Researching Cycling Safety: Using Cyclists Perceptions and Other Measures to Make Recommendations for Sandy Bay, Tasmania

UNIVERSITY OF TASMANIA

by

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Declaration

This thesis contains no materia, which has been accepted for the award of any other higher degree or graduate diploma at any tertiary institution. To the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

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31 March 2003

Abstract

The promotion of safety for cycling is a significant strategy in order to encourage use of the bicycle as a mode of daily transport. Black spots, cyclists' perceptions of danger and bicycle suitability criteria have been used in many other places to assist identifying locations requiring improvement for safer cycling. It is not clear that these criteria and perceptions can actually identify where bicycle accidents are likely to occur, when black spots are excluded from the process. Finding the relationship between the number of bicycle accidents and cyclists' perceptions of danger is an aim of this study. Using their own perception of danger, only 3% of cyclists could predict the occurrence of bicycle accidents at intersections, while 26% could predict the occurrence of bicycle accidents on street sections. Therefore, on street sections, cyclists' perception of danger is a useful element in order to anticipate the bicycle accident rate. Cyclists' perceptions are only one indicator of the locations where bicycle accidents are likely to occur: other factors require further investigation.

The Sandy Bay area has the highest rate of bicycle commuters in Hobart, Tasmania, with the potential to increase bicycle use if safer environments are provided. A questionnaire undertaken by the author shows that around 86% of cyclists think some streets within the study area are dangerous. GIS was used to identify the bicycle accident places and the dangerous locations. The most dangerous streets, known from records of accidents publicly available, were Sandy Bay Road, Regent Street, and Churchill Avenue. Cyclists also said that these needed most improvement for safer cycling. The creation of bicycle lanes, especially on Sandy Bay Road, Regent Street, and Churchill Avenue, was the major requirement. Street-based fieldwork was undertaken to measure the width of these three streets and their footpaths. The width of Sandy Bay Road and Churchill Avenue within the study area can accommodate dedicated bicycle lanes on both sides, but not Regent Street. In spite of this recommendation, the most effective method found to date has been the reduction of speed limits for all vehicles to 30 km/h, as in many European countries, but not in Australia.

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Table of Contents

UTAS

List of Figures

List of Tables

Abbreviations and Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ABS	Australian Bureau of Statistics
ADONIS	Analysis and Development of New Insight into Substitution
Av	Avenue
CGIA	North Carolina Center for Geographic Information and Analysis
CROW	Centre for Research and Contract Standardization in Civil and Traffic Engineering
BCI	Bicycle Compatibility Index
Cres	Crescent
Ct	Court
DIER	Department of Infrastructure, Energy and Resource
Esp	Esplanade
FHWA	Federal Highway Administration
GIS	Geographic Information Systems
GIS-T	Geographic Information Systems for Transportation
HCC	Hobart City Council
ILS	Information and Land Services
La	Lane
LOS	Level of Service
NHTSA	National Highway Traffic Safety Administration
p-value	1-tailed significance level
Pde	Parade
Pl	Place
R^2	R-squared
RCI	Roadway Condition Index
Rd	Road
SBAC	State Bicycle Advisory Committee
Sig.	2-tailed significance level
St	Street
TBC	Tasmania Bicycle Council
TIS	Transportation Information Systems
&	and

Chapter 1 Introduction

1.1 Cycling and its benefits

Cycling is a sport and a leisure activity that is beneficial to individuals, communities and the environment. Some of the benefits associated with cycling include increased physical fitness, psychological wellbeing, enhancing productivity of individuals, improved social skills and body co-ordination among children, maintained mobility in older people, direct and indirect employment, revenue from selling bicycles and related equipment, and tourism-related bicycle activities. Cycling is also said to encourage community interaction and social integration, as means of learning and sharing societal values and perspectives that foster a better understanding among different groups in society (Austroads 1999a; Dekoster *et al.* 1999).

Moreover, cycling is one solution to traffic and environmental problems in cities. Cycling is less harmful to the environment than other forms of transport such as motor vehicles, thereby contributing to the reduction of CO_2 emissions and leading to improved air quality and possibly ameliorating global climate change (Austroads 1999a; Dekoster *et al.* 1999; Petty *et al.* 2001; Vélo Mondial 2002). In addition to these advantages, bicycle transport is silent, and is more economical and accessible to all family members in comparison to car use (Baden *et al.* 1998; Dekoster *et al.* 1999).

Cycling is a significant mode of transport for short trips especially in urban areas (Boyle 1997; Dekoster *et al.* 1999; Petty *et al.* 2001). Dekoster *et al.* (1999) observed that the bicycle can be faster than a car over short urban distances at around 5 km or even further depending on cycling speed and traffic conditions. To support this statement, these authors presented a comparison of the times and distances from door to door between cars and bicycles in European countries (see Figure 1.1). In Australia, no such comparison has been found. However, the principle might be applied to the Australia situation, such as a city like Hobart, Tasmania because more than 50% of urban trips in European countries (Dekoster *et al.* 1999), Australia (ABS 1997) and Hobart (Boyle 1997) that are made by motor vehicles are less than 5 km. Thus, in theory cycling could replace car use for such journeys. More comprehensive information about the benefits of cycling such as environmental perspectives is provided in Dekoster *et al.* (1999) and Austroads (1999a).

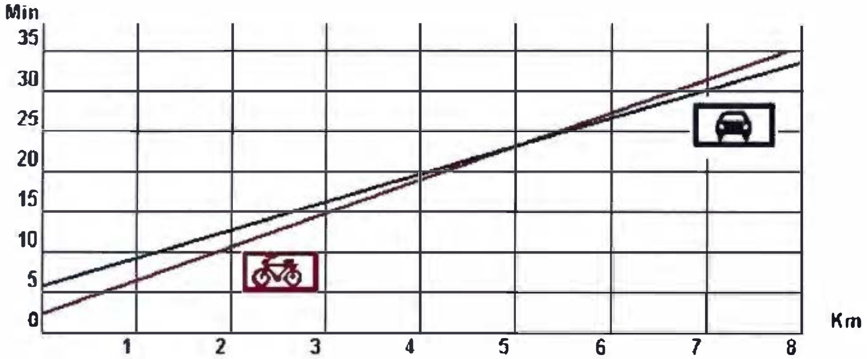

Figure 1.1: Comparison of the times and distances between cars and bicycles in the urban environment in European countries, adapted from Dekoster *et al.* (1999, p 11)

The wide range of advantages that individuals and society can obtain from cycling has resulted in many governments and private organisations all over the world promoting and encouraging cycling[1]. In Tasmania, the State Bicycle Advisory Committee (SBAC)[2] represents the state on the Australian Bicycle council. SBAC together with the Department for Infrastructure, Energy and Resources (DIER), supports an increasing number of cyclists and cycling activities (DIER 2000a). In Hobart, the capital city of Tasmania, Boyle (1997) informed that the Hobart City Council (HCC), with representation on SBAC, also plans to increase the number of cycling trips[3].

1.2 Cycling Safety

There are many ways to increase the number of cyclists and bicycle usage, such as developing the road network for cyclists, providing maps and end-of-trip facilities, promoting the benefits of cycling as mentioned above, and providing community

[1] For examples in Europe Baden *et al.* (1998) and Dekoster *et al.* (1999); in the United States of America see Pedestrian and Bicycle Information Center (2000); and Australia see Austroads (1999a)
[2] Now it is called Tasmania Bicycle Council (TBC) (Broadley 2002, pers. comm.). According to Tse (2003, pers. comm.), '*The TBC was formed out of SBAC to be the implementation and coordination organisation for SBAC policies, but SBAC has not been operational since the division*'.
[3] Trip means a journey to a place and back (Longman Group Ltd 1995). Therefore, one cycling trip means one journey to a place and back made by one cyclist.

education and training (Austroads 1999a; Dekoster *et al.* 1999). However, there is little to be gained by implementing these measures if a safe environment in which to cycle cannot be provided because the lack of road safety is the major obstruction to cycling in general. Thus, improvement in road safety is a central theme of any plans to support cycling (Baden *et al.* 1998; OECD 1998; Dekoster *et al.* 1999). When road environments become safer, it will be more acceptable to travel using bicycles, which consequentially results in a decrease in motor vehicle congestion. For example, the "Hobart BikePlan 1997" of the Hobart Municipality targets a decrease in the bicycle accident rate, as well as to increase the number of urban trips by cycle as mentioned earlier in this section (Boyle 1997).

The encouragement of cycling cannot successfully occur simultaneously with the decrease of bicycle accidents when limited or no appropriate facilities for a safer cycling environment are available such as bicycle paths and lanes, bicycle parking, and bicycle traffic control devices. In order to successfully encourage people to cycle, it is important to provide facilities that are appropriate for each cycling environment, which are sufficient for present and future bicycle usage and demands (Austroads 1999b). For example, the city of Brisbane, Queensland has 450 km of dedicated bikeways that Brisbane City Council plans to extend to 1200 km in the future (Brisbane City Council 2003a, b).

In line with the wide range of cycling benefits mentioned earlier in this section, it is imperative to increase the number of cyclists in the urban environment. The lack of safety and inconvenience can discourage people from cycling as a mode of transport resulting in individuals resorting to car use (Parker 2001). Conflict between cyclists and other road users can take place where roads are narrow or where intersections and roundabouts occur. Therefore, traffic facilities need to be managed and constructed to account for cyclists as well as motorists (CROW 1996a, b; Austroads 1999b; Dekoster *et al.* 1999). Creating safe and comfortable facilities for the use of this transport mode is one of the strategies for sustainable transportation (Petty *et al.* 2001). Good traffic engineering practice in designing roads and cycling paths plays an important role in safety, together with facilitating comfortable, convenient, and efficient cycling. For example, dedicated bike lanes and paths in the Netherlands aided in the reduction in the cyclist death rate from 2.4% to 1.4% from 1990 to 1999 (Parker 2001).

Before decisions for changing or improving road and traffic conditions are made, it is important to identify the locations where they are needed and why. In general, decisions are largely focused on the areas where accidents occur, especially fatal accidents, and where black spots, a place with a high rate of accidents, occur (Baden *et al.* 1998).

There have been many studies to develop the systematic methods, which are referred as bicycle suitability criteria, to measure the operational conditions of roadways for cycling. These studies developed models based on road and traffic environment conditions such as the geometry of intersections, traffic volumes, traffic speed, and other variables (see Section 2.4). Amongst these, some attempts have been taken to validate bicycle suitability ratings against actual cyclists perceptions (see Section 2.5).

To date, the most modernized bicycle suitability validation according to the literature is the work undertaken by Harkey *et al.* (1998) from the University of North Carolina Highway Safety Research Center. Harkey *et al.* (1998) developed a methodology for deriving the bicycle compatibility index (BCI), which included cyclists' perceptions in its rating processes. Later the North Carolina Center for Geographic Information and Analysis (CGIA) has applied the BCI to be part of the development of Geographic information systems (GIS) tools for improving pedestrian and bicycle safety, called "GIS safety analysis tool" (see Section 2.7.3.2).

The one missing element in each of these studies is the use of locations where bicycle accidents actually occurred. Only one effort has been taken to evaluate one bicycle suitability criteria, the modified roadway condition index (RCI), to bicycle accident rate (Epperson 1994; Turner *et al.* 1997). Epperson (1994) found that the modified RCI could only explain 18 percent of the variation in bicycle accident rates.

Epperson's (1994) result and bicycle suitability criteria have helped in designing the present study, as to whether there is a relationship between the number of bicycle accidents occurring and cyclists' perceptions of danger. Without consideration of locations where bicycle accidents occurred, "GIS safety analysis tool" and bicycle suitability criteria might not be meaningful things for identifying the safest route for bicycle riding.

1.3 Study aims and objectives

Based on the locations where bicycle accidents occurred and areas riders consider are dangerous for cycling, the aim of this study is to investigate the dangerous locations for cycling in the Hobart City Council suburb of Sandy Bay. In order to achieve this aim, the following objectives have been devised:

- review the relevant literature related to bicycle safety;
- review the applications and the usefulness of GIS and GIS-T that relate to cycling and safety;
- determine the locations in the study area where it is not safe to cycle by identifying where bicycle accidents occur, and specifying where cyclists think it is dangerous to cycle;
- identify the causes of danger at locations cyclists regard as dangerous;
- use GIS as a tool to map the accident locations and dangerous areas; and
- analyse the relationship between the number of accidents that have occurred along with the perceptions of danger in order to determine whether the locations that were perceived as dangerous by the participants can predict the bicycle accidents that are likely to occurred.

After dangerous locations, together with their causes of danger, are identified, it is appropriate to provide recommendations for improving cycling safety. Therefore, a further aim is to suggest possible and suitable solutions to improve road safety within the study area. Particular consideration will be given to the places that are considered to be dangerous locations for cycling and where bicycle accidents have occurred. In order to reach this aim, the following objectives were devised:

- review the relevant literature related to the strategies associated with the improvement of cycling safety;
- determine the improvements cyclists recommend could be made for safer cycling in the study area;
- propose improvements for safer cycling in the study area, which are based on cyclists' recommendations, together with data from accident occurrences and dangerous locations identified by cyclists, including the causes of danger, and from the literature;

- suggest the most likely and useful practice for better road and traffic conditions in order to improve bicycle safety in the specified risk locations made by cyclists.

1.4 Study approaches

In order to achieve the aims and the objectives, the following approaches were implemented:

- development and distribution of a questionnaire in October 2002 to gather data on bicycle accident locations and dangerous places within the study area, in order to complement bicycle accident data that was collected since 1988 reported by the police for DIER;
- application of GIS as a tool to map the bicycle accident sites and dangerous locations on streets in the study area, based on the existing data and questionnaire data; and
- street-based fieldwork for the improvement of the present road conditions at the locations identified by participants.

A detailed account of the methods employed can be seen in Chapter 3.

1.5 The relevance of GIS

GIS has been increasingly applied to solve a wide range of spatial problems. GIS for Transportation (GIS-T) is a GIS where the particular types of information are related to transportation activities. GIS-T has several requirements for data modelling, data management, and data analysis that are not fulfilled by normal GIS applications (Thill 2000). Section 2.7 gives detailed information on GIS and GIS-T.

Since cycling is a mode of transportation that can be represented spatially, the present study proposed to employ GIS-T as a tool to study bicycle accidents and dangerous locations identified in the study area, and to help in analysing the information collected in order to support the decision-making process. However, the study used only basic functions that can be found in standard GIS applications. Therefore, it is more appropriate to describe GIS-T as GIS in this study. Section 3.4.2 provides the use of GIS in the present study.

1.6 Significance of the study

As described in Section 1.1, the benefits from cycling and safer cycling environments have a positive influence by increasing the number of cyclists and their trips. The present study is important because it analyses the problems identified by cyclists and proposes alternatives for changing the existing road and traffic environments and their management, particularly in the high-risk areas where cyclists considered it dangerous for them to cycle and where bicycle accidents had taken place. The further anticipated benefits of this research are as follows.

- The maps will be useful for updating the current "Hobart Bike Map" (ILS 2002).
- The data from the questionnaire survey will provide additional data to DIER and HCC that will improve the existing statistics and information on bicycle accident locations.
- The information on identified road and traffic environmental factors of roads in the study area will help DIER and HCC to determine the road and traffic factors that make these areas dangerous and will also offer information regarding how to better manage them.

1.7 Significance of data used in the study

In this study, there were three data sets used: bicycle accidents, dangerous locations, and recommendations to improve safety.

1.7.1 Bicycle accidents and dangerous locations

Two of the data sets selected for this study were bicycle accidents and locations considered as dangerous for cycling. This was because both the accidents and the perceived dangerous cycling locations were considered as having a close relationship with cycling safety. Both data sets also contain the spatial information component that can be geographically represented and processed in a GIS tool.

