state controlled road dataset layer on the top. The state controlled dataset is an accurate road alignment measure by a GPS unit mounted on a mobile vehicle.

The procedure for measuring the distance between two known points was simply using the ruler tools. The ruler tool allows user to measures the distance between two points or the total distance of a multi-segment path along a section a road. During the measuring procedure, a digital UBD map is layer in the background as a location reference. These methods of measuring do seem to have to lack consistency in the distance measure. Therefore the distance between the points was measured two times, one in neither direction. The distance measures are then averaged and are recorded in Microsoft Excel (See table 10).

Table 10: Distances recorded in Microsoft excel

ID			dist
S1	-	S2_1	464.9
S2_1	-	S2_1	213.7
S2_1	-	S3	208.2
S3	-	S3_1	251.7
S3_1	-	S4	162.7
S4	-	S4_1	436.8
S4_1	-	S4_2	286.5
S4_2	-	S5	297.7
S5	-	S5_1	373.3

3.3.4 Acquisition of Contour Value

As defined by the Princeton dictionary, a contour is a line drawn on a map connecting point of equal height. Contour line is useful because they allow the shape of the land surface (topography) to be shown on a map. Contour line can be drawn for any elevation, but for easy to read and to simplify thing, only lines for certain elevation are drawn on a topographic map. Usually the contour interval chosen for a map depends on the topography and purposes of the mapped area. In area where there are high reliefs the contour interval is usually larger to prevent the map from having too many contour lines, hence neatness and readability are very important. Therefore contour intervals are constant for each map.

For the purposes of this project, elevation accuracy played an important part therefore one metres interval contour was selected to be used in this project to give the high precision required. The one metres contour interval will gives an accurate representation of the road geology and provide an accuracy calculation of the road grade. The contour acquisition was done at a later stages, this was because a couple of modification was needed on the source contour dataset before it could be used to calculate the height of a location (read section 3.4).

3.3.5 Acquisition of AADT Data

The annual average daily traffic is the number of vehicles passing a point on the road in a 24 hour period, averaged over a whole year. The information was obtained from ARMIS. Below is the MapInfo raw data of the AADT (See Table 11).

Table 11: Example of the supplied AADT data in MapInfo format

SUB_ID	**ROAD_SECT_ID**	**TDIST_START**	**TDIST_END**	**LENGTH**	**AADT_YEAR**	**AADT**	**CV**
1	U15	0	1.15	1.15	2000	35600	0.16
2	U15	1.15	2.42	1.27	2000	33000	0.13
3	U15	2.42	5.12	2.7	2000	35000	0
4	U15	5.12	5.78	0.66	2000	46800	0.08
5	U15	5.78	6.93	1.15	2000	48000	0
6	U15	6.93	11.01	4.08	2000	34200	0
7	U15	11.01	11.87	0.86	2000	44500	0.06
8	U16	0	0.26	0.26	2000	54000	0.175
9	U16	0.26	1.3	1.04	2000	64100	0
10	U16	1.3	3.12	1.82	2000	64100	0
11	U16	3.12	3.95	0.83	2000	64100	0.084

Source: AADT traffic volume, DMR

Reading from the left side to the right side of the table, it interpret to SUB_ID1, road section ID U15 (Mount Lindesay Arterial road), from chainage 0 to chainage 1.15 is 1.15km in length. The total AADT in 2000 for that section of road is 35600 in both directions.

The road in our project area is recognised as Road Section_ID U20, which is known as Griffith Arterial Road in Department of Main Roads. After collected all of the AADT for U20, the table is rewritten in a much more user friendly way. The AADT presented in the table below show the start location of the road and finish of the road. The location is actually represented in street name instead of chainage (See table 12).

Table 12: AADT data represented by street name

LOCATION	1997			1998			1999		
	G	A	B	G	A	B	G	A	B
E'side Granard/Balham Rd	20004	20004	40008	20004	20004	40008	20004	20004	40008
500m West of Orange Grove Rd	15235	14994	30229	15235	14994	30229	15235	14994	30229
Kessels Road, QEII Hospital	19085	18949	38034	19133	19004	38137	19260	19250	38510
100m East of Springfield Street	24152	24152	48304	24152	24152	48304	22394	22394	44788
Mt Gravatt-Capalaba/Palmdale	14540	14540	29080	13846	13846	27692	13846	13846	27692

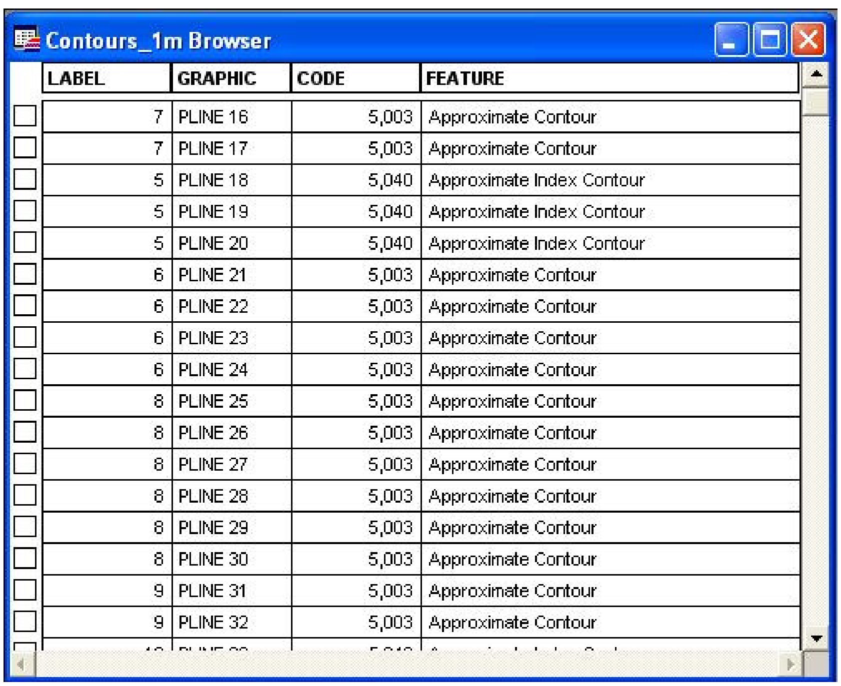
3.4 Data Pre-Processing

Data pre-processing play a very important role. By preparing the data before going straight into analysis can help reduce time and cost in latter stage. Therefore it is very important not to diminish the role of careful attention to data pre-processing efforts.

3.4.1 Data Cleaning

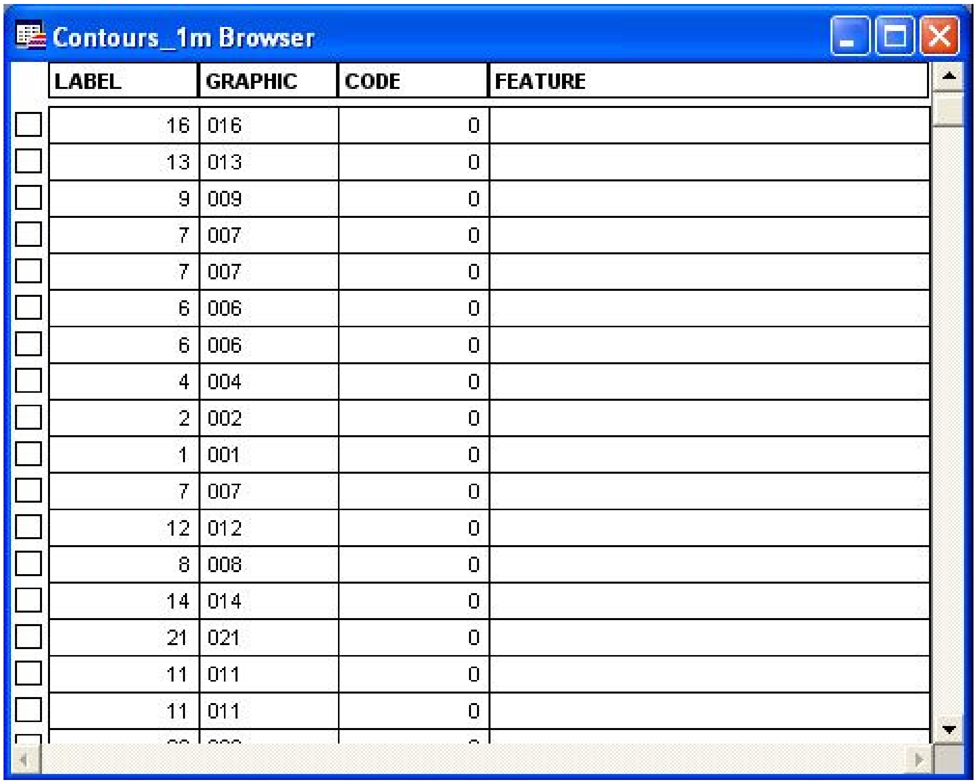
Since data sources are independent, they may adopt independent and potentially inconsistent conventions, therefore significant of time will be spent on the process of detecting and correcting error and inconsistencies. Due to the limited drive storages spaces, all the supplied data have had been crop, where only data of the study area are stored. By storing what is needed had greatly reduced storage spaces and processing power, since some of the dataset contain data for the whole of Queensland.

After viewing the contour table attribute in MapInfo, it was found that the table do have the same heading however different standard or domains are stored under these heading (See Figure 8 and 8). Below is the process for cleaning up the contour data tables.