Another significant reason for employing accident data in this study was that the Australian Govenunent only considers the bicycle safety at black spots that are noted in *Australia Cycling 1999-2004: The National Strategy*. Strategy 4.3 of this document states that it is necessary 'to ensure that safety initiatives such as safety audits and identification of black spots include consideration of cycling' (Austroads 1999a, p 11). The inclusion of dangerous locations and accident locations is important, although the perceived dangerous locations identified by cyclists are not entirely black spots. Nevertheless, dangerous locations of cycling have the potential to be black spots due to the observed possibility of accident occurrences.

1.7.2 Improvement

The third data set were the suggested improvements for safer cycling. This study applied Agenda 21[4] together with a strategy of Günther *et al.* (1999) as its principle to identify the improvement cyclists' need. As stated in a local Agenda 21 of United Nation (1999), the participation of all people in the local development and decision-making processes is important:

> Each local authority should enter into a dialogue with its citizens, ... and adopt "a local Agenda 21". Through consultation and consensus-building, local authorities would learn from citizens and from local, civic, community, ... and acquire the information needed for formulating the best strategies.

This issue was addressed in order to assist government organisations to improve road and traffic conditions for safer cycling, which is highly related to a local Agenda 21. Therefore, because this study aims to improve the road and traffic conditions for safer cycling in the study area, the improvements based on the cyclists' perspectives are crucial. The participants have had experience in the case study area and could give better visions on improvements that they require for safer cycling in the study area.

1.8 Scope and limitations

The time frame and the approaches of this study limited the study area, the amount of data and the details that could be collected.

[4] 'Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally by organizations of the United Nations System, Governments, and Major Groups in every area in which human impacts on the environment.' (United Nation 1999)

1.8.1 Study area

Part of the Hobart City Council suburb of Sandy Bay was chosen as the study area (see Figure 1.2). This study area within Sandy Bay includes many significant travel destinations within Hobart. It contains all three levels of educational institutions: primary, secondary and tertiary. Princes St Primary School, the Hutchins School and the University of Tasmania all attract a large volume of motor vehicles to a suburban area with limited parking. Parents' taking their children to school increases the traffic volume during the rush hours. In addition, students, staff, and visitors travelling to the university by car also contribute to the high volume of traffic on surrounding roads and increase the risk for fellow students and staff who cycle.

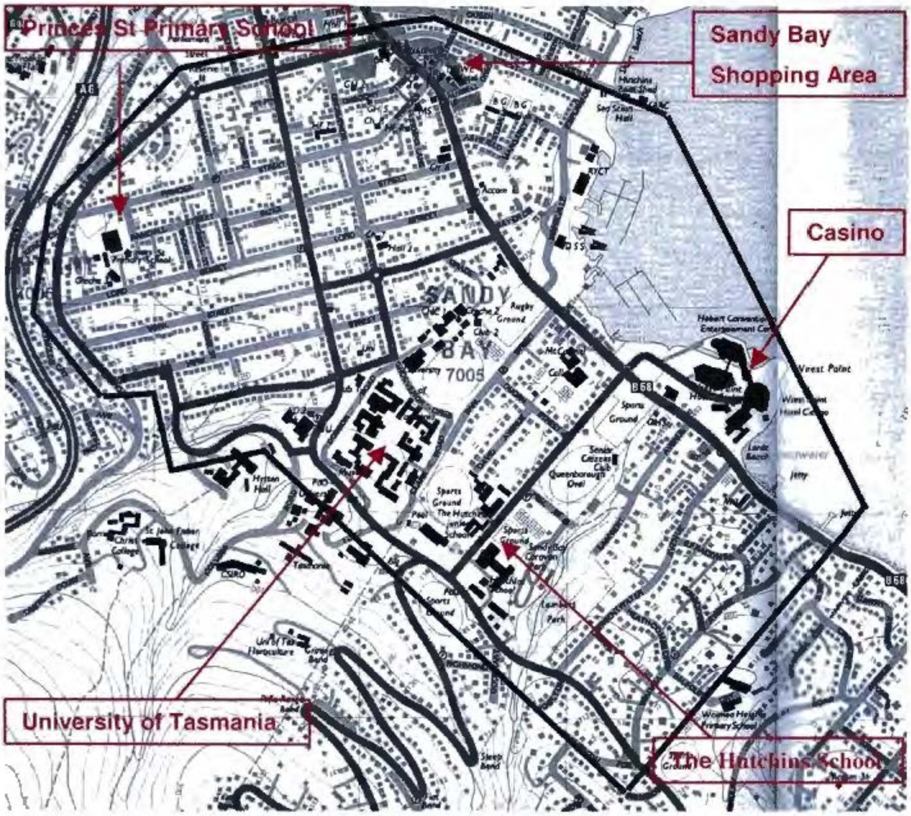

Figure 1.2: Study area, map adapted from Information and Land Services (ILS), (2001)

As can be seen from Figure 1.2, the study area also includes the Wrest Point Casino, hotels, motels, and a shopping area. These draw a high number of local and non-local travellers, again increasing the danger to cyclists who commute on local roads.

Part of the Sandy Bay road network extends from the southern suburbs to the centre of Hobart, including major routes such as Sandy Bay Road and Churchill Avenue. Minor roads such as Grosvenor Street and View Street are different from the major roads with respect to road and traffic environments, and to conditions such as traffic volumes, speeds and lane widths.

This area also contains two travel routes of the main commuter network (Sandy Bay Road and Regent Street) around Hobart Municipality, as indicated by Boyle (1997).

Significantly, according to Boyle (1997), Sandy Bay Road has had the highest bicycle volumes on roads in Hobart, as shown in both bicycle surveys in 1984 and 1996[5]. In addition, in this study area Sandy Bay Road and Regent Street are two of nine roads that have the highest bicycle accident rate within the Hobart City area (see Table 1.1).

Table 1.1: Streets with the highest accident rate in the city of Hobart, adapted from Boyle (1997, p 17)

Road Name	Suburbs
Sandy Bay Road	Sandy Bay / Battery Point
Macquarie Street	Hobart[6] / South Hobart
Augusta Road	Lenah Valley / New Town
Intersection between Augusta Road / New Town Road	New Town / North Hobart
Lansdowne Crescent	West Hobart
Elizabeth Street	Hobart / North Hobart / Battery Point /West Hobart / Mount Stuart
Regent Street	Sandy Bay / South Hobart
New Town Road	NewTown

Unlike other areas of Hobart such as New Town, Moonah and Glenorchy where the Inter-City cycleway runs (ILS 2001) and other Australian capital cities such as Canberra, Melbourne, and Adelaide where bike lanes exist, there are no bike paths and lanes in the study area[7]. This removes potential bias because cyclists tend to use bike paths and/or lanes over roads if available.

[5] This excludes the inter cycleway where had the highest the number of bicycle in the 1996 bicycle survey because the inter cycleway is not a road.
[6] Hobart in this case is the downtown area of the Hobart City.
[7] For information on bicycle lanes in Canberra, Melbourne, and Adelaide see the ACT Government (1998) City of Melbourne (2001) Transport SA (2002), respectively.

1.8.2 Data limitations

As this study has employed GIS as a tool to illustrate results and to assist data analysis, the data used is spatial. The GIS data employed in this study was the street map at 1:25,000 scale from the Fire Service Tasmania (1991). The off-road cycling tracks and roads not open to the general public did not appear in this geographical data and were outside the scope of this study.

Other data and information, such as cyclists' skills and bicycle maintenance, are not included in GIS data processing, because they cannot be geographically presented in the GIS environment. Other parameters, such as cyclists' behaviour, travel patterns, and the volume of bicycles on a given route, were not included in this study because of its focus on the locations of bicycle accidents and dangerous locations for cycling.

The questionnaire used to gain self-reported bicycle accidents did not include fatalities, some serious injuries, and where cyclists could not or would not cycle again. The bicycle accidents obtained from the questionnaire in this study were only accidents that occurred for those who still ride bicycles (Aultman-Hall & Kaltenecker 1999).

1.9 Thesis outline

This thesis consists of five chapters.

In Chapter two, the relevant literature regarding information related to bicycle safety and its solutions is reviewed, followed by cycling issues related to the study area. The review of GIS practice involved in bicycle and safety is then introduced.

In Chapter three, the methodology is outlined. The study design is explained and the two data collection techniques are described, followed by GIS application as well as descriptive statistics, and ending with street-based fieldwork.

Chapter four, presents the main results from the survey; descriptive statistics, spatial data in form of maps together with their description, relationship analysis, and street-based fieldwork.

Chapter five is the discussions of key results; the conclusion of the research outcomes; and ideas for further studies and research.

Chapter 2 Relevant Literature

2.1 Introduction

This chapter is divided into five main sections. Section 2.2 describes safety, accidents and risks related to cycling. Section 2.3 gives examples of strategies for safety cycling in Europe, Australia, Tasmania and Hobart. Section 2.4 lists the existing bicycle suitability criteria, which is associated with cyclists' perceptions of danger, which are explained in Section 2.5. Section 2.6 provides some traffic and road engineering solutions related to safety cycling. Finally, Section 2.7 provides details about GIS and GIS-T in relation to this study. In addition, there is a discussion of cycling activity levels in Tasmania and Hobart that adds information relevant to the chosen study area within Hobart.

2.2 Cycling benefits, safety, accident, and risk

Dekoster *et al.* (1999, p 35) state that 'a large number of potential cyclists are already thinking about cycling today. But they are simply waiting for a sign from the public authorities before they get back on their bicycles along the lines of "it's safe to ride a bike – your area authority is taking care of what needs to be done"'. Therefore, the safety of cyclists is a necessary requirement for promoting cycling as a daily mode of transport in the city area.

Safety is closely related to the absence of accidents and conflicts (road rage) in traffic and 'freedom from injury or risk' (ADONIS 1998, p 82). There are three factors related to the incidence of bicycle accidents: road user behaviour or the human factor, condition of vehicles, and the road environment (Lamm *et al.* 1999; Miller & Shaw 2001; Olson & Dewar 2001). Lamm *et al* (1999, p 20.24) state that 'human error plays an important role in most traffic accidents,' and that 'the major causes of bicycle accidents are:

- Rider error (a conservative estimate): 75 percent (*sic*)
- Vehicle driver error (bicyclists could not escape): 10 percent
- Poor bicycle maintenance: 5 percent
- Defective bicycle trail design or dangerous road condition: 3 percent
- Defective bicycle owner's manual (inadequate instructions): 3 percent
- Defective bicycle assembly at retail level: 2 percent
- Defective bicycle (assembly or design of frame or component): 2 percent'

Günther *et al.* (1999, p 21) said that safety when cycling 'is jeopardised by three main kinds of risk: risk of falling, risk from traffic, and risk from crime.' The last is a social problem rather than a transport problem. This crime problem can be overcome by transport policy, which provides cycling routes that are 'well-maintained, well-lit, well-used and overlooked' and provides cyclists 'with good visibility and intervisibility'(p 21) throughout riding journeys. The risk of falling can be reduced by suitable design and maintenance of cycle paths and roads, and quality of the surface used by cyclists. Risk from traffic can be managed by good road safety policies. In relation to the present traffic system, road safety problems of cyclists are complicated by a combination of many factors, but an underlying cause is the present traffic system - largely designed for car drivers, with insufficient route networks for cyclists (Günther *et al.* 1999).

2.3 Cycling safety strategies

Cycle helmets can provide protection for the head in accidents, but they cannot prevent the occurrences of the accident (Baden *et al.* 1998; Lamm *et al.* 1999). Ways to increase safety for cyclists involve action programs including education, law enforcement, good road and traffic engineering, and encouragement (Geelong Bikeplan Study Steering Committee & the Geelong Regional Commission 1977; City of Madison 2000). However, Baden *et al.* (1998) argued that the best way to reduce injury and death from bicycle accidents is by reducing car speeds and the volumes of motor traffic. These show that there are many different schemes used in different places to improve road safety for cycling. The following sections give some examples of strategies for improving cycling safety in European countries, Australia, Tasmania and Hobart.

2.3.1 European countries

Bicycle safety has improved in many European countries in order to reduce the casualty rate but at the same time encourage the number of trips made by bicycle. The European Transport Safety Council (ETSC) developed key strategies for achieving a safer traffic system for cyclists in European countries, which are:

- managing the traffic mix, by separating different kinds of road use to eliminate conflicts where conditions are favourable to separation;
- creating safer conditions elsewhere for integrated use of road space, for example through speed and traffic management, increased user and vehicle conspicuity, and vehicle engineering and technology;
- modifying the attitudes and behaviour of drivers of motor vehicles through information, training and the enforcement of traffic law;
- consulting and informing cyclists about changes being made for their benefit, and encouraging them in steps that they can take to reduce their risk; and
- mitigating the consequences of crashes through crash protective design and encouraging the use of protective equipment.

And, to these ends

- changing priorities in the minds of professionals and policymakers responsible for the traffic system through sharing of experience and promoting of research findings, and encouraging them to convince the public of the need for change (Günther *et al.* 1999, p 9).

2.3.2 Australia

Australia Cycling 1999-2004: The National Strategy is a national framework from Austroads (1999) for action, which States and Territories take into account to form their own bicycle strategies and plans. Safety for cyclists is an objective of this strategy targeting reductions in the casualty rates, and increasing in bicycle usage at the same time (Austroads 1999a). The safety issues emphasised in the objective are increasing the awareness of all road users for better behaviour when sharing streets or paths (education) and improving the cycling environments (engineering). For an example of applying these strategies, "Bikeplan 2010" of New South Wales focuses on education and engineering for safer cycling (Katz 1998).

2.3.3 Tasmania

Australia Cycling 1999-2004: The National Strategy is also considered as the basis for the Strategic Plan for Tasmania (DIER 2000d). In Tasmania, the programs of the Tasmanian Bicycle Council are developed to reduce the number of bicycle fatalities, cycling injuries, and reported complaints to authorities about the on-road behaviour of cyclists and motorists (DIER 2000b). The main components of the programs are to increase the use of helmets,sufficient lighting on bicycles and motorist awareness of cyclists. The Road Safety Operations Branch of DIER supports cycling safety by providing educational services and resources to schools and community groups throughout Tasmania through its Road Safety Education section (DIER 2000c). The full strategic plan, covering public education, administration, promotion, facilities, and finance, is illustrated in DIER (2000d).

2.3.4 Hobart

The HCC has the "Hobart Bikeplan 1997", which stated strategies to ensure safer cycling by aiming to reduce the bicycle accident rate by 5% by the year 2002 and 10% by the year 2012, relative to the accident rate during the period prior to 1996 (Boyle 1997). Whether the 2002 target has been achieved is not yet known (Broadley 2002, pers. comm.). The "Hobart Bikeplan 1997" focuses on the improvement of facilities for safer, more convenient and more comfortable cycling. It provides recommendations about new infrastructure and improvement of existing facilities.

2.4 Bicycle suitability criteria

Bicycle suitability criteria are rating processes that address bicycle infrastructure: planning, design, and maintenance (Turner *et al.* 1997). Turner *et al.* (1997) carried out a literature review and categorised bicycle suitability criteria into three types: bicycle stress levels, roadway condition index/suitability-based level of service, and capacity-based level of service (LOS). The majority of bicycle suitability criteria are for assessing roadways in urban and suburban areas. Among these criteria, some have applied cyclists' perspectives in their bicycle suitability rating (see Section 2.5).

Bicycle stress level-based criteria are used by Sorton and Walsh (1994), who incorporated only three variables, but not other possible factors assumed to have an effect to bicycle suitability (see more details Section 2.5).