Contours_1m Browser

LABEL	GRAPHIC	CODE	FEATURE
7	PLINE 16	5,003	Approximate Contour
7	PLINE 17	5,003	Approximate Contour
5	PLINE 18	5,040	Approximate Index Contour
5	PLINE 19	5,040	Approximate Index Contour
5	PLINE 20	5,040	Approximate Index Contour
6	PLINE 21	5,003	Approximate Contour
6	PLINE 22	5,003	Approximate Contour
6	PLINE 23	5,003	Approximate Contour
6	PLINE 24	5,003	Approximate Contour
8	PLINE 25	5,003	Approximate Contour
8	PLINE 26	5,003	Approximate Contour
8	PLINE 27	5,003	Approximate Contour
8	PLINE 28	5,003	Approximate Contour
8	PLINE 29	5,003	Approximate Contour
8	PLINE 30	5,003	Approximate Contour
9	PLINE 31	5,003	Approximate Contour
9	PLINE 32	5,003	Approximate Contour

Figure 8 Contour attribute of the first contour table



Contours_1m Browser

LABEL	GRAPHIC	CODE	FEATURE
16	016	0	
13	013	0	
9	009	0	
7	007	0	
7	007	0	
6	006	0	
6	006	0	
4	004	0	
2	002	0	
1	001	0	
7	007	0	
12	012	0	
8	008	0	
14	014	0	
21	021	0	
11	011	0	
11	011	0	

Figure 9: Contour attribute of the second contour table

In this table, only two columns are needed, they are the contours height and its feature description. In order to identify each contour line, an extra column was added, this number contain a unique integer where it can be use to select a specific contour line. The table was then altering modify and edited the end result are shown below (See Figure 10).

_1m Browser

ELEVATION	FEATURE	NO
0	Standard Contour	573
0	Standard Contour	574
0	Standard Contour	575
0	Standard Contour	576
0	Standard Contour	577
0	Standard Contour	578
0	Standard Contour	579
0	Standard Contour	580
0	Index Contour	581
0	Index Contour	582
0	Index Contour	583
0	Standard Contour	584
0	Standard Contour	585
0	Standard Contour	586
0	Standard Contour	587
0	Standard Contour	588
0	Standard Contour	589

Figure 10: Result of the contour after data was clean

3.4.2 Modification of Contours Data

The contour dataset used as mention before are at one metre interval and is indexed every ten metre. The data are captured from photogrammetry and are supplied by the Department of Natural Resources.

The contour dataset supplied by the Department of Natural Resources have two problems that needed to be addressed and fixed up. Firstly the dataset was capture back in 1980's, hence the data are old and may not be accurate or suitable for the currency of this project. This problem is acknowledged, and after some research into the topology of the study area over the 25 years period, it is found that the topology for the study area had not changed much. It was also found that Kessels road have not had any major construction that dramatically alter the topology. Therefore, the contour was acceptable to be used for this analysis.

The second issue with the supplied contour dataset was that the contour dataset was supplied in two different files. This was because it was captured and created by two different organizations. The joined of the two contour dataset actually crosses our study area. After viewing the two contour dataset spatially, it was found that (See Figure 11):

- There were no index contour
- Both contour are at onem interval
- Contour line colour are different in colour
- There were disjoined between the two contour files.

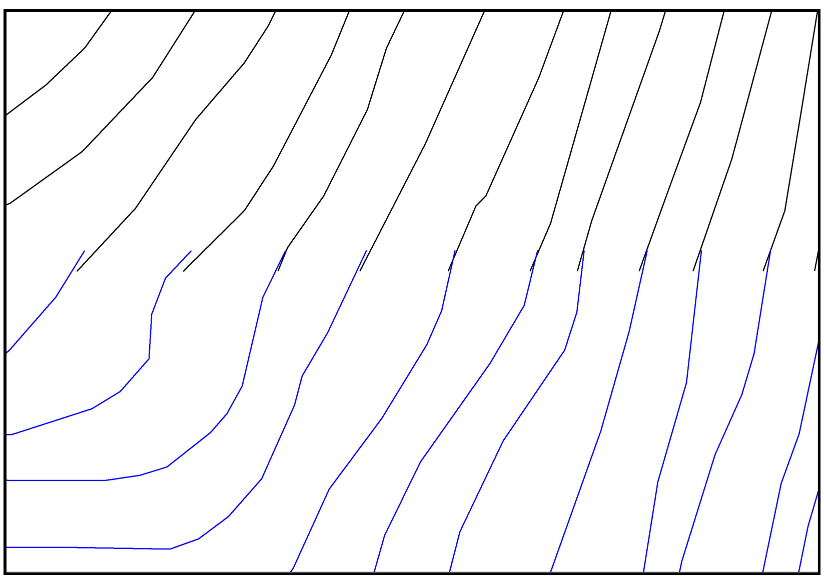


Figure 11: Image shows the four identified problems in the contour data

The difference in contour line style is not really an issues, this is because the contour line style can be easily modify to the desired colour and style by using the line style tools in MapInfo. After some consideration, black was chosen to be the standardised colour for the contour.

After the contour line are standardise in colour, the contour are then index by using MapInfo's SQL query. After looking at the road topology and for neatness reason, the contours are indexed at every 10 meters. The MapInfo SQL command used to select out all contour at 10, 20, 30, and so on are *elevation mod 10 = 0*. After the entire indexed contours are selected, the line styles of the indexed contour are change to red.

After the contours are indexed and standardise, the disjoined between the two contour dataset are needed to be look at. After a closer look at the disjoined, it was found that the disjoined was less then two meter apart in horizontal alignment, hence this is only consider to be a slight discrepancy and is deem not significant enough to affect the result of this project. The contour was then joined manually by using the MapInfo line snapping tools, where one contour line was snap straight on to the other contour line (See Figure 12). In conclusion, the problem with the contour dataset was not a major issue and was consider useable for the purpose of our project.

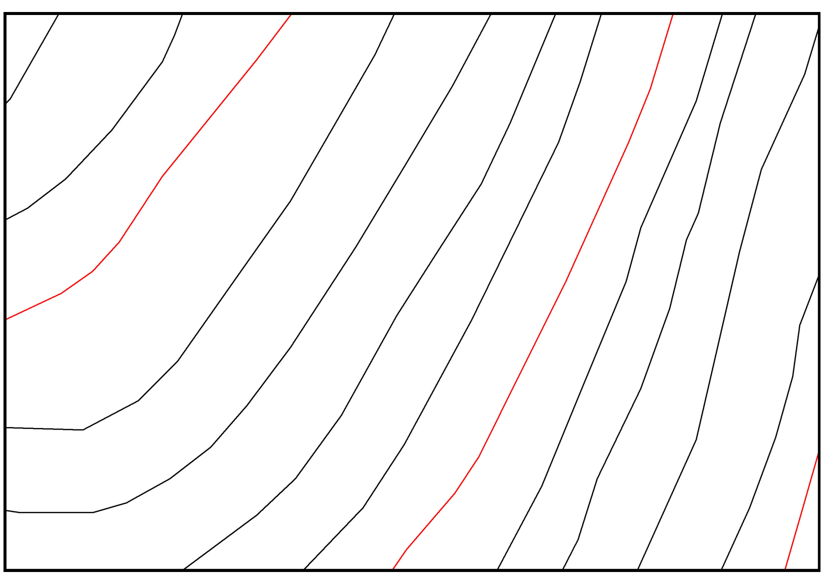


Figure 12: End result of the modify contours dataset

After the modification of the contour file, the height of the road study road was read and collected in MapInfo by using the contour data that was supplied by the Department of Natural Resources. The contour data that was supplied was created by photogrammetry. The supplied contour was created using Digital Terrain Models. Digital Terrain Models is one of the most common photogrammetric products used to represent the Earth's surface elevation as a set of points. These models, derived chiefly from aerial imagery offer users the ability to visualise and manipulate the surface of the earth. DTMs are used to produce ortho-rectify photographs and contour data.

Contours of various resolutions can be derived from digital elevation models and are used in mapping and where a representation of elevations is necessary. For this project, the contour dataset are then layered over the registered digital UBD map.

The way the height on the a small section of road is firstly reading the contour value at the start of the roads, then reading the contour along the road until the contour value head in reverse direction or the end of the road is reached. By collected the data this way we can ensure that each small section of road is a raise, fall or a flat surface hence allow us to work out the grade of the road in a raise or fall direction. The accuracy of the contour dataset is one metres, this accuracy will be accurate enough the purposes of this project (See Figure 13).

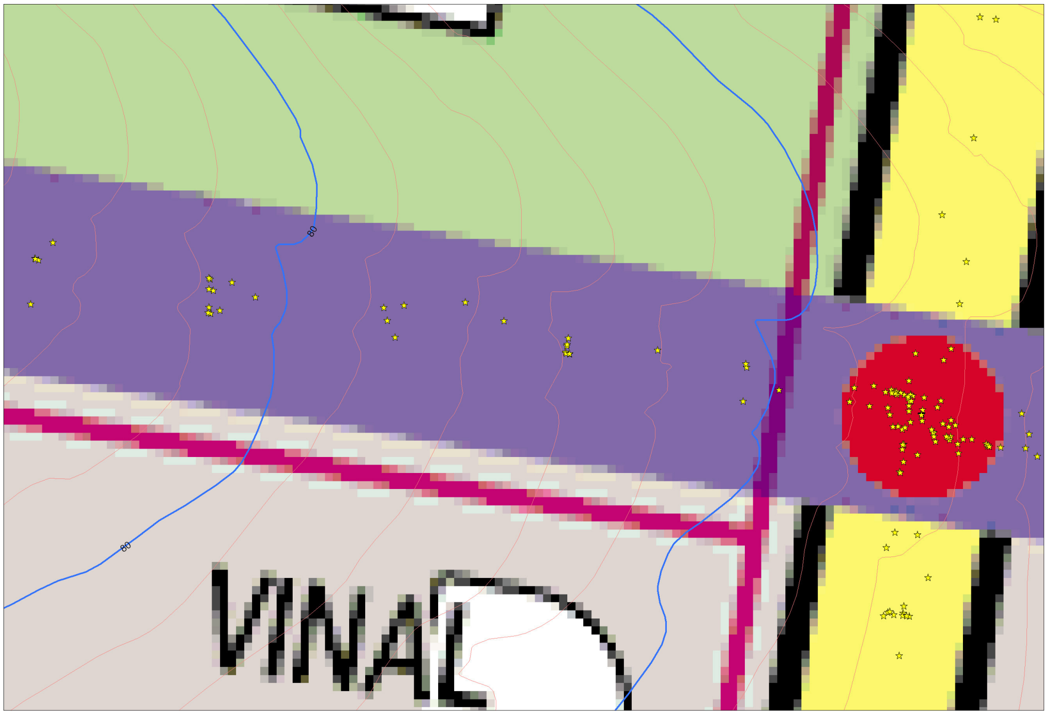


Figure 13: Clean contour at 1m intervals over digital registered UBD and crash data

3.5 Data Analysis

The Objective of this project is to identify the relationship between road grade and road accident. To perform the necessary analysis, information such as accident records and traffic volume are needed. This information is obtained from the dataset that had been selected and supplied during the data preparation stages.

The aim is to collect information under the following heading:

- Section ID (project area breaking into study section)
- The start, intermedia changes and finish in height for each section of road
- The distance between two point of known height
- Number of accident and the severity occur in each section road
- Annual Average Daily Traffic for each section road

The information above are then recorded in a Microsoft Excel Spreadsheet format

3.5.1 Creating Workspaces

What is a MapInfo workspace (.wor) *(John Schlosser, May 2002)*

- A text file containing the MapInfo commands needed to re-create a MapInfo session ending with the extension .wor.
- Commands in workspace files (WORs) open MapInfo tables; create and position the necessary Map, Browser and other windows; define layer style and thematic settings; plus much more.
- A WOR is a MapInfo script or simple program.
- You can view or edit any WOR using Word or Notepad. Usually you won't edit a WOR, although a programmer might.

The analysis of this project required a map of the study area in the background spatially with its different data layer on top of it, such data are road accident data, AADT, Traffic light in it. This map acts as an overview of the type of geological and road features that are on Kessels road. By setting up a MapInfo workspaces, it can act as a maps template and be use for data Processing (See Figure 14).

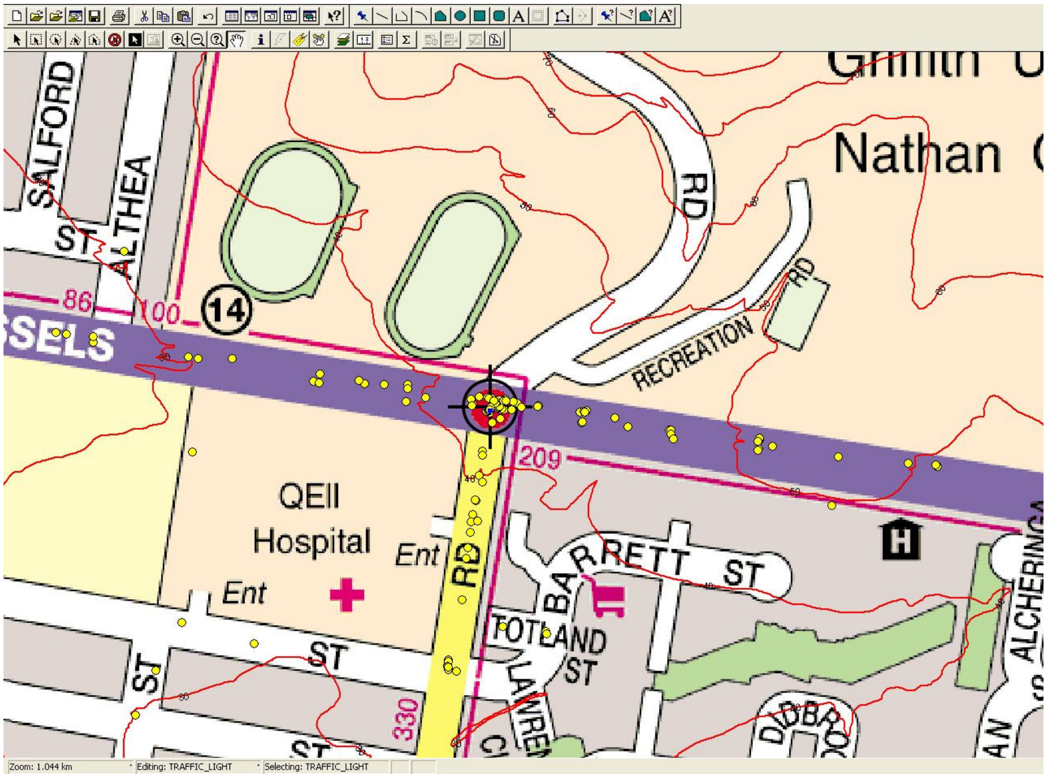


Figure 14: An example of a MapInfo workspace used in this project

3.5.2 Weight Severity Crash Data

In the literature review, it was noticed that there is a method known as Accident Severity in blackspot identification. The fundamental principal behind the accident severity method is that each accident can and should be assigned a weight according to its severity or the cost of damage. This weighted method uses the severity as a measure to how bad or hazardous a road location is. It was consider that to better refect the severity of the accident on our study road, the accident crash data will be weight to better reflect the accident data.

The road that is being study is a state controlled road. Therefore the severity weighting will be based on map road severity record. Below is the cost of an urban accident based on severity, note that all road in the South East Queensland are regarded as Urban Road which include our study area (refer back to table 7).

- Urban Fatal $920, 072
- Urban Casualty $66, 384
- Urban Property $17, 302

From the above accident severity cost classification it was decided that the severity related to each one are

- Severity 5 = Urban Fatal
- Severity 4, 3 = Urban Casualty
- Severity 2, 1 = Urban Property

Looking back at the cost in the severity cost classification it was decided that urban property damage is equal to 1 unit of accident. Therefore from studying the cost comparison of each type of severity it was determine that urban fatal is 53.1 units and urban casualty is 3.8 units. The unit are determined purely from comparing the cost of each type of severity and does not necessary be the best representation to reflect the each accident. The weighted accident result can be view in (see Appendix B)

3.5.3 Calculating Weighted Accident / 10,000 Vehicles

The effective management of the state controlled road network and its infrastructure is becoming progressively critical due to increase in vehicle users. Therefore, when using GIS to identifying the relationship between road accident and road grade, factors such as traffic volume play an important role. Different section of Road have different volume, hence as indicated in the lecturer review in chapter 2, two different road can have the same number of accident, but by looking at the traffic volume it could indicated a different story. Therefore, in this project, the accident record will be standardised to per thousand vehicles, so that the accident record use to represent its section of road is fair and not affected by variable factor such like AADT.

Firstly, the AADT traffic volumes is spatially work out, then assign to their correct section of road (See table 13).

Table 13: AADT traffic volume assign to its relevant section of road

ID		Weighted Total	AADT (both way)
S5_1	- S5_2	13.6	30816.75
S5_2	- S6	14.4	30816.75
S6	- S7	124.2	38579.25
S7	- S7_1	96.7	46446.88
S7_1	- S7_2	12.4	46446.88
S7_2	- S7_3	76	46446.88
S7_3	- S8	105.8	46446.88
S8	- S9	245.8	46446.88
S9	- S10	56.6	46446.88
S10	- S11	29	32501.50
S11	- S12	70.8	32501.50
S12	- S13	13.4	32501.50

Then to calculate the Weight accident / 10, 000 is by using the weighted accident figure divided by the AADT traffic volume for that section of road, then multiply 10,000 to obtain Weighted Accident / 10, 000. See (Appendix C) for result on Weighted accident / 10, 000 and see Appendix D for a comparison of Total accident/ Weighted Accident and Weighted Accident / 10, 000 for each section of road.

3.5.4 Calculation of Slope Angle

A road with a 1% grade means that there is 1 meter of elevation or drop over a distance 100 meters in vertical alignment. Therefore, the grade of a road can be calculated by the formula

Road grade = Change in elevation / distance * 100

For example (see table 14) show a partial record of the height and distance collected. To worked out the grade for S3 – S3_1 it is:

Road grade = (8 – 4) / 251.7 * 100

Road grade = 1.58%

Table 14: Height and distance collected for each boundary

ID			from (m)	to (m)	dist
S1	-	S2_1	6	6	464.9
S2_1	-	S2_1	6	10	213.7
S2_1	-	S3	10	8	208.2
S3	-	S3_1	8	4	251.7
S3_1	-	S4	4	7	162.7
S4	-	S4_1	7	10	436.8
S4_1	-	S4_2	10	9	286.5

3.5.5 Determination of Slope Direction

After calculating the road grade for each section of Kessels road, it was then necessary to categories whether the road was a rising slope, falling slope or a level ground. This is determine simply from working out whether or not it is a higher point to a lower point or from a lower point to a higher point. The slope is consider rasing if the road is heading from a lower height to a higher height, and the slope is consider falling if the road is sloping from a higher height to a lower height. There are also sections of road that are levelled, meaning it is a flat road with no raise or fall.

Working out whether it is a raise or a fall will be useful for the latter of the analysis, because the data and calculated data will be separated into these two group. This is so that the correlation can better represent each individual group instead of one whole group together (see table 15).

Table 15: Example of the data table with direction determined

ID			from (m)	to (m)	Dist (m)	Grade(%)	direction
S1	-	S2_1	6	6	464.9	0.00	Level
S2_1	-	S2_1	6	10	213.7	1.87	raise
S2_1	-	S3	10	8	208.2	0.96	fall
S3	-	S3_1	8	4	251.7	1.59	fall
S3_1	-	S4	4	7	162.7	1.84	raise
S4	-	S4_1	7	10	436.8	0.69	raise
S4_1	-	S4_2	10	9	286.5	0.35	fall
S4_2	-	S5	9	12	297.7	1.01	raise

3.5.6 Table Separation

Before this analysis can take place, the table was divided into three separate tables. The table was separated based on the direction of the grade, hence a table for raise, a table for fall and a table for level or flat surface (See Appendix F).