Turner *et al.* (1997) found eleven roadway condition index/suitability criteria: a bicycle safety index rating; a bicycle suitability rating cited by Turner *et al.* as developed by Davis (1995); a roadway condition index (RCI); a modified roadway condition index; an interaction hazard score; bicycle LOS; and a number of bicycle suitability maps relating to road conditioning developed in Gainesville, Florida, city of Austin, Texas, and Middlesex County, New Jersey; the Gainesville congestion management system/mobility plan; and the BCI. Turner *et al.* (1997) also developed a criterion . Therefore, there are in total twelve roadway condition index/suitability criteria. Turner *et al.* (1997, p 16) said that 'bicycle planners mostly use these types of criteria.' The variables most common to all criteria for bicycle route planning are traffic volumes, curb lane width, speed limit, pavement factors, and location factors. See Turner *et al.* (1997) for discussion and details of each criterion, except the BCI (see Section 2.5 on this last criterion).

Capacity-based level of service criteria are composed of Botma's bicycle path LOS, Navin's bicycle LOS, and North Carolina State University's bicycle LOS. Procedures for these three were adapted from the "Highway Capacity Manual", which 'compares traffic volumes to theoretical capacity to evaluate quality of traffic flow' (Turner *et al.* 1997, p15). Botma's criteria were derived from the frequency of cyclists' meetings and/or passings on bicycle paths separated from the road system (Botma 1995). Navin (1994) used bicycle volumes and grade and curve radius for evaluating bicycle paths. North Carolina State University looked at bicycle facilities based on frequency of meetings and/or passings, total bicycle delay from signalised and unsignalized intersections, and average travel speed of cycling (Turner *et al.* 1997). Turner *et al.* (1997) maintained that capacity-based bicycle suitability procedures are unsuitable for most bicycle planning and suitability evaluation requirements.

2.5 Cyclist perceptions of danger

Dewar (2001) states that there have been many attempts to create a measure of cyclists' perception of risk to themselves on the streets. Sorton and Walsh (1994) and Harkey *et al.* (1998) stated that the concept of bicycle stress level was first developed in Australia by the Geelong Bikeplan Study Steering Committee and the Geelong Regional Commission in 1977. The bicycle stress levels were determined by the cycling experiences of research team members. The results showed that the road and traffic conditions considered to have the most impact on the stress level of cyclists were curb lane width (the width of the lane nearest to the curb), motor vehicle speed, and traffic volume (Geelong Bikeplan Study Steering Committee & the Geelong Regional Commission 1977).

Harkey *et al.* (1998) mentioned that this bicycle stress level concept was applied in 1994 by Sorton and Walsh with the first effort to gather perspectives from three groups of cyclists (experienced, casual, and youth). Sorton and Walsh (1994) proposed that the stress levels were determined by three primary variables identified in the *Geelong Bikeplan*, and a number of secondary variables (parking turnover, number of commercial driveways and percentage of heavy vehicles using streets).

Another measure is the relative danger index (RDI) developed by Moritz (1997). Moritz (1997) found that for North American cyclists, riding on the sidewalk was the greatest danger, followed by major streets without bicycle facilities, minor streets without such facilities, streets with bicycle lanes, and bicycle paths. In 1998, Moritz measured RDI for old cyclists. He discovered similar phenomena, namely, that streets with bicycle lanes had a considerably lower collision rate than major and minor streets without any bicycle facilities. Multi-use paths had a high collision rate, and it was extremely dangerous to cycle on the sidewalk (Moritz 1998).

Harkey *et al.* (1998) developed the BCI from the *Geelong Bikeplan* and the work of Sorton and Walsh (1994). The bicycle compatibility index contains eight main geometric and operational variables, which are related to the comfort levels of only adult cyclists when cycling on streets with motor vehicle traffic environments. The bicycle compatibility index shows that the existence of bicycle lanes or paved shoulders (at least 0.9 metre wide) increases the level of comfort for cyclists. In contrast, the level of comfort for the cyclists decreases when traffic volume, motor vehicle speed and the existence of on street parking increases. Three additional variables contributing to the lower level of comfort are large trucks or buses, vehicles turning left into driveways or minor intersections, and vehicles pulling into or out of on-street parking spaces.

2.6 Engineering solutions

Improving road and traffic engineering is significant for safer cycling. The bicycle suitability criteria in Section 2.4 were mainly developed in order to improve road and traffic engineering. Cyclists' perceptions of danger in Section 2.5 confirmed that conditions of road and traffic engineering have the highest effect on the safety of cyclists' on the streets. Moreover, Baden *et al* (1998, p 14) concluded that 'all of the countries with the highest levels of bicycle use and the lowest risks per kilometre cycled, have chosen to create safer road conditions. They have decided that it would be unfair to fail to deal with the causes of the danger and then make road users protect themselves against an inhuman traffic system.'

One example of the successful application of traffic engineering is the separation of bicycles from motor vehicles (such as bicycle lanes/paths) on urban streets in European countries. There was a reduction of cyclist casualties from 1980 to 1995 by 10.5% in Austria, 8.3% in Denmark, 44.2% in France, 43.9% in Germany, 37.2% in the Netherlands, and 29.3% in Switzerland (Lamm *et al.* 1999). Another successful practice is observed in the Netherlands, where a 30 km/h speed limit zone was created, reducing injuries from crashes by 22 % (Günther *et al.* 1999).

Engineering practice in relation to road safety for cyclists is different from place to place because each place has different road and traffic conditions. The author found that "Sign up for the bike: Design manual for a cycle-friendly infrastructure" of Centre for Research and Contract Standardization in Civil and Traffic Engineering (CROW) of the Netherlands has widely been adopted for road and traffic engineering practice for bicycles in many countries such as the United States of America (AASHTO 1999), the Great Britain (Bicycle Association 1996), and Australia (Austroads 1999b).

In Australia, "Guide to Traffic Engineering Practice, Part 14 - Bicycles" (1999b) of Austroads is a standard guideline to all States and Territories. Based on this guideline, three sections of road engineering practice that are suitable for the established carriageway of existing roads, or for the carriageway of new roads, are road design, road intersections, and separate paths. The eight road engineering requirements for cyclists presented in the guide are; exclusive bike lanes[8], bicycle/car parking lanes, contra-flow bicycle lanes, sealed shoulders, protected two-way lanes, advisory engineering requirements, wide kerbside lanes and bus/bicycle lanes. This engineering practice part 14 guides engineering to solve issues at non-signalised and signalised intersections, roundabout, and intersections for bicycle lanes. There are three categories of paths: shared use, separated use and exclusive use.

2.7 GIS and transportation

GIS is a computer-based management system of spatial information that people apply to capture, store, retrieve, control, illustrate and analyse geographic information and is different from other systems due to its multiple functions (Burrough & McDonnell 1998). These GIS functions include geo-visualization capability, analytical capability, and database management of geographic locations (spatial data) and information about the locations (attribute data) (Vonderohe *et al.* 1993; Burrough & McDonnell 1998; Thill 2000; Miller & Shaw 2001). According to this explanation, GIS consist of four main components: technology (hardware and software), data, trained users (people and organisation), and methods of analysis (Vonderohe *et al.* 1993; Burrough & McDonnell 1998; ESRI 2001).

GIS designed initially for defence and intelligence, has been successfully applied in many fields such as business, communications, education, engineering, environmental management, government human and health services, natural resources and utilities (Köninger & Bartel 1998; Longley *et al.* 1999; Crabbe *et al.* 2000; Roberts *et al.* 2000; ESRI 2002b; Government of New Brunswick 2002; Hess & Cheshire 2002; Oldak *et al.* 2002). Despite this, transportation applications of GIS have only been realised since 1988, but have been increasingly used in recent years (Vonderohe *et al.* 1993; Waters 1999; Miller & Shaw 2001).

[8] Exclusive bike lanes are referred to as bicycle lanes in this thesis.

2.7.1 GIS-T

> GIS-T are interconnected systems of hardware, software, data, people, organizations, and institutional arrangements for collecting, storing, analysing, and disseminating information about areas of the earth that are used for, influenced by, or a affected by transportation activity (Fletcher 2000, p 1).

Miller & Shaw (2001) apply this definition in *Geographic Information Systems for Transportation, Principles and Applications*. According to this definition, cycling is a transportation activity that can be represented spatially and this study applied GIS-T as a tool to study cycling safety.

Nevertheless, Vonderohe *et al.* (1993) and Thill (2000) state that GIS-T is more than just one area of GIS application. GIS-T has several requirements on data modelling, data management, and data analysis that are not fulfilled by normal GIS applications. For example, Shaw (2003) claims that GIS-T:

> … has developed its own unique analysis methods and models. Examples include shortest path and routing algorithms (e.g., traveling salesman problem, vehicle routing problem), spatial interaction models (e.g., gravity model), network flow problems (e.g., user optimal equilibrium, system optimal equilibrium, dynamic equilibrium), facility location problems (e.g., p-median problem, set covering problem, maximal covering problem, p-centers problem), travel demand models (e.g., the 4-step trip generation, trip distribution, modal split, and traffic assignment models), and land use-transportation interaction models.

In addition, Shaw (2003) states that GIS-T:

> … covered much of the broad scope of transportation, such as infrastructure planning, design and management, transportation safety analysis, travel demand analysis, traffic monitoring and control, public transit planning and operations, environmental impacts assessment, hazards mitigation, and intelligent transportation systems (ITS). Each of these applications tends to have its specific data and analysis requirements. For example, representing a street network as centerlines and major intersections may be sufficient for a transportation planning application. A traffic engineering application, however, may require a detailed representation of individual traffic lanes. Turn movements at intersections also could be critical to a traffic engineering study, but not to a region-wide travel demand study.

Moreover, 'many of the operations commonly found in commercial GIS-T packages ... would incorporate the standard capabilities to be found in any GIS. These operations include data edition, display, and spatial and conditional search functions' (Waters (1999, p 830). Additionally, Shaw (2003) states that 'GIS-T applications have benefited from many of the standard GIS functions (query, geocoding, buffer, overlay, etc.) to support data management, analysis, and visualization needs.' Therefore, in many cases such as in *the present study*, GIS-T is referred to with the term of GIS rather than GIS-T because the basic functions have been used rather than special functions described above. From the author's observation, even though GIS-T special functions have been applied to solve transportation problems, GIS-T users tend to use the term GIS rather than GIS-T.

In accordance with Miller & Shaw (2001), GIS-T has two fundamental components: principles and applications, but here the focus will only be directed to GIS-T applications rather than its underlining principles.

2.7.2 GIS capabilities for transportation matters

GIS data and functions, such as analytical capabilities, lead to a major change in transportation research and decision making because the transportation industry is increasingly employing GIS in order to better understand and plan the complexities and problems of transportation (Lang 1999; Miller & Shaw 2001). Potentially, GIS will allow greater access to transportation information by the general public that encourages wider participation in the transportation planning process and analytical decisions that can in turn reduce the gap between analysis and communication (Miller & Shaw 2001).

2.7.3 GIS applications for transportation

GIS has a broad scale of applications that covers the wide array of transportation modes such as land, water, air and even space. The main GIS application centres on road transportation, because this is the major form of transportation (Miller & Shaw 2001). There are many aspects within on-road transportation as shown in the previous section. The following sections cover the applications related to safety, accidents and bicycle safety.

2.7.3.1 An application related to road safety and accidents

There are many GIS applications to road safety and accidents. One example presented here is an application in San Leandro, northern California since 1998 (Lang 1999). GIS was used to investigate traffic collisions in order to prioritise traffic areas in most need of improvement. Transportation Division engineers use GIS to find accident information on locations, cause, date, time of day and type of vehicle. An additional data overlay would present all of the collisions occurring on a specific street during a past year. Each collision was categorised by causes, the type of involved vehicles, time, and severity such as property damage only injuries, or fatalities. Querying the system on the type of collision over a selected time can reveal high frequency collision areas. As a result, the engineer would be able to better and more specifically evaluate the situation in the field and speed decision making processes by motorists (Lang 1999).

2.7.3.2 Bicycle safety and GIS

There have been many uses of GIS for bicycle safety and accidents. Examples include Staats (2000) applying GIS to identify municipalities in New Jersey with the highest accident occurrences involving cyclists. Spagnola (1994) used GIS in accident analysis: correlation of bicycle accident and school locations. The result of this research showed that bicycle accidents occurred in proximity to school zones more frequently than others. Aultman-Hall & Kaltenecker (1999) utilised GIS to estimate the travel exposure of cyclists using different types of infrastructure in Toronto: on road, off road and sidewalks. Aultman-Hall & Hall (1998) conducted the same study as the previous application in Ottawa.

The last application discussed here is "GIS safety analysis tools", which use the BCI to find the best bicycle route by calculating the comfort of each street segment based on roadway and traffic characteristics (CGIA 2000; FHWA 2000). The result is a colour-coded map of all streets derived from the BCI.

2.8 Promoting cycling activity in Tasmania and Hobart

This section covers the interest in cycling occurring in Tasmania and Hobart, and further supports the selection of both study topic and study area.

2.8.1 *Tasmania*

In Tasmania, individuals, communities, private organisations (such as Bicycle Tasmania and CyclingSouth) and even governments departments (such as the Department of Energy Infrastructure and Resources, the Hobart City Council and the Tasmanian Bicycle Council) are aware of a wide range of benefits that they can obtain from cycling (DIER 2000a). Cycling activities are increasingly promoted and encouraged by these institutions. Examples of cycling activities include the State Bike Week, The Bicycle Education Unit for 8 to 13-year-olds, the Five-Alive! School Holiday Program and the 18 - 25 days bicycle tour around Tasmania called GIRO TASMANIA (DIER 2000d; DIER 2000b; CyclingSouth 2001; Beggs & Phillips 2002).

2.8.2 *Hobart*

According to (Peters 2002), Hobart, the capital city of Tasmania, has the highest rate per 100,000 population of any Municipality in Tasmania for accidents involving cyclists. Therefore, the need for safer road environments is essential to reduce potential conflicts and accidents between cyclists and motor vehicles, in order to succeed in raising the number of cyclists and usage of bicycles. Moreover, bicycle accidents are a financial burden for the wider community. Between 1985 and 1995 in the Hobart Municipality alone the cost to the community of bicycle accidents was estimated at $5.6 million (Boyle 1997). The average costs per cycling accident, based on levels of severity, were $752,400 for fatality, $113,100 for serious injury with hospitalisation, $11,900 for minor injury without hospitalisation and $5,000 for minor and major property damage.

Hobart is a suitable case study because only a small proportion of Hobart residents (approximately 1%) use bicycles to travel to work and study (ABS 2001) compared with the national average of 2.4% (ABS 2002). Despite the small size of Hobart, and the closeness of educational institutions to cyclists' houses, the proportion of cyclists is very low. Furthermore, this percentage is low considering the number of government and private bicycle organisations in Hobart, including the Tasmanian Bicycle Council, Bicycle Tasmania, Giro Tasmania, Veterans Cycling Council, Tasmanian Cycling Federation, CyclingSouth, Triathlon Tasmania, Hobart Wheelers, and Cycling Tasmania.

In Hobart, there are many government and private organisations who support increases in the number of cyclists. Examples include the Hobart City Council which has developed the Hobart City Bike Plan (Boyle 1997) as well as the Corporate and Community Greenhouse Local Action Plan (HCC 2001). The Corporate and Community Greenhouse Local Action Plan identifies a variety of strategic objectives and actions to reduce greenhouse gas emissions from Council's corporate greenhouse emissions (such as vehicle, waste and sewage treatment plant) by 70% and community greenhouse emission (such as industrial, transport, waste, residential and commercial) by 20%. In order to achieve this, one of the goals is to increase the use of bicycles for recreational and commuting activities as a greenhouse friendly alternative to vehicular transport, thus reducing community transport sector greenhouse gas emissions. In order to achieve this, the Hobart City Council implemented the Hobart City Bike Plan along with coordination from the Tasmania Bicycle Councils (HCC 2001).