For the level road grade data table, there are four entries, this will probably be too weak of an analysis when performing correlation on this categories. However since the objective of this project is to determining if there is a relationship between the road grade and road accident, the result from the level road grade data table will not be as affect our overall objective.

The raise road grade data table have 15 entries, while the fall road grade data table have 14 entries. The number of entries in these tables will be sufficient for the purposes of this analysis. Hence the result from the correlation analysis will be an acceptable and will fulfil the objective of this project.

3.5.7 Final Consolidation

At this stage, all the necessary data had been collected and had it necessary adjustment and modification. The next part is to perform the necessary analysis to determine whether or not there is a relationship between road grade and road accident. Attached in (Appendix E) is the completed table ready for the analysis. The analyses that are going to be use to determine whether or not there is a relationship between road grade and road accident will be known as a correlation analysis.

3.5.8 Correlation

Correlation is an analysis for determining whether there is a relationship between the variable in the study. The way correlation work is by plotting a relational graph between the two variables and sees if there is a linear relationship between the two variables. A correlation coefficient is a number between -1 and 1, which measures the degree to which two variables are linearly related. A perfect position linear correlation had a correlation coefficient of 1, while a prefect negative linear correlation had a correlation coefficient of –1. A correlation coefficient of 0 means that there is no linear relationship between the variables. The result from the correlation will be able to determine if relationship exist between road grade and road accident.

3.6 Validation / Accuracy Assessment

Dataset used in the analysis of this project were supplied by different government department and authority. Therefore the data will only be as accuracy as the way and method the different authority had collected these information them in the first place. To check the accuracy of these supplied data, the data are all imported into MapInfo. In MapInfo, data such as the road alignment, contours and traffic location are all compared with ortho-rectify imagery and each other. The result from this testing showed that the data sit on to the ortho-rectify images doesn't seem to have any major discrepancy.

Secondly, the 1980's contour was checked and compare with a 2004 aerial photogrammetry survey that was done by DMR. The contour data supplied by the

DNR was found to have a 1 – 2 meter different. This 1 – 2 meter different over a hundred meters of road are not significant enough to affect the calculation of road grade. Therefore it was consider that the slight difference in contour height was not a problem for the purpose of this study.

Besides checking our dataset, a field check was also done to ensure that there isn't any major road design problem with our study area. The field check indicated that the roads are in reasonable condition and only contains small number of pothole and cracking.

Finally, the data acquisition of the number of accident in a our study boundary was done manually, therefore it was double checked to ensure their was no error in the during the acquisition process. Contour height and Distance was also double check to ensure that was no discrepancy in the measurement.

CHAPTER 4

Results

4.1 Chapter Overview

This chapter will look at the result found in our project analysis. The results are broken into three categories.

The first category is the result of the correlation for all combine road grade direction. The second category contains the result of the correlation for the raise direction. The third category contains result of the correlation for the fall direction. For each category, there will also be a scattered plot to help justify the result of the correlation. This chapter are for presenting the result from the analysis only. The interpretation, and discussion of the chart and result are in chapter 5.

4.2 Accident Total Comparison

The total accident, weighted total, and weighted total per 10, 000 vehicles had been plot on to a graph, this will give a comparison of what the weighted do to the number of accident (See Appendix D).

4.3 Correlation Result for Road Grade in All Direction

The project analysis correlation was done in Microsoft Excel. The Microsoft excel has the ability to allow user to enter in the two set of data, and then a comparison will be done automatically within Microsoft excels. Below are the results from the correlation analysis. The result shows the relationship between (See table 16):

- Road grade in all direction vs accident total
- Road grade in all direction vs Weighted total
- Road grade in all direction vs Weighted total / 1000 vehicles

Table 16: Result of the correlation of road grade in all road direction

Correlation for combination of direction	
Total	0.326505286
Weighted Total	0.386242369
Weighted Total / 10, 000	0.390544232

Below are the scatted plot for each the total accident, weighted total, and weight total / 10, 000 verse Road grade in all direction (see Figure 15, 15, 16)

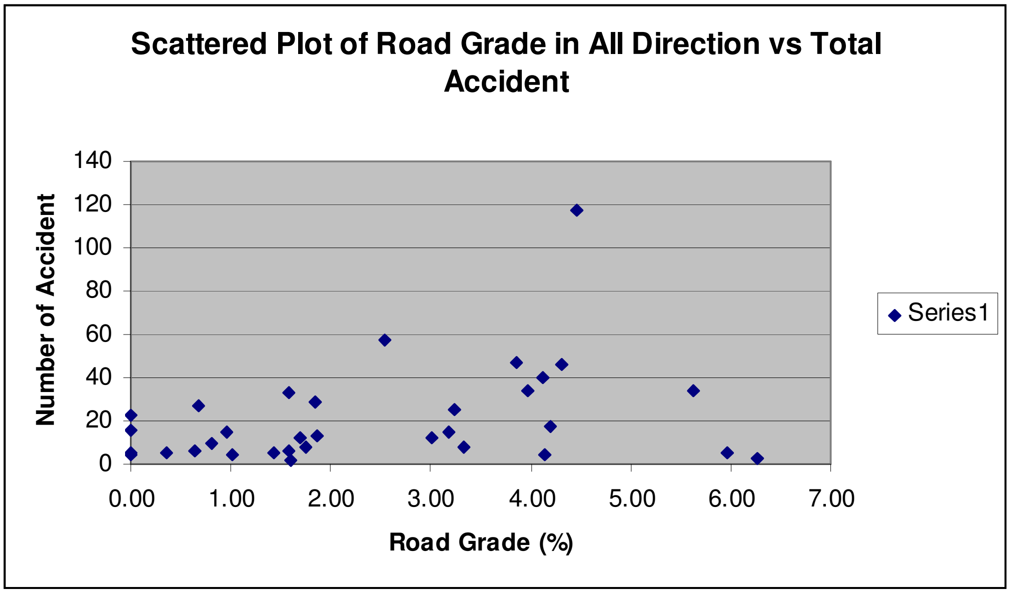


Figure 15 Scattered plot of road grade in all direction vs total accident

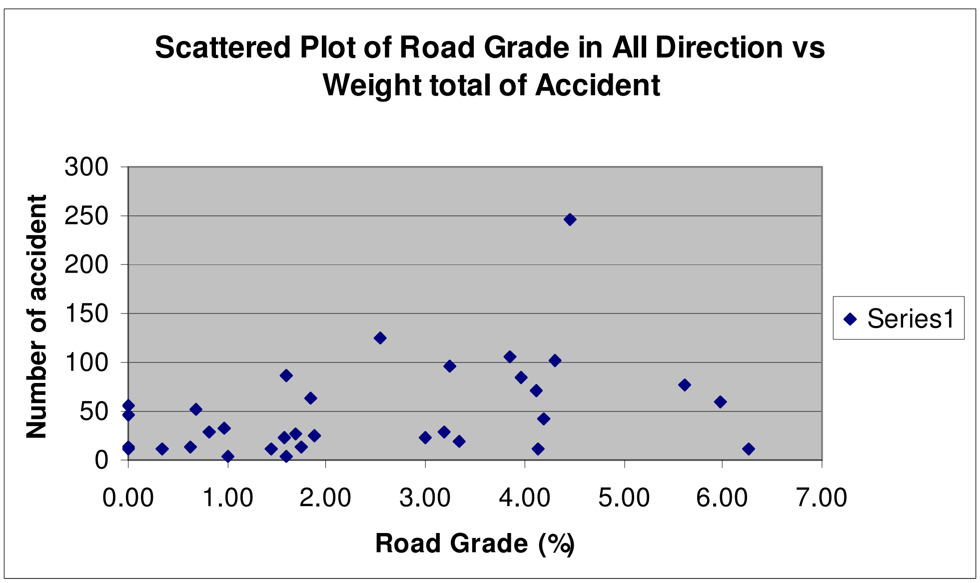


Figure 16 Scattered plot of road grade in all direction vs Weight total accident

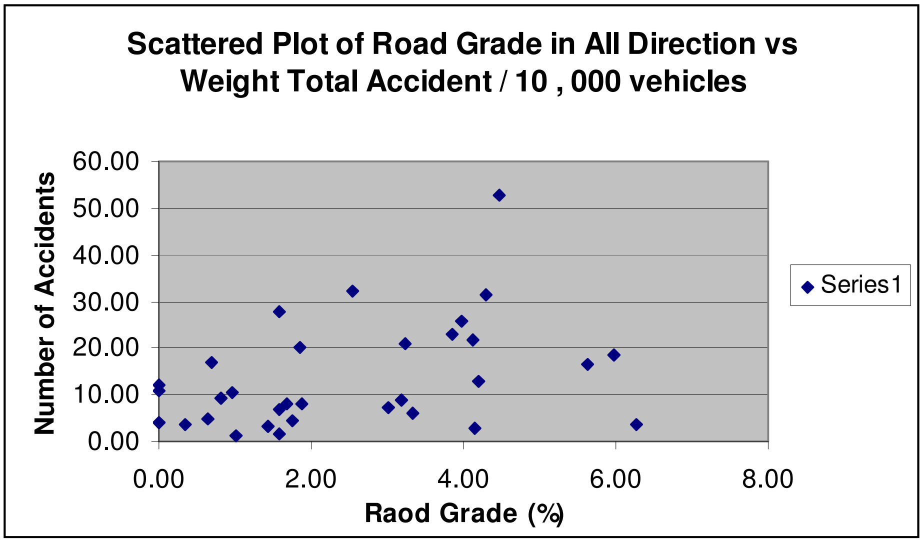


Figure 17 Scattered plot of road grade in all direction vs Weight total / 10, 000 vehicles

4.4 Correlation Result for Road Grade in Raise Direction

The result in this section is for road grade in the raise / uphill direction. Below are the results from the correlation analysis. The result shows the relationship between (See table 17):

- Road grade in raise direction vs accident total
- Road grade in raise direction vs Weighted total
- Road grade in raise direction vs Weighted total / 1000 vehicles
-

Table 17: Result of the correlation of road grade in raise road direction

Correlation for uphill direction	
Total	0.122188317
Weighted Total	0.170925891
Weighted Total / 10, 000	0.084697346

Below are the scatted plot for each the total accident, weighted total, and weight total / 10, 000 verse Road grade in raise direction (See Figure 18, 18, 19)

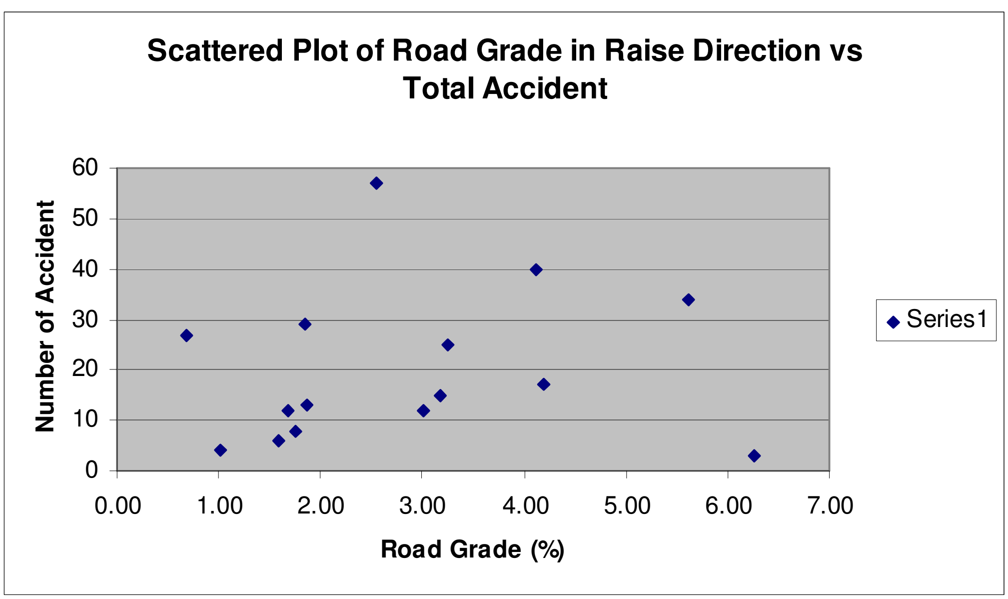


Figure 18 Scattered plot of road grade in raise direction vs total accident

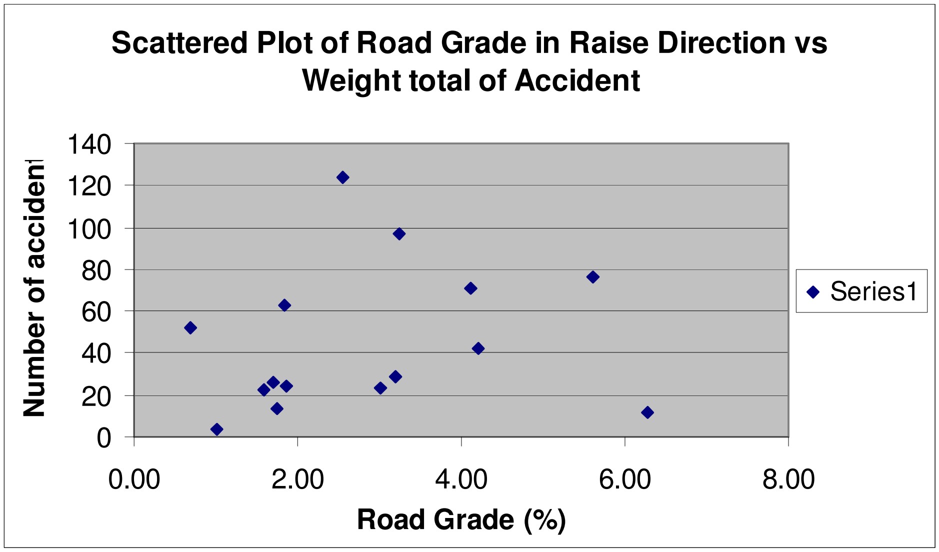


Figure 19 Scattered plot of road grade in raise direction vs Weight total accident

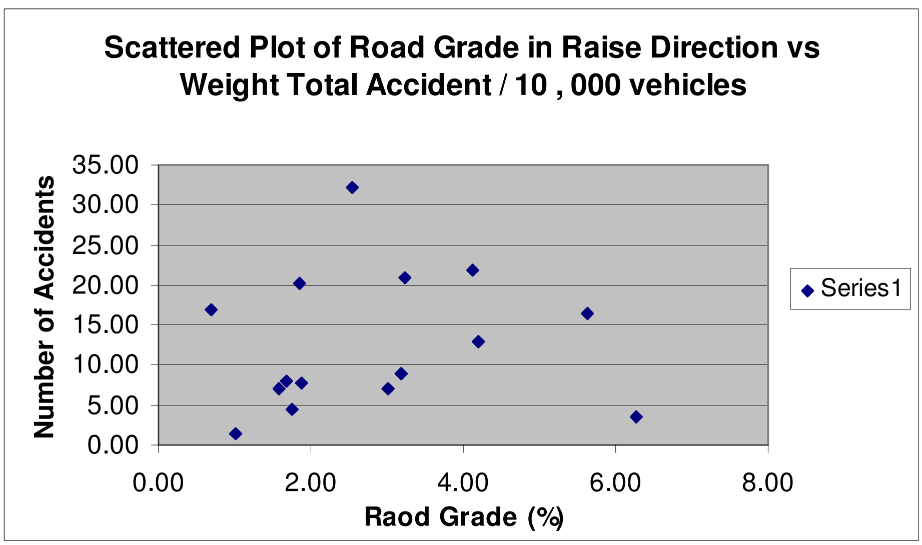


Figure 20 Scattered plot of road grade in raise direction vs Weight total / 10, 000 vehicles

4.5 Correlation Result for Road in Fall Direction

The result in this section is for road grade in the fall / downhill direction. Below are the results from the correlation analysis. The result shows the relationship between (see table 18):

- Road grade in fall direction vs accident total
- Road grade in fall direction vs Weighted total
- Road grade in fall direction vs Weighted total / 1000 vehicles
-

Table 18: Result of the correlation of road grade in fall road direction

Correlation for downhill direction	
Total	0.409344002
Weighted Total	0.519607331
Weighted Total / 10, 000	0.533278232

Below are the scatted plot for each the total accident, weighted total, and weight total / 10, 000 verse Road grade in fall direction (see Figure 21, 21, 22)

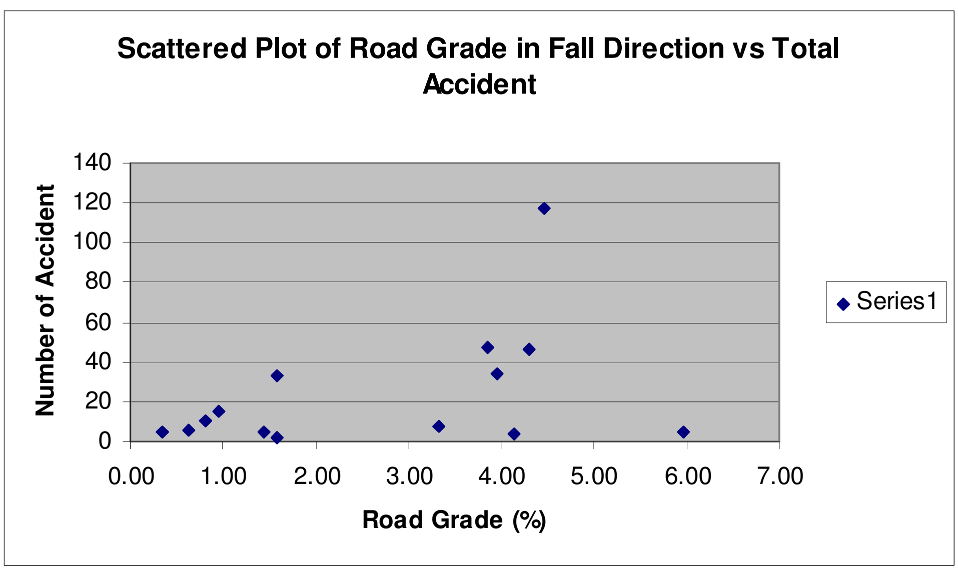


Figure 21 Scattered plot of road grade in fall direction vs total accident

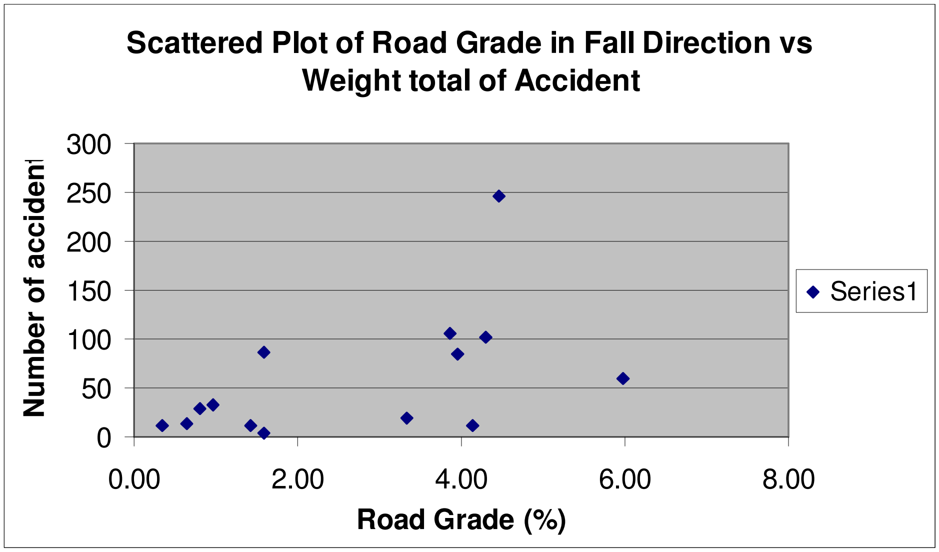


Figure 22: Scattered plot of road grade in fall direction vs Weight total accident