The "Hobart Bikeplan 1997" states strategies to increase the activity of cyclists by 5% for the year 2002 and 10% by the year 2012 based on the bicycle volume survey undertaken in 1996 (Boyle 1997). These figures are the same as the figures of the reduction in bicycle accidents as mentioned earlier. In addition, the Tasmanian Bicycle Council, under the Minister for Infrastructure, Energy and Resources (2000d), supports the increase in both the number and the safety of cyclists on roads by aiming to:

- increase community health and well-being;
- reduce the impact of travel on the overall transport system; and,
- increase travel opportunities for those without access to private motor vehicles (DIER 2000d).

The desired result is a reduction of car use in the urban environment. Concern for the safe movement of cyclists through urban environments such as Hobart is demonstrated by the wide range of membership of the Tasmanian Bicycle Council. Such members include:

- Department of Infrastructure, Energy and Resources,
- Tasmania Police,
- Office of Sport and Recreation, Department of Environment and Land management,
- Bicycle Tasmania, Local Government, including individual councils,
- Bicycle Industries and Traders Association,
- Local Government Association of Tasmania,
- Royal Automobile Club of Tasmania,
- Tasmanian Cycling Federation, and
- Individual cycling clubs (DIER 2000a).

The wide ranges of cycling activities and encouragement taking place in Tasmania makes Hobart an interesting location for study.

2.9 Chapter conclusions

Accidents and risks are major threats to cycling and in many places safety strategies have been developed to reduce these by promoting cycling safety. However, Tasmania and Hobart are examples of places where the development of safety strategies lags behind, compared to some of the European countries. Recently, there has been the development and use of bicycle suitability criteria as well as cyclists' perceptions of dangers for bicycle planning. However, none of the bicycle suitability criteria rating systems use black spots as one of the variables. None of the criteria are used to predict and identify black spots. Bicycle suitability criteria are mainly related to the comfort of riding rather than the safety aspects.

GIS-T as GIS for transportation has been applied to an increasingly wide range of transportation problems in air, water and land transport. It is found that generally the term GIS-T has not been referred to when GIS applications related to transportation matters. It is rather described as GIS. The thesis author found very few GIS applications related to bicycle safety and accidents. The recent GIS application associated with cycling safety is a combination of GIS and BCI (bicycle suitability criteria and cyclists' perception of dangers).

The city of Hobart, Tasmania is an important study place as Hobart has the highest bicycle accident rate in Tasmania and a low proportion of bicycle commuters compared with the rest of Australia. The private and government organisations in Hobart together with the "Hobart Bikeplan 1997" support an increase in bicycle usage and reductions in bicycle accidents.

BCI, GIS application, and the promotion of bicycle use in Hobart point to the focus of this study; the relationship between bicycle accident rates and cyclist perceptions of danger. Moreover, it is also important to identify improvements for safer cycling.

Chapter 3 Methodology

3.1 Introduction

The function of this chapter is to describe the methods that were developed to achieve the aims and objectives of the study. The next section describes issues related to study design, which influenced the methodology of this study. Then, the data collection methods are introduced. Section 3.4 presents an account of the data management for descriptive statistics and the use of GIS to illustrate the spatial component of the results in the form of maps. Based on the map results, together with the information from the cyclists, Section 3.5 gives details of practical street-based fieldwork as an input to the recommendations for changes in the existing infrastructure.

3.2 Study design and orientations

The study was designed to apply a quantitative approach in order to gain the data needed to fulfil the aims and objectives. A quantitative approach was suitable because the collected data were manipulated numerically in meaningful ways as required for descriptive statistics and GIS application. The quantitative approach to research has the orientation to generate the methodology for this study. The orientations of a quantitative study are stated as follows:

> Almost all quantitative researchers rely on a positivist approach to social science. They are likely to use a technocratic perspective[9], apply "reconstructed logic[10]," and follow a linear research path[11] (Neuman 2000, p 122).

Since this study was carried out on a quantitative basis, a social science approach described as positivism[12] was selected as a suitable to fulfil the aims of this study. Positivism is closely associated with the quantitative approach. Neuman (2000, p 66)

[9] Technocratic perspective is 'the perspective of technician who serves bureaucratic needs' (Neuman 2000, p 123).
[10] Reconstructed logic is the logic of organising study is in a systematic form (Neuman 2000).
[11] A linear research path is 'a fixed sequence of steps' (Neuman 2000, p 124).
[12] Positivist social science is broadly defined as positivism (Neuman 2000).

mentioned that 'positivist researchers prefer precise quantitative data and often use ... surveys and statistics', and 'almost all quantitative researchers rely on a positivist approach to social science' (p 122).

The author applied the linear research path, which heads in one explicit direction. In line with the use of reconstructed logic, the practical procedures were conducted step-by-step with clear methods of data collection, application of GIS and fieldwork (see Figure 3.1). Due to the potential interest of this study to government organisations, the technocratic perspective in this study is given by analyses directed towards increasing their competence in planning for cycling safety. For example, the results of the study will help organisations involved with planning and management of the urban road environment.

Data collection

↓

Data management and GIS application

↓

Fieldwork based on GIS maps, dangerous places,
accidents locations, and cyclists' recommendations

Figure 3.1: Linear research path of the study

3.3 Data collections

The appropriate means of data collection for this study was the quantitative technique, which is in line with the aim of using GIS, and analysing and representing quantitative data. According to Singleton and Straits (1999, p 369) 'large samples generally enhance our confidence in study results', therefore this study adopted two quantitative data collection techniques: existing statistics, and the survey of cyclists.

In addition, the additional accident data were needed in this study to enhance the existing bicycle accident data. This supplementary data were obtained from the implementation of the questionnaire survey because Dewar (2001) indicated that it is important to have sufficient statistics on road accidents, but when it comes to bicycle accident data, it is often insufficient. Dewar (2001) also said that the main reason for the under-reported accident is that many bicycle accidents are not involved in property and people damage that necessitates the reports to police and insurance companies like motor vehicle accidents. In Australia, Bicycle Federation Australia (BFA) analysed that road accident hospitalisations of cyclists were 19%, which was five times higher than the road crash casualties collected by the police (Katz 1999). In Tasmania, Boyle (1997) mentioned in the "Hobart Bikeplan 1997" that the proportion of the bicycle accident under the police report in the Hobart city area is one reported accident to nine unreported accidents. For these reasons, there was a need to gather the supplementary accident data.

As a result, the bicycle accident data were obtained from two sources: the existing data collector and the implemented survey while the cycling dangerous location data were gained only from the questionnaire survey.

3.3.1 Existing statistics research

The first step was to locate the data by seeking out information from documents, the Internet, and relevant organisations specific to the study area. After a search, only two documents were found. The first document was the Hobart Bikeplan 1997, which identified four sources of accident data: police reports to DIER, the Motor Accidents Insurance Board (MAIB), Menzies Centre for Population Health Research, and Hospital Admissions to private hospitals (Boyle 1997). The second document was the Road Safety Strategy for Hobart (Peters 2002) containing one source: police report to DIER.

It turned out that DIER held the relevant bicycle accident data with the necessary spatial component for GIS. Therefore, police reports to DIER were then selected, as data from the Motor Accidents Insurance Board (MAIB), Menzies Centre for Population Health Research, and Hospital Admissions to private hospitals did not include location details suitable for GIS.

The DIER data are in the form of published compilations available on a computerised database (Cure 2002). The data collected dates from 1988 to November 2002. The author decided to use the data from this entire period. This was due to the small amount of accident data available; so, to better identify the black spots, the larger amount of data, collected over many years was valuable. Of the 87 bicycle accidents that occurred within the Sandy Bay area as a whole, 48 bicycle accidents occurred in the study area. These 48 represented 55.17% of reported bicycle accidents in the Sandy Bay area.

3.3.2 Survey

The survey was undertaken by using a questionnaire to gather data. The copy of the questionnaire can be seen in Appendix 1 and details of the questionnaire design can be seen in Appendix 2. The following sections describe survey matters undertaken in this study: ethics; validity and reliability; the population, the sample and location of survey; time and data collection techniques.

3.3.2.1 Ethics

Prior to commencing the survey, a formal approval was obtained from the Human Research Ethics Committee of the University of Tasmania. The ethics approval helped to ensure that the survey methods and the questionnaires did not include risks that could affect participants. Confidentiality was maintained by the investigator, and anonymity was ensured by de-identifying the information collected. Trustfulness was gained by giving each participant an information sheet explaining the purpose of the study, participants' rights in the study, and the investigator's contact information.

3.3.2.2 Reliability and validity

The author checked the validity and reliability of the questionnaire before administering the survey, as 'both ideas are important in establishing the truthfulness, credibility, or believability of findings' (Neuman 2000, p 164).

Neuman (2000) stated that reliability can be improved by undertaking a pre-test or a pilot test. Thus, both techniques were adopted to increase the reliability of this study. The pre-test was conducted first. The first draft of a questionnaire was developed from the author's knowledge. Initially, the pre-test was sent to five government officials, who are the experts in relation to bicycle issues and accident matters and one academic.

Two experts provided their feedback and comments, which were incorporated into a second draft, along with those from the academic[13].

The pilot was developed to improve the second draft before launching the final version, but also incorporated an earlier, different phase. As Neuman (2000, p 166) stated, 'the principle of using pilot tests extends to replicating the measures other researcher have used.' The second draft was developed not only from the suggestions from the pre-test, but also other research undertaken in the past. This draft applied parts of some questions from Burden and Burgess (1978) and Safe Routes to Schools Information Service (2000). See Appendix 2 for full questionnaire detail.

A pilot study is different to a pre-test because a pilot test is directed at a sample of the population (Babbie 1990). Babbie also mentioned that the pilot test sample could be chosen in the same way as the final survey. The pilot test was undertaken with a group of cyclists from the study sample. The participants were 10 cyclists, all postgraduate students, who were regularly riding bicycles to the University of Tasmania, Sandy Bay campus. Problems with questions and questionnaire design were detected and improvements made.

The validity of this study was measured during the pre-test and pilot test by adopting one type of measurement, face validity. Face validity[14] was chosen because it is the most basic type of validity and the easiest to attain (Neuman 2000). In this case, face validity was achieved by asking experts and cyclists to comment on the questionnaire form and to give their understanding of each question. Respondents suggested changes in both format and expression used in questions.

[13] Sarah Boyle from DIER, Mark Broadley from HCC, and Assoc. Prof. John Todd, recently resigned from the University of Tasmania.

[14] Face validity is 'a type of measurement validity in which an indicator "makes sense" as a measure of a construct in the judgment of others' (Neuman 2000, p 510).

3.3.2.3 Population, sample, and location of survey

In theory, all people who have ever participated in any type of cycling activity, at any point in or through the study area, were the population of interest. However, the total population is unknown. Therefore, the author selected availability sampling[15] from amongst non-random sampling techniques[16].

The sample selected was cyclists who parked their bicycles on the bicycle racks within the University of Tasmania, Sandy Bay campus, which is in the study area. These cyclists were students, staff and possibly visitors to the campus. This selection was based on anecdotal evidence that cyclists who ride bicycles to university tend to know the area better and use many more roads than other cyclists who do not ride bicycles in the study area at all, or who cycle less in the area. Anecdotally, they were also the majority of cyclists in the study area.

The number of samples (cyclists) was identified based on preliminary work undertaken by the author during work for an earlier coursework unit in the same year as the survey (2002). The number of cyclists from this previous work varied between 50 and 80 per day. This excluded then unknown cyclist, mainly staff and postgraduate students, who kept their bicycles within the buildings. From this past experience, the author estimated the number of the samples would be approximately 100 cyclists.

Due to the limited number of staff members, students and visitors to the campus who commute by bicycle, as close to a 100% sample as possible was aimed for, in order to obtain as comprehensive a list as possible of dangerous places, bicycle accident locations and recommendations for improving the safety of cycling within the study site. The overlap between the survey and the pilot test was not considered a problem (Babbie 1990, p 226). Therefore, cyclists, who participated in the pilot test, were included in the survey, and 100 questionnaires were distributed to cyclists.

[15] 'Availability sample is a form of non-random sampling in which the sample units are selected simply because they are available' (de Vaus 1995, p 388).
[16] 'A non-random sample is a type of sample in which the sampling elements are selected using something other than a mathematically random process' (Neuman 2000, p 515).

3.3.2.4 Period and techniques of data collection

Questionnaires were handed out at all 18 bicycle racks on the University of Tasmania, Sandy Bay campus. Surveys were undertaken on a face-to-face basis, and also "bicycle-mail" questionnaires were handed out in order to save and manage time efficiently, as it was difficult to see all cyclists face-to-face. The survey was conducted over 30 days, between 14th October and 12th November 2002.

The bicycle-mail questionnaire was conducted at bicycle racks, where the questionnaire and associated papers were taped onto bicycles in envelopes, or by handing the questionnaires directly to people at university who were known cyclists. A bicycle-mail questionnaire contained an information sheet with explanations, a self-addressed and stamped envelope to return the questionnaire, and a note stating the limits of the survey period. This bicycle-mail procedure at racks was followed on one day, to avoid duplication. Sixty-eight questionnaires were distributed at this time. The 32 face-to-face questionnaires were conducted at bicycle racks.

3.4 Data management

In order to gain insight into the data, both spatial and non-spatial data had to be manipulated. Since data were processed into numerical form, each of the returned questionnaires was entered into Microsoft Excel 2000. The data were managed in three ways: descriptive statistics[17], GIS application for spatial and related non-spatial data, and linear regression. The following sections describe each data management method.

3.4.1 Descriptive statistics

Descriptive statistics were used to summarize a set of responded observations. Descriptive statistics were suitable because the primary interest was the features of existing data and the attitudes and characteristics of survey respondents. As Neuman (2000) stated that the availability-sampling technique, which this study applied, is highly unrepresentative and ineffective, the patterns in the sample are unlikely to apply in a population as chosen in this study. This is contrary to a random sampling

[17] Descriptive statistics is 'a method for presenting quantitative descriptions in a manageable form' (Babbie 1990, p 283) and 'a general type of simple statistics used by researchers to describe basic patterns in the data' (Neuman 2000, p 508).

technique. Therefore, it was not considered appropriate for this study to apply inferential statistics[18] to generalise the results from the sample to the population because the sampling method was not a random sampling.

Suitable descriptive statistics for describing data vary depending on the type of quantitative data (de Vaus 1995; Denscombe 1998).

- Responses to Questions 1, 5 to 8, 10 to 13, and 15 were in the form of nominal data. Frequency (counting) and percentage were applied to describe this type of data.
- Questions 2 to 4, with answers set up as ratio data, were arranged into interval data by grouping into five broad categories. Questions 2 and 3 were organised into ten-year categories while Question 4 was arranged into five-year categories. Thus, the mode, range, minimum, maximum, median, frequency, percentage, and cumulative percentage were used to describe the data.
- It is realised that it is appropriate to perform cross-tabulation between Question 13 and Questions 1, 2 and 3. Frequency was applied in order to present the results.
- Questions 9 and 14 provided spatial data components (locations) arranged by using frequency in a form that could be entered in GIS attribute tables (see Section 3.4.2 for details).
- Question 16 was open-ended, in which the answers were grouped into two main groups based on the given suggestions: specifically to particular streets or generally applying to the whole study area. These two groups were further divided into four categories based on more specific given suggestions, which were further separated into greater detail (see Table 3.1 and Table 3.2). Frequency and percentage were used to quantify and describe all given suggestions.

[18] Inferential statistics is 'a branch of applied mathematics or statistics based on a random sample' (Neuman 2000, p 512) and 'a class of statistics which enables one to estimate whether sample results are likely to hold in the population' (de Vaus 1995, p 390).