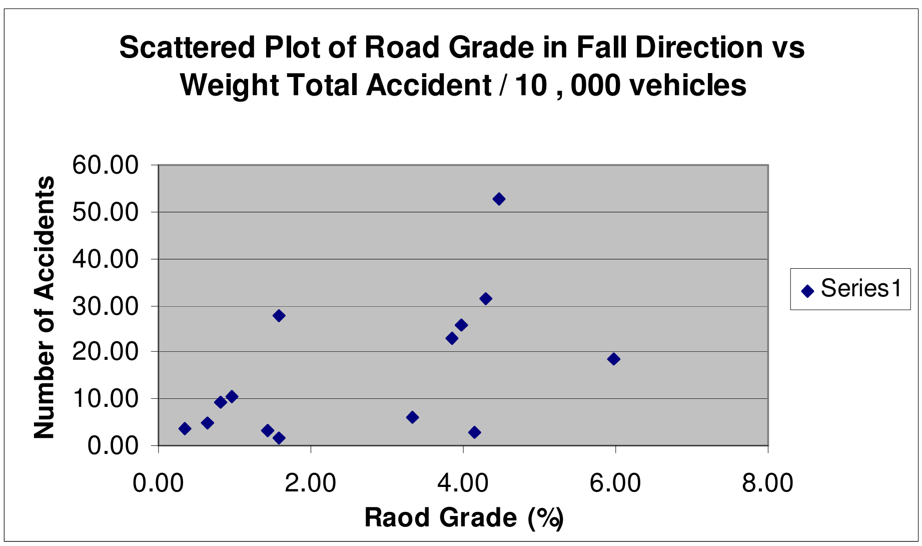


Figure 23 Scattered plot of road grade in fall direction vs Weight total / 10, 000 vehicles

CHAPTER 5

Discussion

5.1 Chapter Overview

This chapter will focus on the interpretation of the chart and result and state what the result actually indicated. The chapter will go on to discussed whether or not there is a relationship between road grade and road accident. This chapter will also look whether or not the result was expected, and how the result compare with previous study.

5.2 Interpretation of the Result

The result of our study based strongly on the correlation analysis. The correlation analysis will help identify if there is a relationship between road gradient and road accident. The result of the analysis are broken into three categories, uphill, downhill and all direction. The result are broken into categories because by separating the road grade direction, it can help better understand which specific road grade in a specific direction tends to caused more accident than others.

5.2.1 Interpretation of the result in uphill and downhill direction

When both uphill and downhill road grades are combined and analysis together, the result indicated that there is slight relationship between road gradient and road accident. The correlation value for the number of accident without any severity or traffic volume weighting is at 0.32. A correlation of 0.32 indicated that there is low correlation, hence there is little relationship between road gradient and road accident. However, the correlation improved to 0.38, when the number of accident is weighted by the severity and cost method. At 0.38, it indicated that there is better relationship between road gradient and road accident, but still the correlation is still insignificant to show that there is a relationship between road grade and road accident.

After considering that each road had different traffic flow and volume, and the number of accident had been standardise to per ten thousand vehicles, the correlation once again improve slight to 0.39. However, at 0.39 it still shows that there is little relationship between road grade and road accident.

The increase of the correlation value are actually expected, this is because the number of accident had being weighted according to how bad of a crash the road and traffic volume had caused. For example S14_2 – S14_3 had a road grade of 6% but only had 5 accidents, however when looking at the severity of the crash data, it was noted that there was actually 1 fatalities in that section of roads, hence the weighted method help to provide a better representation of the hazard on that section of road and gives a more reasonable figure for the correlation.

The increased in the correlation were expected when weighting had been applied, however the correlation was a lot less than expectation. In chapter 2 the literature review indicated that steep road tends to cause more accident. This is because steep road can varies the speed of a light or heavy vehicle, causing it to have higher chance of rear end collision. Also steep road limit the sight distance. From these reason, it was expected that the correlation would indicated that there are strong relationship between road accident and road grade, but this was not the case.

From studying the scatter plot Figure 12, it was noticed S14_2 – S14_3 and S15 – S15_1 both had a road grade of around 6%, but with only 5 and 3 accident respectively.

Also from the scattered plot it was noticed that section S8 – S9 had 117 accidents, this figure was two times more than S6 – S7 which is second highest number accident in the study area with 57.

By studying the geographical location it was noticed that S8 – S9 had a lot of giant retailer shop next to along the road. This could be the main caused of all the high number of accident in that section of road. As for section S14_2 – S14_3 and S15 – S15_1, it was still unclear why there was so little accident on the steep slope.

5.2.2 Interpretation of the result in uphill direction

By separating road grade in to uphill and downhill direction help to give a better identify which direction of road grade causing more accident. The result from the correlation analysis show that there was close to no relationship between road grade and road accident in the uphill direction. This result was very surprising and was not expected. This was because road grade in an uphill direction causing the most variation in light and heavy vehicle speed. Therefore it was expected that road in uphill direction should have higher correlation between road grade and road accident.

The correlation value with out any weighting in the number of accident in an uphill direction is 0.12. This value increased to 0.17 when the severity / cost are used to weight the number of accident. However out of expectation, after the consideration that each road had different traffic volume, and the number of accident had been standardise to per ten thousand vehicles, the correlation value drop downs to 0.08.

This drop in correlation was very surprising, and the AADT figure for the uphill direction section of road was look at. It was noticed that majority of the road in the uphill direction had a traffic volume at low 30, 000 where the traffic volume for other road are at mid to high 40, 000. However, even thou this low traffic volume figure were noticed it was still unclear on why the correlation analysis indicated that there was no relationship between road grade in uphill direction and road accident.

The study of the chart also indicated that the section S4 – S4_1, which had a very flat grade at 0.69% but had 27 accidents. After looking at the geological location, it was noticed that at the end of S4_1, there was a railway track. Perhaps the railway track was the caused of the high number of accident in such a flat graded road.

5.2.3 Interpretation of the result in downhill direction

By separating road grade into uphill and downhill direction helps to better identify which direction of the road grade are causing more accident. The result from the downhill correlation analysis indicated moderate correlation between road grade and road accidents. However, the correlation result is only moderate and is lower than expected. From the literature review, it indicated that road grade in the downhill direction was expected to caused more accidents because of the momentum of the vehicle that affect the braking ability.

The correlation value for the number of accident without any weighting in the downhill direction is 0.4. This value was increased to 0.51 after the number of accidents had been weighted in accordance with the severity and cost of the accidents. The correlation increase even more to 0.53 after the volume traffic (AADT) was taken into consideration.

When studying the scatter plot, it was noticed that for section S8 – S9 there was 117 accidents. By studying the geographical location it was noticed that the surrounding area was a retail area, where there was a lot of shop. It was also noticed from field checking that there was car constantly leaving these giant retailers such as super A mart and Clive Peters and on to Kessels road. This could be the main cause of the high number of accident in that section of road.

5.3 Summary

The result from the correlation analysis was different to what was expected. The expectation was that the result will indicate high level of relationship between road grade and road gradient. However from the project analysis, it show that relationship do exist between road grade and road accident in downhill direction. In an uphill direction, no relationship was found between road grade and road gradient.

The result from the scatter plot indicated there are other factors that are influencing the result of this project. This is clearly shown where roads with grades of 6% had little or no accident. While other section of roads that are very flat or with less then 2% grades had extremely high number of accident. Both of these cases indicate that there could be other factors beside road grade that are affecting the result of the analysis.

After further analysis into its geographical location, it show that there the high number of accident could be caused by the retail shop on the side of the roads where large number of customer are constantly stopping to leave or go in to these premises.

The data collected in this project can be more accurate by reviewing the initial crash report of each road accident to better determine what caused the road crashed. This can help eliminate accidents that are caused from human factors such as fatigue or inattention. By selecting all the number of accident that is caused as a result of the high change in grades will ensure the correlation process only correlate accidents that are caused by road grade on that section of roads, hence the result can give a much more accurate and clear pictures of whether or not that changes of road grade have a relationship with road accident.

CHAPTER 6

Conclusion

6.1 Chapter Overview

This chapter will conclude the project. It will discuss on what had been learn from this project and the significance and relevance.

6.2 Conclusion

In conclusion, this project had achieved its objective and aims, however the result indicate that there are little relationship between road grade and road gradient.

It was noticed that there could be other design element or geological features that are affecting the project correlation analysis and there are need to have these element remove to obtain a more accurate result.

Brisbane are constantly expanding, the number of vehicle user are increasing each year. Road authority should review on their current standard not only on road grade but also on other road design element. The project analysis method used in this project are not limit to road grades, the method can also be used on other road features such as relationship of speed limit and road accident. In reality the correlation analysis can be perform on finding a relationship between any road features and road accident.

6.3 Further Work

The project topic is largely open and could still be expand. The same project analysis method can be perform on another study area for result comparison.

The main advantage of using this approach to identify a relationship between road features and road accident is that it allow work to be done in a GIS environment, , not costly and some data can be reused for analysis of other features. Therefore, the approached in this project can be used to easily for planning road safety measure and act as a quick heck on concerned road features or area.