Table 3.1: General suggestions on the improvement for cycling safety applying to the whole study area

General suggestions to the study area	
Modify human behaviour	Improve cyclists' riding skills and awareness
	Increase drivers' awareness
Dedicated bicycle route[19]	Establish bike lane/path
	Establish bicycle route from New Town to University
	Establish bicycle route from city to University
	Establish bike path from Inter-City Cycleway to University
	Establish waterfront bike path to Casino
Other road and traffic engineering practices	Wider streets
	Reduce speed limit
	Remove potholes
	Establish roundabouts at intersections
	Install traffic light for cycling
	Install traffic time for cycling
	Install bicycle signs to warn driver about the exist of cyclists
Legislative matter	Permission to ride bicycles on footpath

Table 3.2: Specific suggestions to improve the safety of cycling on the particular streets

Specific suggestions to particular streets	
Sandy Bay Road	Reduce traffic volume
	Reduce traffic speed limit
	Establish bike Lane
	Remove car parking
	Improve Intersection between Earl and Sandy Bay
Regent Street	Remove car parking
	Move car parking into footpath
	Establish bike lane
Churchill Avenue	Establish bike lane
	Improve Intersection between French and Churchill
Governors Crescent	Allow riding against traffic

3.4.2 Use of GIS

The study applied GIS for data representations by mapping identifying the bicycle accident locations and dangerons places that contributed to the analytical purposes of this study. Visual representation is important as it portrays descriptive information unequivocally. The spatial components of the data were represented in the form of maps, together with their attribute data in the form of tables. GIS mapping development was undertaken after finishing the data collection and organisation.

[19] Dedicated bicycle route is one road and traffic engineering practice. Due to the high number of cyclists selecting dedicated bicycle route, it would be appropriate to separate dedicated bicycle route from other road and traffic engineering practices.

The GIS programs available for this study were ArcView 3.2a (ESRI 2000) and ArcGIS 8.2 (ESRI 2002a). Both were used in spatial data processing and mapping. ArcGIS 8.2 was applied for map illustration. GIS street map data used in this study was 1:25,000 Street Network of Hobart (Fire Service Tasmania 1991). This street data is available in an ArcInfo™ coverage.

3.4.2.1 Arrangement of spatial and non-spatial data

Following a preliminary analysis of the questionnaires as well as the DIER data, the spatial data were categorised into three groups: entire streets, street sections and intersections. The grouping was based on locations (intersections or not) and the areas they covered (entire street or not). Within street section and intersection data, groups were divided into two subcategories, based on two sets of spatial data: accidents and dangerous locations (see Figure 3.2). The spatial data used in making accident maps were from the combination of questionnaire and DIER data. Consequently, five maps were generated from nominal data and placed in these five categories.

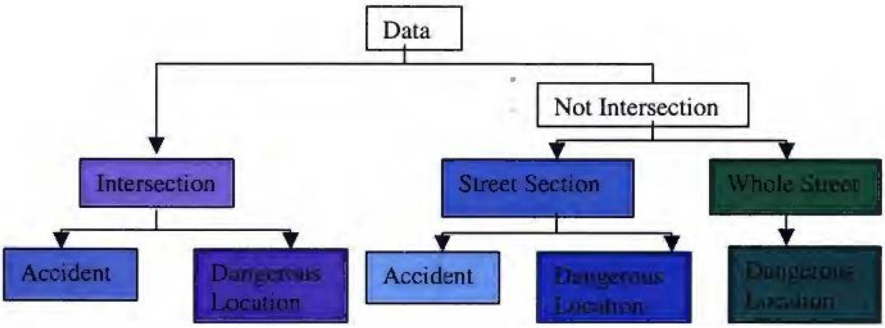

Figure 3.2: GIS mapping, based on five different maps of accidents and dangerous locations, derived from processing three sets of spatial data: intersection, street section, and entire street.

In order to gain a better understanding of the data maps of dangerous locations, their descriptive information was placed in conjunction with the maps. After the dangerous locations were identified, the reasons, which made them so provided a clearer picture of why they are dangerous. The reasons behind the danger lay in the data about road and traffic environmental conditions. These data were then split into three groups based on the three dangerous location maps.

In the cases of the accident maps, the data were not presented because accident data from DIER did not use the same kind of information as the questionnaire. Checking the possible duplication between the DIER data and the survey was based on whether it was reported or not. Two bicycle accidents were found, reported to police. However, areas and time of bicycle accidents did not match in the DIER data. Therefore, both were used in the accident data processing. All accidents occurred in the study areas from the DIER data and the survey were included in the mapping process.

The connection between spatial and non-spatial data was the street names. From the questionnaire maps, the street names of each location could be identified. The GIS base map contained street names as one part of its attribute data. Based on street names, road and traffic environment data were organised by using frequency. In this case, frequency was the most suitable way to show the quantity of accidents at each location. Frequency displayed which streets were selected and how many cyclists identified. Moreover, it gave a clearer picture of which road and traffic conditions contributed to the cycling danger in particular entire streets, street sections, and intersections.

3.4.2.2 Map making

GIS operation for making maps comprised three processes based on which categories they belong to (see Figure 3.2). The processes were operated in ArcView 3.2a and ArcGIS 8.2. The only spatial data in numerical form used in this program were the frequencies of accidents and the number of places being selected.

3.4.2.2.1. GIS data management and preparation

The only data required in the mapping processes were line figures to represent streets within the study area, and 10-metre street sections outside the study area either continuous with study area streets or intersecting them. Therefore, the study area data needed was extracted from the original data (see Figure 3.3). A check of the GIS data used in this study was conducted. Two errors were found and fixed.

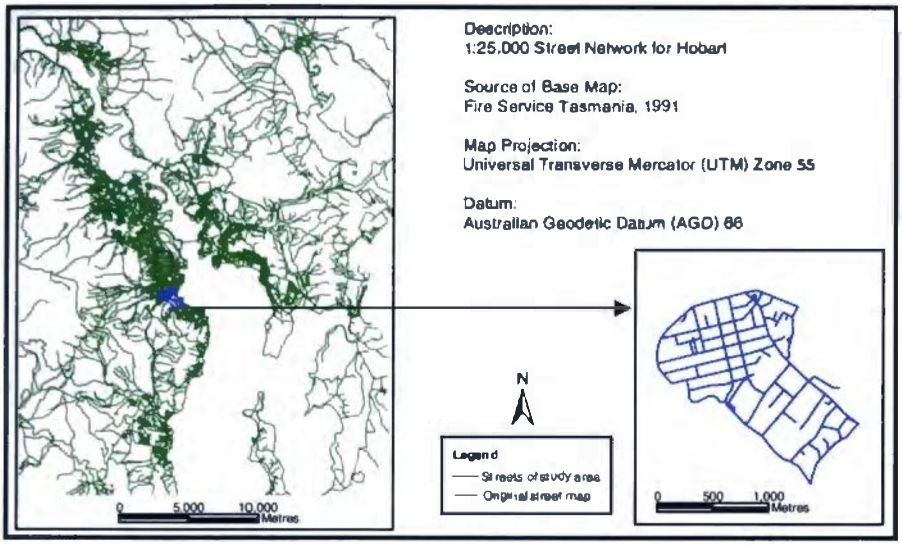

Figure 3.3: Street maps show the study area map extracted from the original map adapted from Fire Service Tasmania (1991)

Preparing GIS data prior to launching into the three mapping processes began by dissolving the street line figures that had the same street names. This process merged all adjacent arcs that had the same name for a street item between two adjacent nodes.

3.4.2.2.2. Entire streets

Entire streets in this study refer to: 1) entire sections of streets within the study area such as Sandy Bay Road and Churchill Avenue and 2) entire short streets such as French Street. Entire streets were only relevant for dangerous locations.

The "Dissolve" function of ArcView was used to generate a theme showing one street name per line. After frequencies of each street were identified, these were added into a newly created field (called frequency) of the GIS attribute table (see Figure 3.4).

entirefreq.dbf

Shape	Street	Frequency
PolyLine	SANDY BAY RD	16
PolyLine	REGENT ST	9
PolyLine	CHURCHILL AV	4
PolyLine	GREGORY ST	2
PolyLine	LOWER PART NELSON RD	2
PolyLine	PROCTORS RD	1
PolyLine	RANDALL ST	1
PolyLine	FRENCH ST	1
PolyLine	DERWENTWATER AV	0
PolyLine	BINNEY CT	0
PolyLine	CRISP ST	0
PolyLine	CLARK RD	0

Figure 3.4: Attribute table of entire streets showing frequencies of each entire street

3.4.2.2.3. Street sections

Street sections refer to sections of streets between two adjacent intersections. The figures considered as sections were:

- accident spots from DIER and respondents-identified accidents taking place between two adjacent intersections;
- dangerous spots between adjacent intersections; and
- dangerous sections where the lines drawn by respondents did not cover the entire street.

The bicycle accident spots were point figures, but treated as line figures. The bicycle accidents from DIER did not contain any mapped location data (only street names) or coordinates. For this reason, bicycle accidents occurring between intersections were treated as line figures. Frequency was used to describe and illustrate the accident rate.

The street sections representing dangerous places were a combination of point and line figures. The dangerous spots, which were point figures appearing between adjacent intersections were specified as line figures. This technique was adopted to avoid the potential inaccuracy based on marks on the questionnaire maps completed by the respondents, and possible imprecise positioning due to the digitising process when the maps scale of the questionnaire and GIS maps were different. Sometimes a respondent selected a length of street, which covered more than one sections.

Frequency of dangerous places was based on the combined number of dangerous spots and places selected by respondents. The number of times each street section was selected ranged from 0-23 occurrences. Representing all 23 levels in different colours might be confusing to interpret. Based on the number of people selecting each street section, they were grouped into 0, 1, 2, 3-5, 6-10, 11-15, 16-20 and 21-25 because the majority of data were less than 5 (see Appendix 5). The interval of 1-5 was subdivided into smaller groups because the majority of data were within the 1-5 interval. Sandy Bay Road was individually illustrated based on frequency, as all street sections along the street were selected. In the case of road and traffic environments including dangerous sections, each subsection retained the same value as the original length.

Each section was given a name based on the streets they were a part of and adjacent intersections. The streets outside the study area but connected to streets within the study area, created intersections and separated street sections were included.
There are three streets, which have two street parts joined to the same streets, creating two intersections each: Nelson Road connected to Churchill Avenue, Magnet Court connected to Sandy Bay Road and Reynolds Court connected to Proctors Road. These three were divided into six names based on the directions: north named "Upper Section" and south named "Lower Section" (see Figure 3.5).

Note: two street sections on Sandy Bay Road between King Street and Gregory Street are: 1) King Street to Upper Section Magnet Court, and 2) Upper Section Magnet Court to Gregory Street. The dangerous locations were shown as two sections. However, the DIER accident data identified accidents occurring between King Street and Gregory Street. Therefore, the accident data were presented as occurring between King Street and Gregory Street.

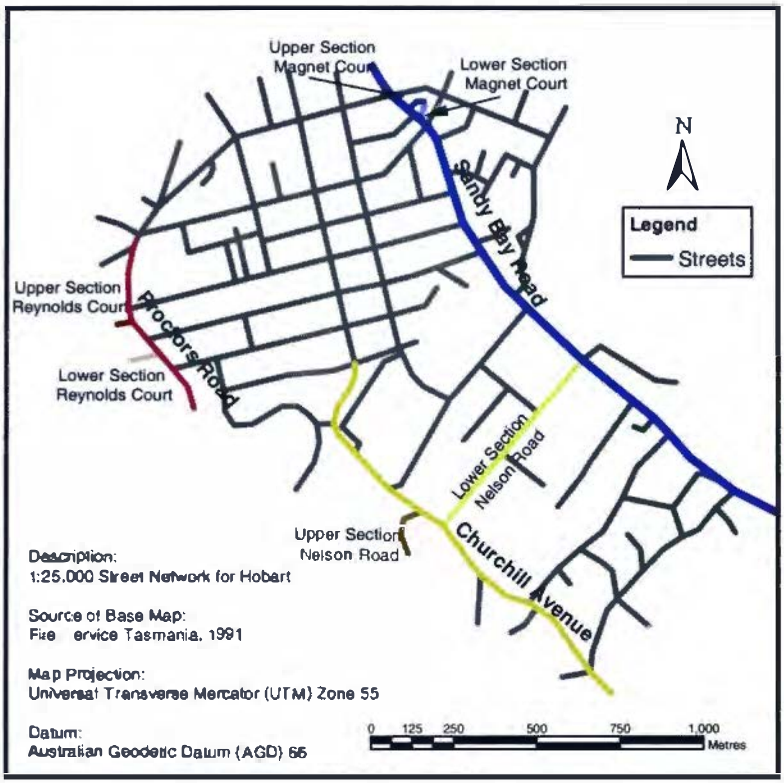

Figure 3.5: Upper and lower sections of Megnet Court, Nelson Road, and Reynolds Court

3.4.2.2.4. Intersections

Intersection maps were divided into two groups: accidents and dangerous locations. The intersection data were derived from accidents at intersections from DIER data and questionnaires. The data regarding dangerous places were from questionnaires only, where respondents marked intersections.

According to Cure (2002), police record bicycle accidents that occur within 10 metres of intersections, as having occurred at the intersection. Therefore, the created intersections were specified 10 metres from the node figure. Figure 3.6 shows the process of creating 10 metre intersections from the intersections using GIS 'buffer' and 'clip' functions. The accident frequency at each intersection was added into the newly created field of the attribute table. The data illustration was based on these frequencies.

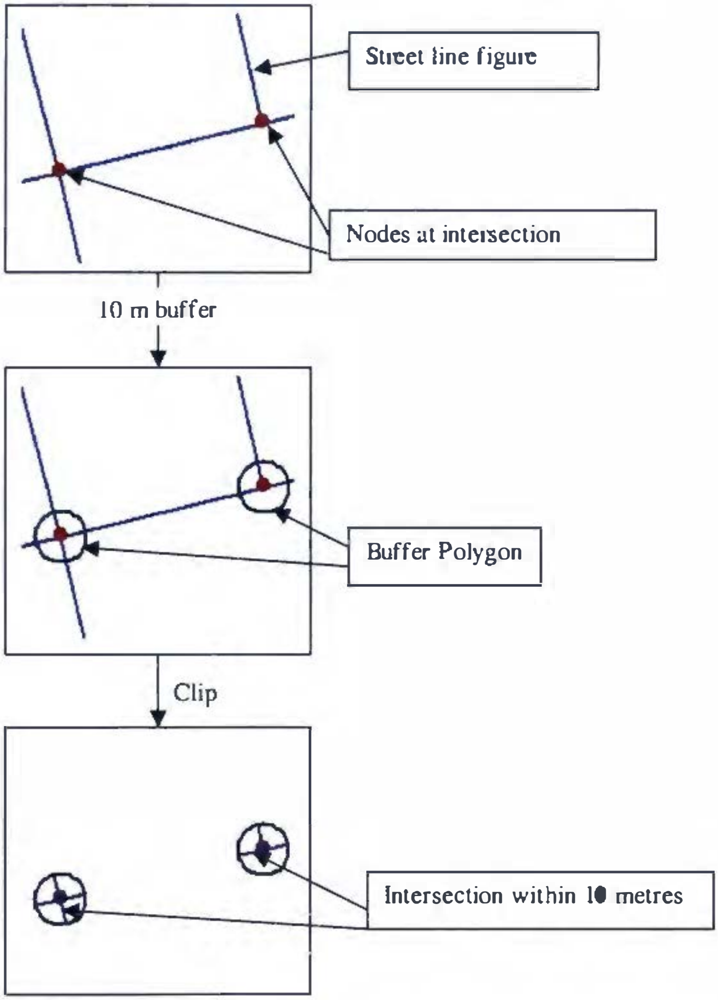

Figure 3.6: Buffer and clip process in GIS environment

Each intersection was given a name based on the two streets that created it. The streets outside the study area but connected to streets within the study area and created intersections were included.