However, the accuracy of this approach highly depends on the data acquired and how it had been cleaned. The disadvantage of this project is it assumes that there are no human factors involve in all of the historical accident that occurs on Kessels road. The project assumes that all accident is of a cause due to the condition of the road grade, hence the change in the road grades. However it is recognised that human error is the main cause of accident.

There are other additional dataset that can be incorporated into the project approached. These additional dataset include consideration of speed limit, considering of curve and the straightness of the road. These considerations can help weight the road actual condition instead of just weighting the number of accident.

The use of GIS in this project had been very useful due to its common database operation such as query and statistical analysis and the unique visualization ability and geographical analysis benefits offered by maps. These GIS abilities help distinguish it from other information system. It also allows the ability to limit the amount of field checking, with the use of aerial imagery.

6.4 Recommendation for Practical Application

The approach in this project can be used for a quick indication of determining whether or not there is a relationship between any spatial road features and road accident. The analysis side of the project uses Microsoft excel which was widely available.

This approached can be adopted by road authorities to easily and quickly identify if an relationship between road features and road accidents. The use of the scattered plot can also help to identify unique accident event where a particular section of road are behaving unexpected.

6.5 Recommendation for Future Research

This project is very significant to road authorities, it allow road authorities to identify problem area and problem features hence very beneficial.

In this project the most important dataset the accident data supplied by the Department of Police. There are a total of 687 accidents in the study area. Together the project area was broken into 33 smaller study area, this equate to about 20 accidents per study area. This figure could be a bit to small if it was to be used to represent a project of such scale and so significant.

The correlation analysis in this project included all roads with a road grade. Perhaps a correlation analysis on road with grade more than 4%. This correlation analysis may show stronger correlation between the relationship of steep road grade and road accident.

It will be interesting to see if the result would be the same if the same analyses are perform on another location with higher number of accident. Also the current study area speed limit is mostly 60 kilometres per hour, even thou this is a common speed on Brisbane sub arterial road, perhaps the study could be carried out to area where faster speed limit are in place. Also note that the severity cost method may also be over exaggerated or under exaggerated the real amount of accident. Therefore it would be an interesting research to see how the define a suitable severity / cost ratio to be used on the number of road accident.

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http://www.atsb.gov.au/road/aspx

Appendix A

University of Southern Queensland

Faculty of Engineering and Surveying

ENG 4111/ 4112 Research Project

PROJECT SPECIFICATION

FOR: **Alan Wong**

TOPIC: Using GIS to explore the relationship between road grade and accidents

SUPERVISOR: DR. Armando Apan

ENROLMENT: ENG 4111 – S1, E, 2005;
ENG 4112 – S2, E, 2005

PROJECT AIM: To assess the relationship between road grade and road accidents using GIS. This will involve the analysing of road grade standard and preforming correlation analysis to identify if relationship exists.

PROGRAMMED: Issue A, 15 December 2004-12-15

1. Research information on aspect of road grade standard and road accident history.

2. Gather source datasets, eg. a road management information system (ARMIS), traffic volume, traffic accident records, contours.

3. Conduct pre-processing tasks on spatial and attribute data, such as geocoding, registration, clipping, database editing, and so on.

4. Analyse road accident data, eg. Identify clustering or patterns formed by the crash data.

5. Produce statistic tables on the crash data, such as accident per year and traffic volume vs. accident.

6. Performing correlation analysis

7. Analyse the result and consult.

AGREED:____________________ (Student) ____________________(Supervisors)

(Date) ____ / ____ / __

Appendix B

Working out

ID			SERIVITY RATING 1	2	3	4	5	Total	Weighted Total
S1	-	S2		5	6	1	4	16	46.8
S2	-	S2_1		1	3	3	6	13	24.2
S2_1	-	S3		1	5	3	6	15	31.8
S3	-	S3_1		9	10	6	8	33	86.2
S3_1	-	S4		6	6	7	10	29	62.6
S4	-	S4_1		3	6	6	12	27	52.2
S4_1	-	S4_2		1	1		3	5	10.6
S4_2	-	S5				2	2	4	4
S5	-	S5_1		1	2		1	4	12.4
S5_1	-	S5_2		1	1	2	4	8	13.6
S5_2	-	S6		1	2		3	6	14.4
S6	-	S7		8	16	5	28	57	124.2
S7	-	S7_1	1	3	4	5	12	24	96.7
S7_1	-	S7_2		1	2		1	4	12.4
S7_2	-	S7_3		5	10	5	14	34	76
S7_3	-	S8		5	16	5	21	47	105.8
S8	-	S9		13	33	19	52	117	245.8
S9	-	S10		6	6	4	7	23	56.6
S10	-	S11		1	4	4	6	15	29
S11	-	S12		2	9	14	15	40	70.8
S12	-	S13		2	1	1	1	5	13.4
S13	-	S14		3	4	2	1	10	29.6
S14	-	S14_1		6	14	5	21	46	102
S14_1	-	S14_2		1	4	1	6	12	26
S14_2	-	S14_3	1		1		3	4	59.9
S14_3	-	S15		1	3	2	6	12	23.2
S15	-	S15_1			3			3	11.4
S15_1	-	S15_2		4	14	8	8	34	84.4
S15_2	-	S15_3		4	5	1	7	17	42.2
S15_3	-	S15_4		3	1	1	3	8	19.2
S15_4	-	S16		2	4			6	22.8
S16	-	S17			1		1	2	4.8
S17	-	S18			2	1	2	5	10.6

Description	Cost	Comparison
Urban Fatal	$ 920,072	53.1 unit
Urban Casualty	$ 66,384	3.8 unit
Urban Property	$ 17,302	1 unit

Description	Severity Rating
Urban Fatal	1
Urban Casualty	2, 3
Urban Property	4, 5

Weighted Total Accidents

Appendix C

ID			Weighted Total	AADT (both way)	Weighted Accident per 10, 000
S1	-	S2	46.8	43369.00	10.79
S2	-	S2_1	24.2	30816.75	7.85
S2_1	-	S3	31.8	30816.75	10.32
S3	-	S3_1	86.2	30816.75	27.97
S3_1	-	S4	62.6	30816.75	20.31
S4	-	S4_1	52.2	30816.75	16.94
S4_1	-	S4_2	10.6	30816.75	3.44
S4_2	-	S5	4	30816.75	1.30
S5	-	S5_1	12.4	30816.75	4.02
S5_1	-	S5_2	13.6	30816.75	4.41
S5_2	-	S6	14.4	30816.75	4.67
S6	-	S7	124.2	38579.25	32.19
S7	-	S7_1	96.7	46446.88	20.82
S7_1	-	S7_2	12.4	46446.88	2.67
S7_2	-	S7_3	76	46446.88	16.36
S7_3	-	S8	105.8	46446.88	22.78
S8	-	S9	245.8	46446.88	52.92
S9	-	S10	56.6	46446.88	12.19
S10	-	S11	29	32501.50	8.92
S11	-	S12	70.8	32501.50	21.78
S12	-	S13	13.4	32501.50	4.12
S13	-	S14	29.6	32501.50	9.11
S14	-	S14_1	102	32501.50	31.38
S14_1	-	S14_2	26	32501.50	8.00
S14_2	-	S14_3	59.9	32501.50	18.43
S14_3	-	S15	23.2	32501.50	7.14
S15	-	S15_1	11.4	32501.50	3.51
S15_1	-	S15_2	84.4	32501.50	25.97
S15_2	-	S15_3	42.2	32501.50	12.98
S15_3	-	S15_4	19.2	32501.50	5.91
S15_4	-	S16	22.8	32501.50	7.02
S16	-	S17	4.8	32501.50	1.48
S17	-	S18	10.6	32501.50	3.26

Weighted Total Accidents Per 10, 000 Vehicle

Appendix D

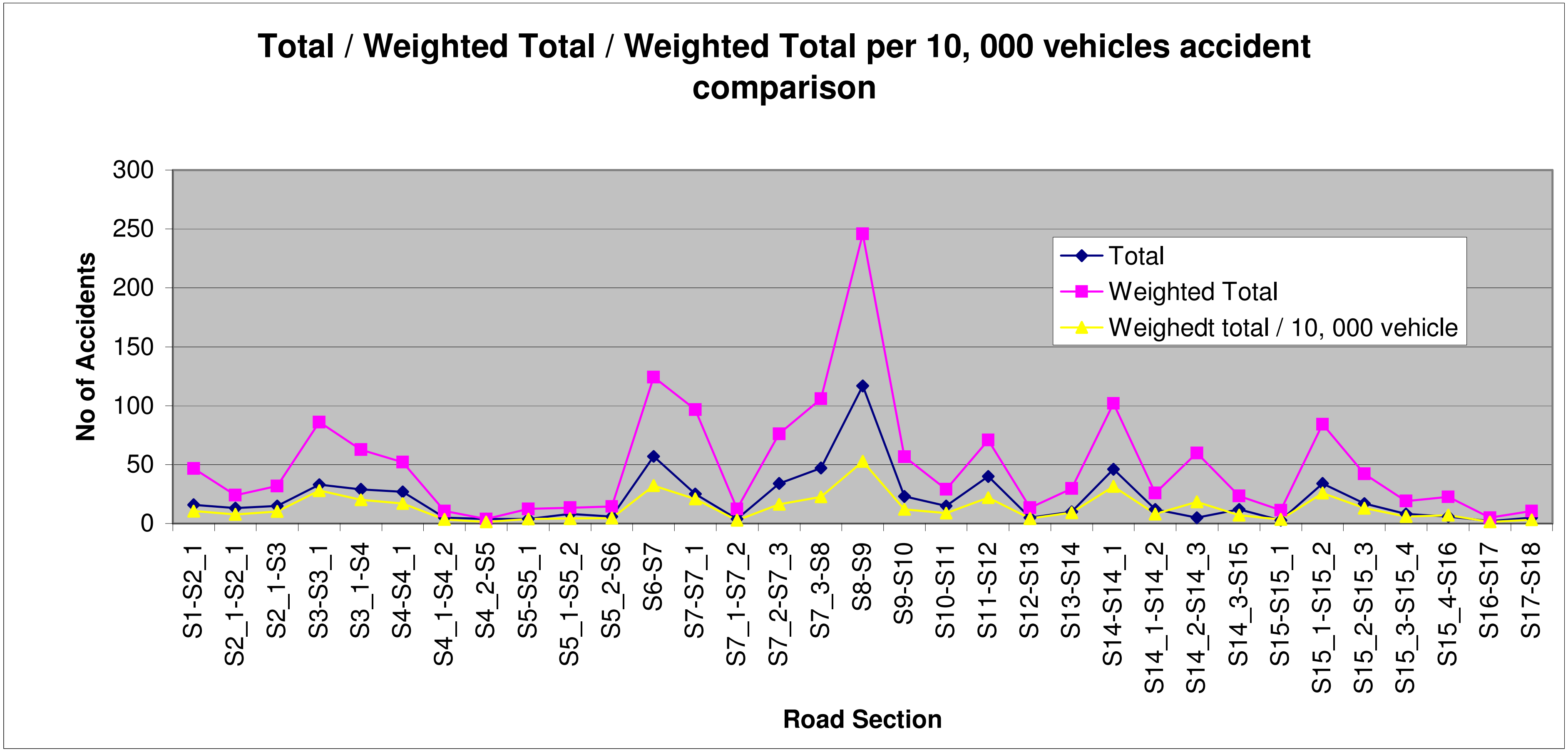

Chart of Total / Weighted Total / Weighted Total per 10, 000 Vehicles comparison

Appendix E

ID			from (m)	to (m)	dist (m)	grade (%)	direction	Accident severity 1	2	3	4	5	Total	Weighted Total	AADT	Weight total / 10, 000 vehicle
S1	-	S2_1	6	6	464.9	0.00	Level		5	6	1	4	16	46.8	43369	10.79
S2_1	-	S2_1	6	10	213.7	1.87	raise		1	3	3	6	13	24.2	30817	7.85
S2_1	-	S3	10	8	208.2	0.96	fall		1	5	3	6	15	31.8	30817	10.32
S3	-	S3_1	8	4	251.7	1.59	fall		9	10	6	8	33	86.2	30817	27.97
S3_1	-	S4	4	7	162.7	1.84	raise		6	6	7	10	29	62.6	30817	20.31
S4	-	S4_1	7	10	436.8	0.69	raise		3	6	6	12	27	52.2	30817	16.94
S4_1	-	S4_2	10	9	286.5	0.35	fall		1	1		3	5	10.6	30817	3.44
S4_2	-	S5	9	12	297.7	1.01	raise				2	2	4	4	30817	1.30
S5	-	S5_1	12	12	373.3	0.00	Level		1	2		1	4	12.4	30817	4.02
S5_1	-	S5_2	12	17	285.7	1.75	raise		1	1	2	4	8	13.6	30817	4.41
S5_2	-	S6	17	15	315.6	0.63	fall		1	2		3	6	14.4	30817	4.67
S6	-	S7	15	42	1060	2.55	raise		8	16	5	28	57	124.2	38579	32.19
S7	-	S7_1	42	53	338.9	3.25	raise	1	3	4	5	12	25	96.7	46447	20.82
S7_1	-	S7_2	53	46	169	4.14	fall		1	2		1	4	12.4	46447	2.67
S7_2	-	S7_3	46	85	694.2	5.62	raise		5	10	5	14	34	76	46447	16.36
S7_3	-	S8	85	72	336.9	3.86	fall		5	16	5	21	47	105.8	46447	22.78
S8	-	S9	72	43	650.2	4.46	fall		13	33	19	52	117	245.8	46447	52.92
S9	-	S10	43	43	196.2	0.00	Level		6	6	4	7	23	56.6	46447	12.19
S10	-	S11	43	47	125.6	3.18	raise		1	4	4	6	15	29	32502	8.92
S11	-	S12	47	62	363.8	4.12	raise		2	9	14	15	40	70.8	32502	21.78
S12	-	S13	62	62	78	0.00	Level		2	1	1	1	5	13.4	32502	4.12
S13	-	S14	62	61	123.6	0.81	fall		3	4	2	1	10	29.6	32502	9.11
S14	-	S14_1	61	48	302.2	4.30	fall		6	14	5	21	46	102	32502	31.38
S14_1	-	S14_2	48	52	236.7	1.69	raise		1	4	1	6	12	26	32502	8.00
S14_2	-	S14_3	52	40	200.9	5.97	fall	1		1		3	5	59.9	32502	18.43
S14_3	-	S15	40	48	266.2	3.01	raise		1	3	2	6	12	23.2	32502	7.14
S15	-	S15_1	48	58	159.6	6.27	raise			3			3	11.4	32502	3.51
S15_1	-	S15_2	58	44	353.2	3.96	fall		4	14	8	8	34	84.4	32502	25.97
S15_2	-	S15_3	44	61	404.6	4.20	raise		4	5	1	7	17	42.2	32502	12.98
S15_3	-	S15_4	61	49	359.7	3.34	fall		3	1	1	3	8	19.2	32502	5.91
S15_4	-	S16	49	52	189.9	1.58	raise		2	4			6	22.8	32502	7.02
S16	-	S17	52	46	377	1.59	fall			1		1	2	4.8	32502	1.48
S17	-	S18	46	38	557.6	1.43	fall			2	1	2	5	10.6	32502	3.26
								2	99	199	113	274	687			

Appendix F

ID	from (m)	to (m)	dist (m)	grade (%)	direction	Accident severity 1	2	3	4	5	Total	Weighted Total	AADT	Weight total / 10, 000 vehicle
S1 - S2_1	6	6	464.9	0.00	Level		5	6	1	4	16	46.8	43369	10.79
S5 - S5_1	12	12	373.3	0.00	Level		1	2		1	4	12.4	30817	4.02
S9 - S10	43	43	196.2	0.00	Level		6	6	4	7	23	56.6	46447	12.19
S12 - S13	62	62	78	0.00	Level		2	1	1	1	5	13.4	32502	4.12
						0	14	15	6	13	48			

Level data table

ID	from (m)	to (m)	dist (m)	grade (%)	direction	Accident severity 1	2	3	4	5	Total	Weighted Total	AADT	Weight total / 10, 000 vehicle
S2_1 - S2_1	6	10	213.7	1.87	raise		1	3	3	6	13	24.2	30817	7.85
S3_1 - S4	4	7	162.7	1.84	raise		6	6	7	10	29	62.6	30817	20.31
S4 - S4_1	7	10	436.8	0.69	raise		3	6	6	12	27	52.2	30817	16.94
S4_2 - S5	9	12	297.7	1.01	raise				2	2	4	4	30817	1.30
S5_1 - S5_2	12	17	285.7	1.75	raise		1	1	2	4	8	13.6	30817	4.41
S6 - S7	15	42	1060	2.55	raise		8	16	5	28	57	124.2	38579	32.19
S7 - S7_1	42	53	338.9	3.25	raise	1	3	4	5	12	25	96.7	46447	20.82
S7_2 - S7_3	46	85	694.2	5.62	raise		5	10	5	14	34	76	46447	16.36
S10 - S11	43	47	125.6	3.18	raise		1	4	4	6	15	29	32502	8.92
S11 - S12	47	62	363.8	4.12	raise		2	9	14	15	40	70.8	32502	21.78
S14_1 - S14_2	48	52	236.7	1.69	raise		1	4	1	6	12	26	32502	8.00
S14_3 - S15	40	48	266.2	3.01	raise		1	3	2	6	12	23.2	32502	7.14
S15 - S15_1	48	58	159.6	6.27	raise			3			3	11.4	32502	3.51
S15_2 - S15_3	44	61	404.6	4.20	raise		4	5	1	7	17	42.2	32502	12.98
S15_4 - S16	49	52	189.9	1.58	raise		2	4			6	22.8	32502	7.02
						1	38	78	57	128	302			

Raise data table

Appendix F continue

								Accident severity								
ID			from (m)	to (m)	dist (m)	grade (%)	direction	1	2	3	4	5	Total	Weighted Total	AADT	Weight total / 10, 000 vehicle
S2_1	-	S3	10	8	208.2	0.96	fall		1	5	3	6	15	31.8	30817	10.32
S3	-	S3_1	8	4	251.7	1.59	fall		9	10	6	8	33	86.2	30817	27.97
S4_1	-	S4_2	10	9	286.5	0.35	fall		1	1		3	5	10.6	30817	3.44
S5_2	-	S6	17	15	315.6	0.63	fall		1	2		3	6	14.4	30817	4.67
S7_1	-	S7_2	53	46	169	4.14	fall		1	2		1	4	12.4	46447	2.67
S7_3	-	S8	85	72	336.9	3.86	fall		5	16	5	21	47	105.8	46447	22.78
S8	-	S9	72	43	650.2	4.46	fall		13	33	19	52	117	245.8	46447	52.92
S13	-	S14	62	61	123.6	0.81	fall		3	4	2	1	10	29.6	32502	9.11
S14	-	S14_1	61	48	302.2	4.30	fall		6	14	5	21	46	102	32502	31.38
S14_2	-	S14_3	52	40	200.9	5.97	fall	1		1		3	5	59.9	32502	18.43
S15_1	-	S15_2	58	44	353.2	3.96	fall		4	14	8	8	34	84.4	32502	25.97
S15_3	-	S15_4	61	49	359.7	3.34	fall		3	1	1	3	8	19.2	32502	5.91
S16	-	S17	52	46	377	1.59	fall			1		1	2	4.8	32502	1.48
S17	-	S18	46	38	557.6	1.43	fall			2	1	2	5	10.6	32502	3.26
								1	47	106	50	133	337			

Fall Data Table