3.4.3 Linear regression

The objective stated in Section 1.3, was to analyse the relationship between the number of accidents occurred and cyclists' perceptions in danger. Finding these relationships was based only on the locations identified as either places where accidents occurred or locations selected as dangerous. The number of bicycle accidents that occurred was derived from the DIER data and the survey, and the number of cyclists selecting places as dangerous was derived from the map-making processes. There were three linear regression processes based on 1) street sections, 2) intersections and 3) the combination of both locations (for finding the relationship of all accidents). This was because they contained both data: identified dangerous places and the specified accident areas.

The anticipation was that if places were perceived as dangerous by a large number of cyclists, these places would have had a high number of the bicycle accidents. Therefore, it was hypothesised that *the number of accidents occurring is positively related to the cyclists' perception of danger.* It was considered that the cyclists' perceptions would provide good indicators of places that have the potential to cause accidents.

In this study, regression analysis was used as it enables estimation of the relationship between the number of accidents that occurred and the number of cyclists that perceive the danger. It also aids in identifying the number of accidents that can be predicted from the number of cyclists selecting dangerous places. Linear regression was adopted for this study and stepwise was selected as a variable selection method. The linear regression consists of Pearson correlation coefficient (R), the 1-tailed significance level (p-value), adjusted R-squared (adjusted R^2)[20], and the 2-tailed significance level (Sign.).

Note: as mentioned in Section 3.4.2.2.3 about the street section on Sandy Bay Road between King Street and Gregory Street, the accident data, which were identified in this area, were equally placed into 1) between King Street and Upper Section Magnet Court, and 2) between Upper Section Magnet Court and Gregory Street.

[20] 'Adjusted R squared attempts to correct R squared to more closely reflect the goodness of fit of the model in the population (SPSS Inc 1999).'

3.5 Practical street-based fieldwork

After the accident and dangerous places were identified (see Section 4.3) and the improvements suggested by respondents were noted (see Section 4.4), establishing dedicated bicycle routes was most recommended. According to Broadley (2002, pers. comm.), the Hobart City Council has no infonnation about the widths of roads, lanes and footpaths and car parking areas within the study area. Therefore, the practical street-based fieldwork was conducted to measure the widths of footpaths, two-way strcets, and street islands (if existing).

Selecting areas for the street-based fieldwork was based on identified locations on the results, illustrated as five maps (see Section 4.3). Significant streets were selected, including Sandy Bay Road, Regent Street, Churchill Avenue, King Street and Nelson Road (sec Figure 3.7). The measurement was undertaken on one or both of the streets and the footpaths next to the sclected intersections. A measuring wheel was used to measure the width. The total street width was calculated by adding the width of two ways together or by adding two ways plus a street island together. The type of parking and signs indicating cycling prohibited areas on footpaths were also recorded.

In addition, many trips were made to observe both road and traffic conditions (including motor vehicle and cyclist behaviour) at most sites where accidents and dangerous conditions were identified (see Figure 3.8). Notes were taken, and these were used to inform the discussion of results.

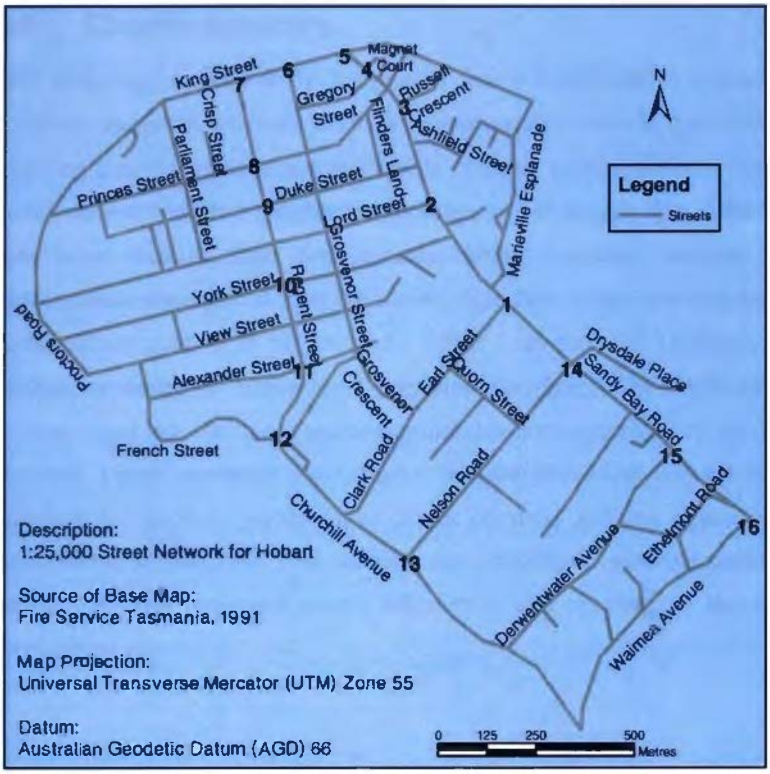

Figure 3.7: Street-based fieldwork locations

Figure 3.8: Sandy Bay Road at location 1 looking northwest

3.6 Chapter summary

This study was a social study designed to follow a quantitative approach. Bicycle accidents, dangerous locations and safety improvements were the quantitative data used requiring quantitative collection techniques. Finding existing statistics and developing questionnaires were two quantitative techniques used to gain data. Bicycle accident data were obtained from both sources, while dangerous locations and safety improvements were gained from the survey. The face-to-face and questionnaires were completed by cyclists at bicycle racks within University of Tasmania, Sandy Bay campus, or during the respondents' own time elsewhere. The results of spatial data were arranged into GIS maps and non-spatial data were organised by using descriptive statistics. Linear regression was applied to find the relationship between the number of accidents and cyclists' perception of danger on street sections, intersections and the combination of these two. The practical street fieldwork involving measurement was carried out using maps and related information, and observations also made during many occasions on-site.

Chapter 4 Results

4.1 Introduction

The aim of this chapter is to present the main results obtained from the implemented methods from the previous chapter. The results have been divided into five separate sections. Section 4.2 describes the data collected from the survey about participants' characteristics and bicycle accidents in the study area. Section 4.3 illustrates the maps of bicycle accident locations and dangerous places together with their relationship. Section 4.4 presents cyclist's recommendations for improving the safety of cycling in the study area. Section 4.5 shows the results of street-based fieldwork.

4.2 Survey results

This section presents the study findings of the data obtained from returned questionnaires. The section begins with a discussion on the response rates to the questionnaires, and then proceeds with the descriptive statistics of results from each question (Questions 1 to 8, 10 to 13, and 16).

4.2.1 Response rate

A total of 100 questionnaires were distributed to cyclists who ride to the University of Tasmania, Sandy Bay campus. Forty-nine of 68 bicycle-mail questionnaires were posted back to the author and 32 questionnaires were completed during from face-to-face questionnaires. In total, there were 81 questionnaires returned. The survey contained data checks for consistency. No duplication between the DIER data and the survey was found. Two of the returned questionnaires were incomplete and could therefore not be used for the analysis. There were 79 valid forms, yielding a useable response rate of 79%.

4.2.2 Descriptive statistics: cycling accidents

Accident data from cyclists were summarised by using descriptive statistics as mentioned in Section 3.4.1 (frequency, percentage, mode, median, minimum, maximum and, range). Bicycle accident data from the questionnaires were divided into two sections based on cyclists' characteristics (Questions 1 to 7) and bicycle accidents (Questions 8, and 10 to 12).

4.2.2.1 Descriptive statistics of respondent characteristics

The respondents' characteristics were gender, age, cycling experience, cycling regularity and involvement in bicycle accidents. These characteristics were divided for presentation into two groups, based on whether the data were nominal (Questions 1, 5 to 7) or ratio (Questions 2 to 4).

It can be seen from the data summarised in Table 4.1 that men were the predominant gender participating in the survey (approximately 77%). Nearly three quarters of cyclists regularly rode bicycles within the Sandy Bay area. Of the 79 cyclists, 25 had experienced bicycle accidents within the Sandy Bay area. Approximately 77% of the bicycle accidents that occurred in the suburb of Sandy Bay were within the study area.

Table 4.1: Summary of cyclists' characteristics (Questions 1, 5 to 7), showing the number of cyclists and the percentage of cyclist characteristic categories: gender, cycling frequency, and the involvement in bicycle accidents in the Sandy Bay area and the study area

Cyclist characteristics	Number of cyclists	Percentage of category
Gender of cyclists (n = 79)		
Male	61	77.22
Female	18	22.78
Frequency of riding in the Sandy Bay area (n = 79)		
Occasionally	22	28.95
Regularly	54	71.05
Involvement in bicycle accidents in the Sandy Bay area (n = 79)		
No accident experience	54	68.35
Involved in bicycle accidents	25	31.65
Involvement in bicycle accidents in the Study Area (n = 25)		
No accident experience	5	23.08
Involved in bicycle accidents	20	76.92

Note: n = number of respondents

Table 4.2 shows that more than 90% of the cyclists were younger than 50 years and more than half the cyclists were between 21 and 30 years old. The youngest cyclist was 19 years old and the oldest was 57 years. Twenty-five was the most common age of respondents. The cycling experience of respondents varied between 1 and 50 years. Two-thirds (65.79%) of all cyclists had been riding less than 20 years. More than three quarters had ridden in the Sandy Bay area for less than 5 years. The cycling experiences of cyclists within the Sandy Bay area were between 1 month and 30 years.

Table 4.2: Summary of respondents' ages and cycling experience (Questions 2 to 4), showing the number of cyclists, percentage and cumulative percentage of cyclist characteristic categories: age, total cycling experience, and cycling experience in Sandy Bay

	Number of cyclists	Percentage of category	Cumulative % of category
Age (n = 79)			
Mode = 25 Years			
Range = 38 Years			
Minimum = 19 Years			
Maximum = 57 Years			
Median = 27 Years			
10-20 Years	4	5.06	5.06
21-30 Years	44	55.70	60.76
31-40 Years	16	20.25	61.01
41-50 Years	8	10.13	91.14
51-60 Years	7	6.86	100.00
Total cycling experience (n = 76)			
Mode = 20 Years			
Range = 49 Years			
Minimum = 1 Year			
Maximum = 50 Years			
Median = 17 Years			
1-10 Years	26	34.21	34.21
11-20 Years	24	31.56	65.79
21-30 Years	16	21.05	66.64
31-40 Years	7	9.21	96.05
41-50 Years	3	3.95	100.00
Cycling Experience in Sandy Bay (n = 79)			
Mode = 2 Years			
Range = 29 Years and 11 Months			
Minimum = 1 Month			
Maximum = 30 Years			
Median = 2.5 Years			
1 Month-5 Years	62	76.46	78.48
6-10 Years	10	12.66	91.14
11-15 Years	1	1.27	94.94
16-20 Years	3	3.60	97.47
21-25 Years	1	1.27	98.73
26-30 Years	2	2.53	100.00

4.2.2.2 Descriptive statistics of accident information

From the 20 cyclists involving in bicycle accidents shown in Table 4.1, 31 bicycle accidents were identified. Table 4.3 shows that the majority of the cyclists (65%) who had bicycle accidents were only involved in one accident, 20 % had been involved in two accidents, 10% (two cyclists) in three accidents and one cyclist had been involved in four accidents.

Table 4.3: Number of accidents cyclists had involved (Question 8), showing the number of cyclists and percentage of responding cyclists

Number of accidents (n = 20)	Number of cyclists	Percentage of respondents
1 accident	13	65.00
2 accidents	4	20.00
3 accidents	2	10.00
4 accidents	1	5.00

Cyclists, who experienced bicycle accidents within the study area, provided the accident details of each bicycle accident (Question 10). Only one quarter of all cyclists indicated in the questionnaire that their accident(s) were reported to either the police and/or insurance companies (see Table 4.4). Approximately 61% of bicycle accidents occurred when the weather was clear and around 64% when the road surface was dry. Most of the bicycle accidents occurred on straight (77.5%) and level sections of the roads (45%). For full results of this question see Appendix 3.

Table 4.4: Information concerning the accident details (Question 10), showing the number of cyclists and percentage of categories: reporting accidents, who cyclists reported to, weather condition, surface condition, light condition, and alignment and slope of road

	Number of cyclists	Percentage of category
Reporting of bicycle accidents (n = 29)		
Not reported	22	75.86
Reported	7	24.14
Who cyclists reported bicycle accidents to (n = 7)[21]		
General practitioner	2	28.57
HCC	1	14.29
Insurance company	2	28.57
Police	2	28.57
General practitioner	2	33.34
HCC	1	16.67
Insurance company	1	16.67
Police	1	16.67
Police and Insurance company	1	16.67
Weather condition (n = 31)		
Clear	19	61.29
Clear and windy	2	6.45
Raining	9	29.03
Windy	1	3.23
Surface condition (n = 31)		
Dry	20	64.52
Wet	11	35.48
Light condition (n = 31)		
Dark with street light	3	9.68
Dark without street light	1	3.23
Dawn or dusk	2	6.45
Daylight	25	80.65
Alignment of road (n = 31)		
Curve	7	22.58
Straight	24	77.42
Slope of road (n = 31)		
Gentle slope	10	32.26
Level	14	45.16
Steep	7	22.58

The personal details about each bicycle accident were obtained from cyclists in Question 11 displayed in Table 4.5. All cyclists had accidents while they were riding their bicycles, as opposed to when in stationary position. More than three quarters of the cyclists who were turning at road intersections did not indicate their intention. One of the 31 cyclists had an accident when riding the wrong way on a one-way road and two had accidents when they were riding against traffic. Approximately 35% of bicycle

[21] Appendix 3, one respondent (accident No. 12) reported a bicycle accident but has not provided whom the respondent has reported to. Therefore, n in this case should be 6. However, as seen in Appendix 3, one respondent (accident No. 28) reported to both police and insurance company. This respond was put into the category of police and insurance. As a result, n = 7.

accidents occurred when cyclists were riding at high speed. No bicycle accident occurred during a riding competition. Most cyclists (96.77%) were wearing helmets when they had accidents. More than half (56%) of cyclists were wearing light coloured clothing when they had accidents. Approximately 10% of the bicycles were not in a good condition when cyclists experienced accidents. For full results of this question see Appendix 4.

Table 4.5: Cyclists' details when they had bicycle accidents (Question 11), showing the number of cyclists and percentage of categories: status at accidents, giving signal turns, riding wrong way, against traffic at high speed, competition, doing trick, wearing helmet and light coloured clothing, and bicycle condition

	Number of cyclists	Percentage of category
Cyclists' status during accidents (n = 31)		
Riding	31	100.00
Stationary	0	0.00
Giving signal turns (n = 13)		
No	10	76.92
Yes	3	23.08
Riding wrong way on one-way road (n = 31)		
No	30	96.77
Yes	1	3.23
Riding against traffic (n = 31)		
No	29	93.55
Yes	2	6.45
Riding at high speed (n = 31)		
No	20	64.52
Yes	11	35.48
Riding competition (n = 31)		
No	31	100.00
Yes	0	0.00
Doing trick (n = 31)		
No	30	96.77
Yes	1	3.23
Wearing helmet (n = 31)		
No	1	3.23
Yes	30	96.77
Wearing light coloured clothing (n = 25)		
No	11	44.00
Yes	14	56.00
Bicycle condition (n = 31)		
No	3	9.68
Yes	28	90.32

When respondents were questioned about the road and traffic conditions associated with their accidents, the traffic volume was perceived to be the major problem (see Table 4.6). A high number of cars were identified as the most dangerous aspect of riding a bicycle (29.90%), followed by narrow lane width and wet and slippery surfaces (both at 25.81%). However, a range of other conditions or circumstances was also important. See Appendix 5 for full road and traffic conditions associated with all accidents.

Table 4.6: Road and traffic conditions related to accidents (Question 12), showing the number of cyclists and percentage of respondents

Road and traffic conditions (n = 31)	Number of cyclists	Percentage of respondents
High volume of cars	9	29.03
Narrow lane width	8	25.81
Wet and slippery surface	8	25.81
Intersection	6	19.35
Parked car with door opened or opening	5	16.13
Parked car/s narrowing cycling space	5	16.13
Road obstructions such as rubbish, glass, grit, and pot hole	5	16.13
Curve/Corner/Bend	5	16.13

Accident severity was mostly within the minor property damage range, as shown in Table 4.7. However, eight cyclists of the 30 involved in accidents indicated that they needed first aid and one was hospitalised.

Table 4.7: Level of severity of bicycle accidents (Question 12), showing the number of cyclists and percentage of respondents

Levels of accident severity (n = 30)	Number of cyclists	Percentage of respondents
First aid	6	20.00
Not hospitalised	2	6.67
Minor property damage	13	43.33
Minor property damage and first aid	2	6.67
Minor property damage and not hospitalised	3	10.00
Minor property damage and hospitalised	1	3.33
Major property damage	3	10.00

4.2.3 Descriptive statistics: dangerous locations for cycling

It can be seen in Table 4.8 that approximately 86% of cyclists thought that the study area contained dangerous places for cycling. Almost all cyclists (94.94%) had ideas about improvements for cycling safety in the study area. For descriptive infonnation on dangerous locations see the next section, and for actual improvements cyclists have suggested see Section 4.4.

Table 4.8: Cyclists' comments (Questions 13 and 16), showing the number of cyclists and percentage of categories: identifying dangerous locations in the study area and comments on improvement

	Number of cyclists	Percentage of category
Identifying dangerous locations in the study area (n = 79)		
No identified locations	11	13.92
Identified locations	68	86.08
Comments on improvement (n = 79)		
No comments	4	5.06
Comments given	75	94.94

Table 4.9 shows that all female cyclists (18) thought that the study area is dangerous and only a minority of male cyclist (11 out of 61 male cyclists) considered that it was safe to ride in the study area. All cyclists in the age range of 31 to 50 believe that the study area is dangerous for riding bicycles. The majority of cyclists who did not think the study area dangerous for them were between the ages of 10 and 30. Only cyclists who have had 1 to 20 years cycling experience did not think the study area dangerous.

Table 4.9: Cyclists' comments together with gender, age and total cycling experience (Question 1, 2, 3 against Question 16), showing the number of cyclists thinking the study area dangerous

Thinking study area is dangerous for cycling (n = 79)		Number of cyclists	
		Not Think dangerous	Think dangerous
Gender (n = 79)	Female	0	18
	Male	11	50
Age(n =79)	10-20Years	2	6
	21-30 Years	8	32
	31-40 Years	0	16
	41-50 Years	0	8
	51-60Years	1	6
Total cycling experience (n = 76)	1-10 Years	2	24
	11-20 Years	8	16
	21-30Years	0	16
	31-40 Years	0	7
	41-50 Years	0	3

4.3 Spatial data results and descriptions

Since this study applied a GIS tool for illustrative purposes to assist with data analysis, this section is divided into three parts, based on street characteristics: entire streets, street sections and intersections.

4.3.1 Entire streets

Figure 4.1 and Table 4.10 show that 36 cyclists selected entire streets. There were eight streets so selected. Sandy Bay Road was considered as the most dangerous street for cycling in the study area. The second most selected street was Regent Street with nine of cyclists selecting it. Four cyclists chose Churchill Avenue, and two cyclists selected Nelson Road and Gregory Street each. French Street, Randall Street and Proctors Road were selected once each.

Table 4.10: Entire streets selected by cyclists as dangerous locations together with the number of cyclists selecting entire streets

Street names	Number of cyclists
Sandy Bay Road	16
Regent Street	9
Churchill Avenue	4
Gregory Street	2
Lower Section Nelson Road	2
French Street	1
Proctors Road	1
Randall Street	1
Total	36

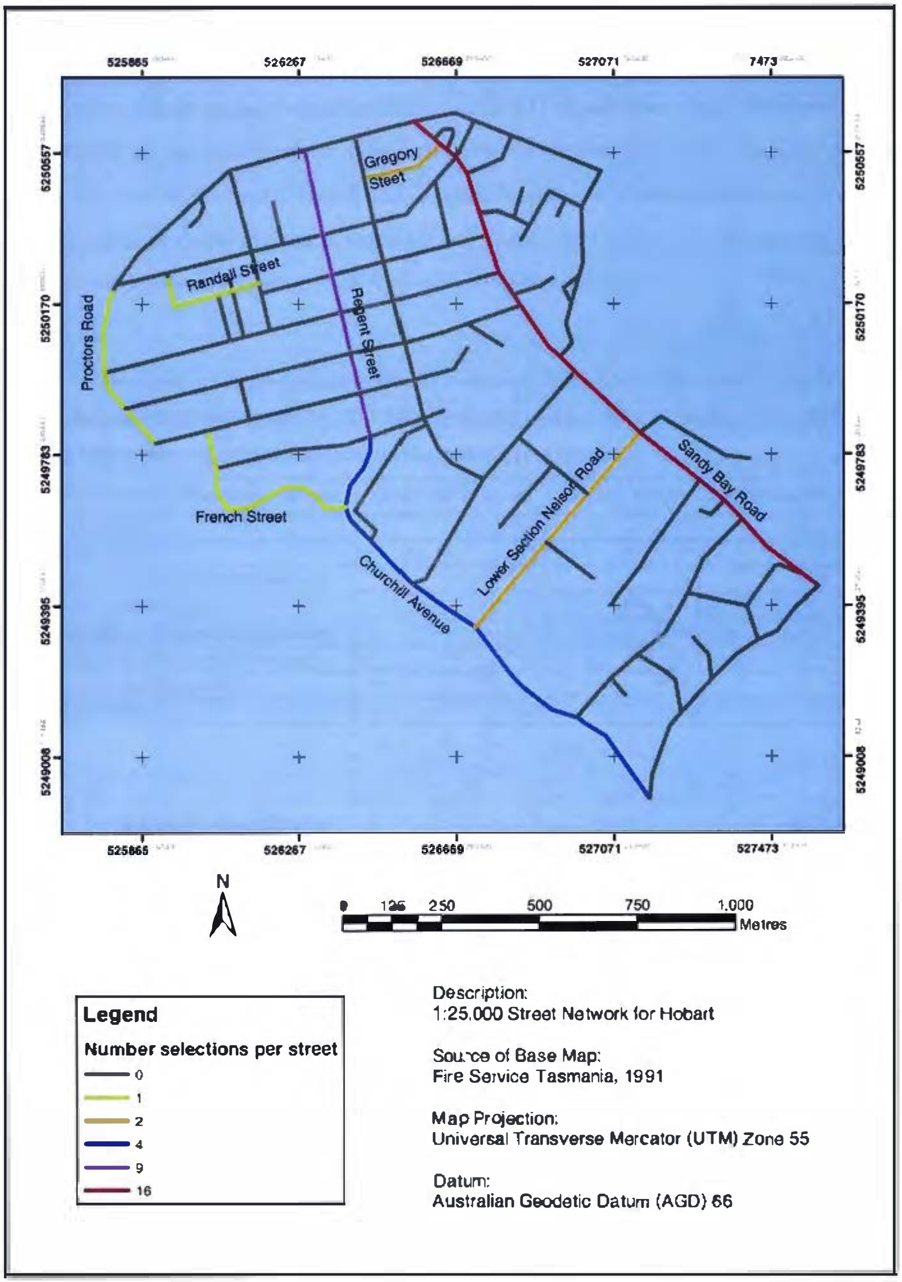

Figure 4.1: Street map of the study area illustrating the number of selections for the entire streets selected as dangerous locations for cycling

Cyclists who selected entire streets as dangerous locations to cycle in the study area also provided road and traffic environment factors, which are related to their perceptions of danger when riding on those entire streets. Table 4.11 shows that a high volume of cars was selected as the most frequent road and traffic environmental factor associated with danger for cycling on Sandy Bay Road, Regent Street, and Churchill Avenue. Parked cars with door or doors opened or opening and parked cars narrowing the cycling space were the second most frequent. See Appendix 6 for full details.

Table 4.11: Road and traffic environment factors associated with cyeing danger on Churchill Avenue, Regent Street and Sandy Bay Road (Question 15) together with the number of cyclists selecting each street and related road and traffic environment factors

Road and traffic environment factors	Churchill Avenue	Regent Street	Sandy Bay Road
Number of cyclists	4	9	16
High volume of cars	4	9	12
High volume of large trucks and buses	2	3	8
High speed motor vehicles	2	4	8
Parked car with door opened or opening	3	8	9
Parked car/s narrowing cycling space	3	7	9
Parked car/s reducing visibility	2	6	6
Narrow lane width	3	4	5

4.3.2 Street sections

The results of street sections are divided into three parts. The first is on bicycle accidents, followed by dangerous locations, and ending with an examination of the relationship between bicycle accidents and dangerons locations.

4.3.2.1 Bicycle accidents on street sections

Combining the data from DIER and the survey resulted in a record of 41 accidents confined to street sections. Figure 4.2 shows the street sections. The highest incidence of bicycle accidents on one street section was three, occurring on Regent Street, Dobson Road and Sandy Bay Road. The two main localities, with most of the bicycle accidents, were the street sections within the University of Tasmania (Dobson Road and Grosvenor Crescent) and the shopping areas (Sandy Bay Road from King Street to Ashfield Road). Sandy Bay Road has the highest number of street sections on which bicycle accidents occurred, followed by Regent Street.

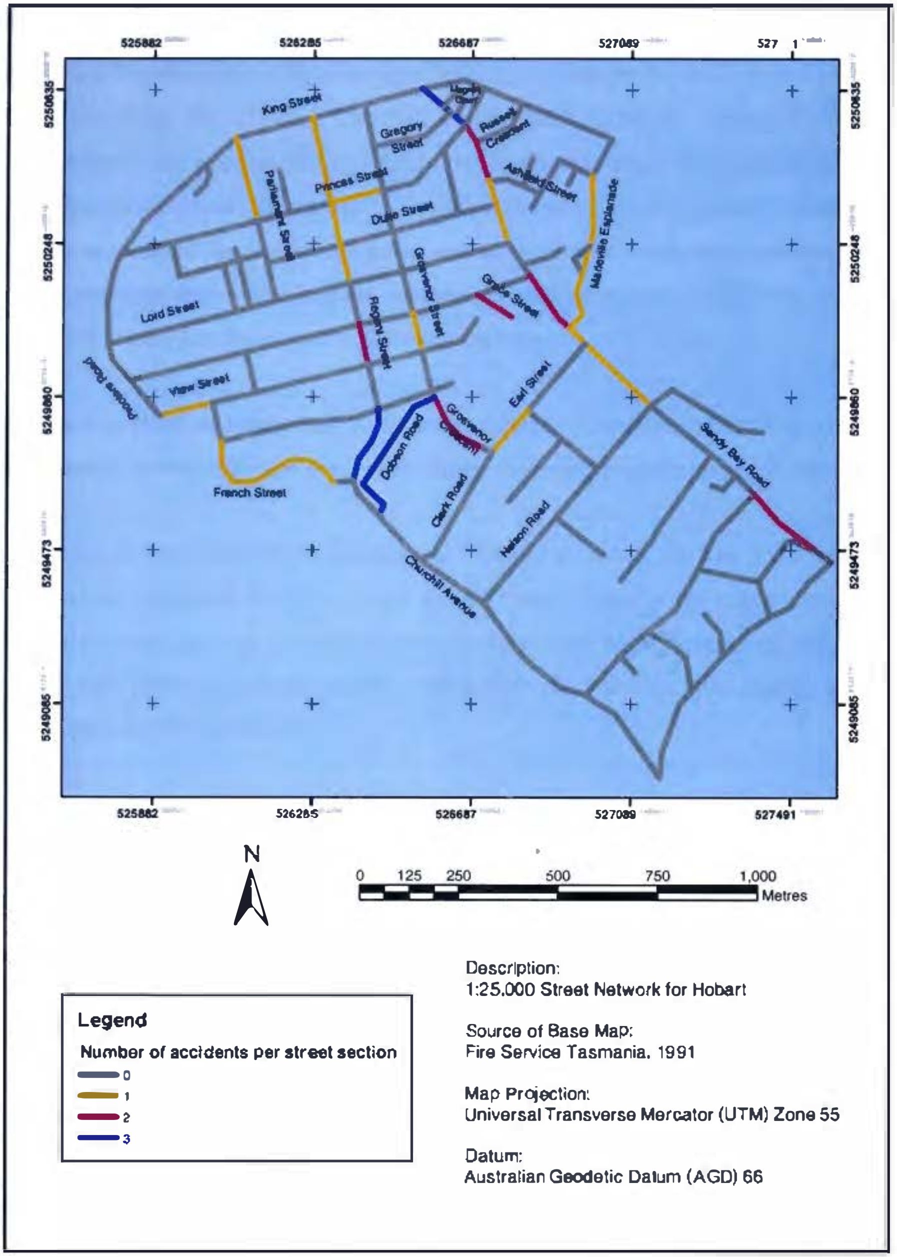

Figure 4.2: Street map of the study area illustrating the number of bicycle accidents occurring on street sections

4.3.2.2 Dangerous street sections

Figure 4.3 illustrates that most street sections selected were on the major streets such as Sandy Bay Road, Regent Street, Churchill Avenue and King Street. Among all selected street sections, the street sections of Sandy Bay Road and Regent Street that were most identified as dangerous to cyclists. The area identified by the greatest number of cyclists as the most dangerous for cyclists was the section of Sandy Bay Road proximal to the shopping area. The highest numbers of cyclists selecting the street sections referred to Sandy Bay Road next to the shopping area.

All street sections on Sandy Bay Road were selected. Therefore, Sandy Bay Road is individually shown in Figure 4.4, which shows the number of selections of individual street sections on the road. It can be seen that the number of selections drops with increasing distance from the shopping area. Table 4.12 shows the five street sections that cyclists considered to be the major danger areas. Three of the major hazards in these five street sections as identified by cyclists, were high volumes of cars, cars parked with door/s opened or opening, and parked cars narrowing the cycling space. See Appendix 7 for full details.

Table 4.12: Road and traffic environment factors on the five street sections most frequently selected as associated with danger (Question 15) together with the number of cyclists selecting each street and related road and traffic environment factors

Road and traffic environments	Between GregorySt and Lower Part Magnet Ct	Between Gregory St and Upper Part Magnet Ct	Between King St and Upper Part Magnet Ct	Between Lower Part Magnet Ct and Princes St	Between PrincesSt and Russell Cres
Number of cyclists	23	22	22	23	19
High volume of cars	21	20	20	21	18
High volume of large vehicles	12	10	10	12	12
High speed motor vehicles	11	10	10	11	11
Parked car with door opened or opening	21	20	20	21	17
Parked car/s narrowing cycling space	18	17	17	18	15
Parked car/s reducing visibility	12	10	10	12	11
Parking car	14	13	13	14	13

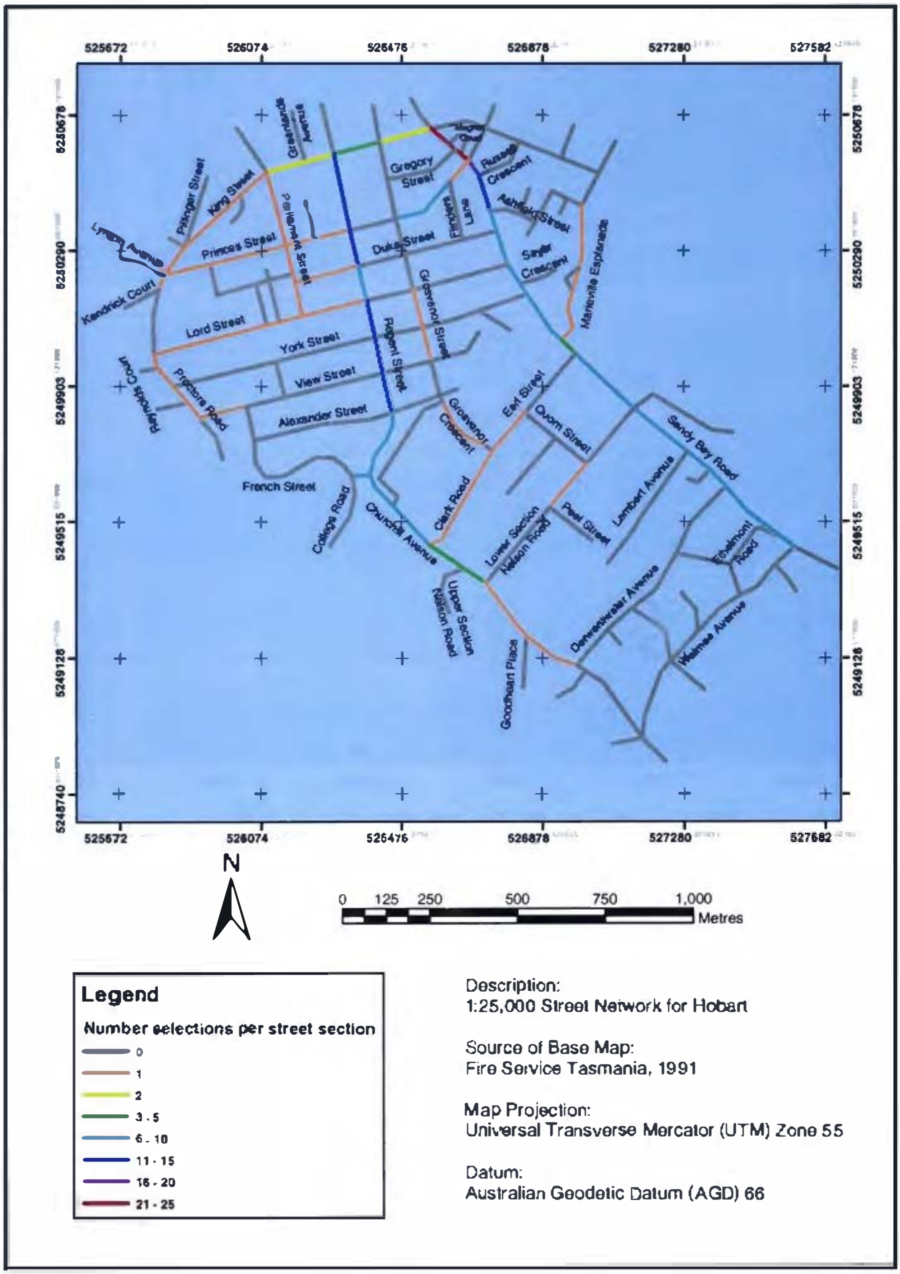

Figure 4.3: Street map of the study area illustrating the number of selections for street sections perceived as dangerous for cycling

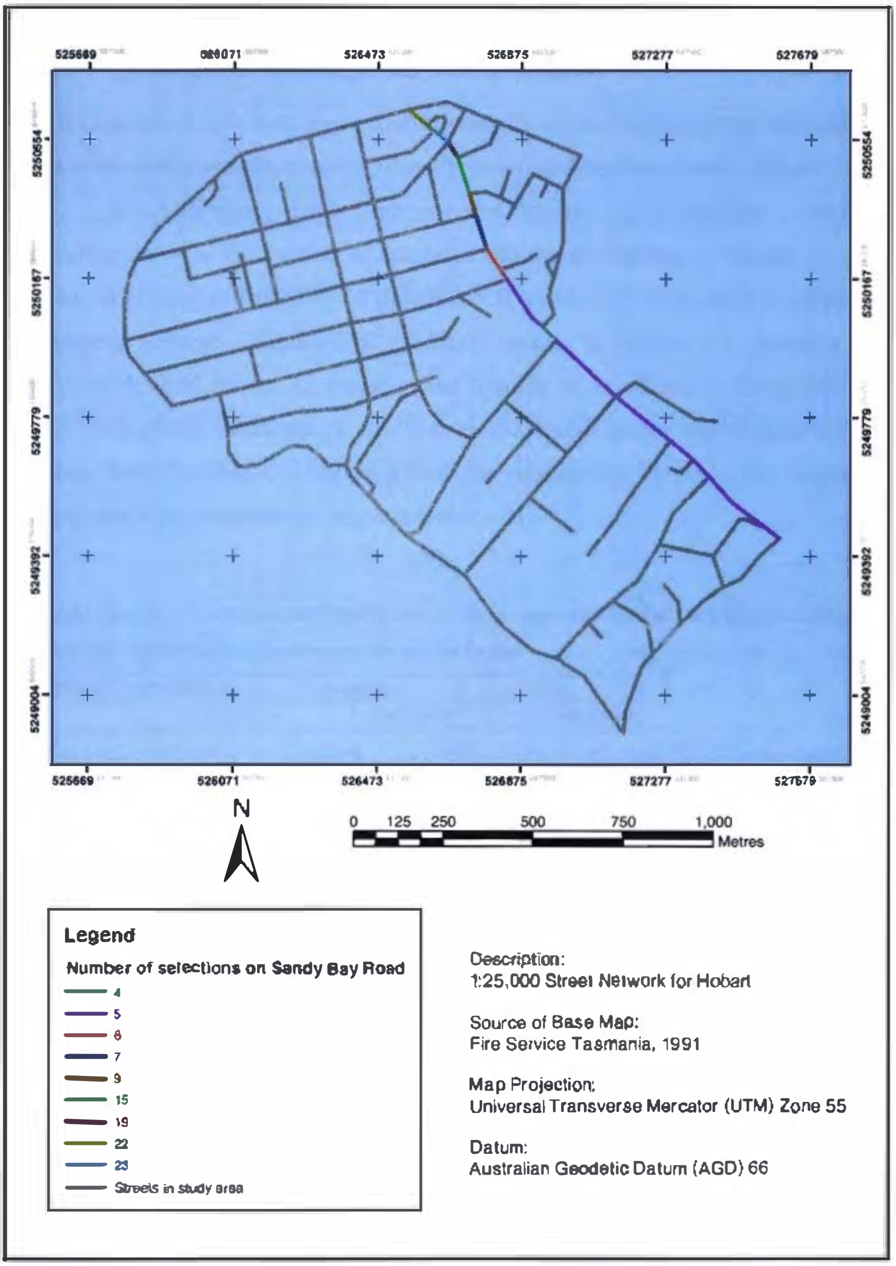

Figure 4.4: Street map of the study area illustrating the number of selections for each street section on Sandy Bay Road that was perceived as dangerous

4.3.2.3 Relationship between the number of accidents and cyclists' perception of danger on street sections

A linear regression was used for testing whether the number of accidents that occurred have a relationship with the number of cyclists naming dangerous locations (see Section 3.4.3). Table 4.13 shows that a Pearson correlation of 0.5220 indicates a moderate relationship between the number of accidents and the perceptions of danger on street sections. A p-value of 1.08429E-06 (less than 0.05) shows the correlation is significant and linearly related. Adjusted R^2 (0.2623) shown in Figure 4.5 indicates that approximately 26% of the variation in the number of accidents is associated with cyclists' perceptions of danger on streets sections. However, the significance value is less than 0.05 (2.1686E-06) showing that the relationship between the number of accidents and the perception of danger is real.

Table 4.13: Pearson correlation and significance levels (p-value and Sig.) of the number accidents occurring and the number of cyclists perceiving the danger

Pearson Correlation	p-value	Sig.
0.5220	1.0843E-06	2.1686E-06

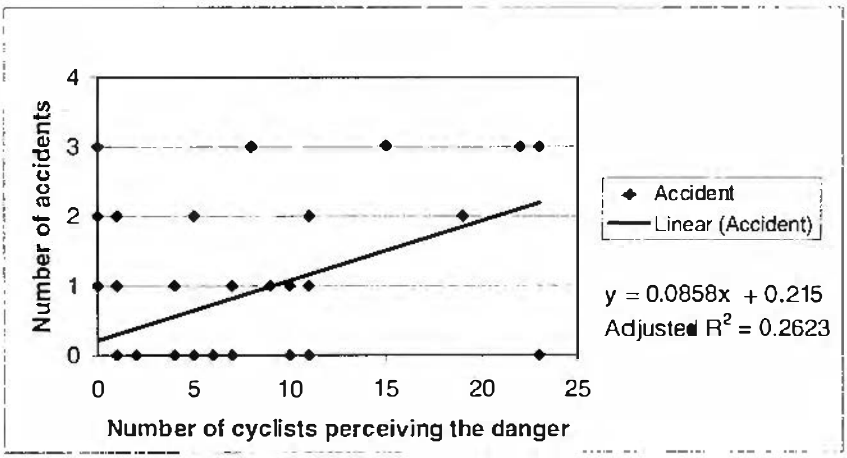

Figure 4.5: Linear regression showing the model and adjusted R^2 of the number of accidents occurring and cyclists' perception of danger in street sections

4.3.3 Intersections

This part of the results chapter presents bicycle accidents at intersections and, in particular, intersections considered as dangerous. The relationship between the two is presented at the end.

4.3.3.1 Bicycle accidents at intersections

Using bicycle accident data from DIER in combination with the survey, there were 39 bicycle accidents at intersections in the study area. The intersection between Russell Crescent and Sandy Bay Road, which has had the highest number of bicycle accidents (with a total of five) can be seen in Figure 4.6. Sandy Bay Road includes the highest number of intersections where bicycle accidents have occurred overall. The second and the third highest number of bicycle accidents occurred at intersections on Regent Street. Three bicycle accidents occurred at each of the intersections between Regent and Duke Streets and between Regent and Lord Streets, with two accidents occurring at the intersection between Regent and Alexander Streets. The majority of the bicycle accidents occurred in the area between the University of Tasmania and the shopping area of Sandy Bay on Sandy Bay Road.

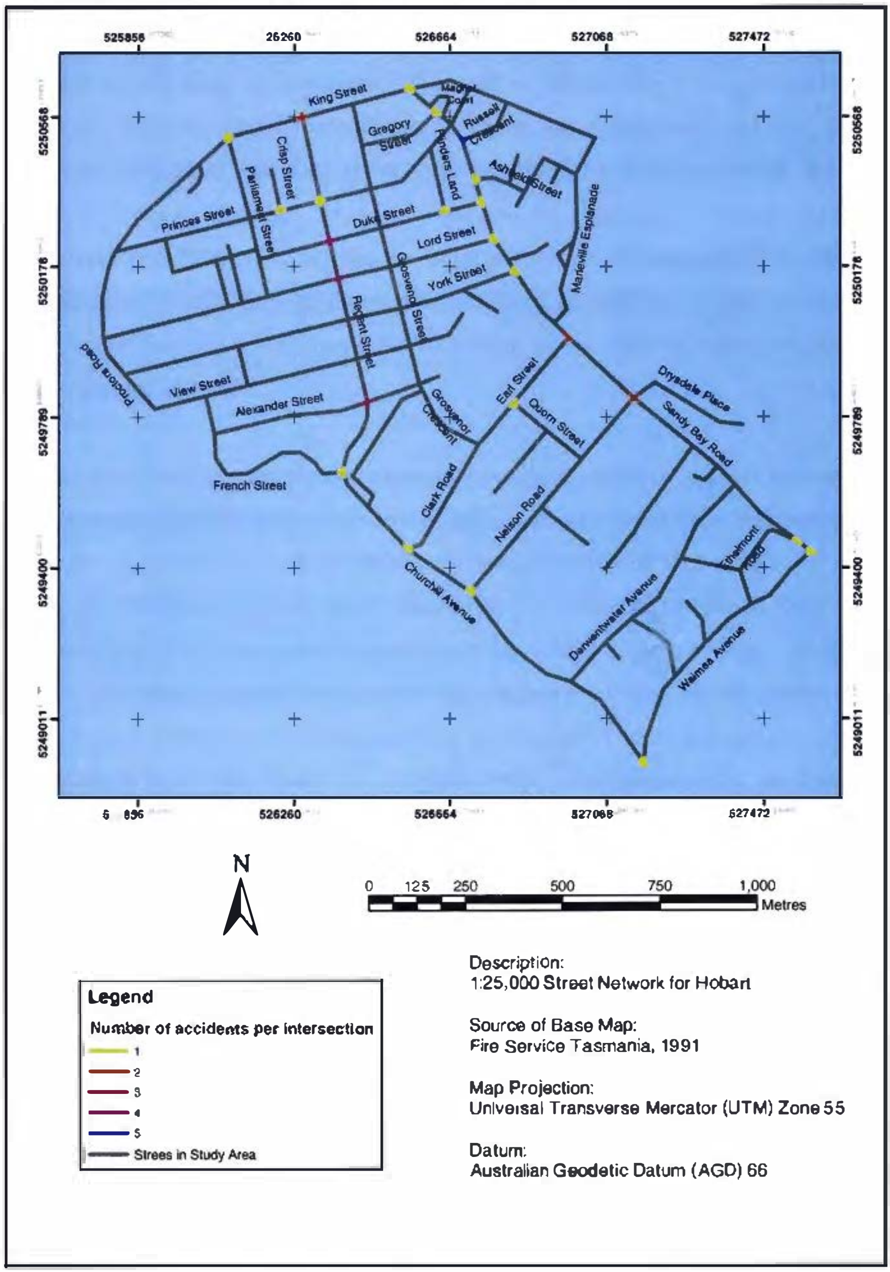

Figure 4.6: Street map of the study area illustrating the number of bicycle accidents occurring at intersections

4.3.3.2 Dangerous intersections

From the survey, many cyclists identified dangerous intersections within the study area. Figure 4.7 illustrates that the intersections between Sandy Bay Road and King Street, and Sandy Bay Road and Earl Street were perceived by eight cyclists as the most dangerous areas for cycling. Six cyclists selected the intersection between Alexander Street and Regent Street and Alexander Street and Churchill Avenue (which coincide, as Regent and Churchill are continuous) as dangerous intersections. Most intersections along Sandy Bay Road, Grosvenor Street, Regent Street, Princes Street and Proctors Road were also selected.

Cyclists who identified dangerous intersections provided information about the road and traffic conditions, which they considered as having an association with their perception of danger. As can be seen from Table 4.14, cyclists perceived high volume of cars a major risk for cycling at these intersections. At the intersection between King Street and Sandy Bay Road, the second highest threat was a high volume of large "trucks and buses". High-speed motor vehicles were the second main concern of cyclists when riding at these intersections: Alexander Street & Churchill Avenue & Regent Street, and Earl Street & Sandy Bay Road. See Appendix 8 for other intersections, and road and traffic factors.

Table 4.14: Road and traffic environment conditions associated with perception of danger at intersections together with the number of cyclists selecting each street and related road and traffic environment conditions

Road and traffic environments	Alexander St & Churchill Av & Regent St	Earl St & Sandy Bay Rd	King St & Sandy Bay Rd
Number of cyclists	6	8	8
High volume of cars	4	8	7
High volume of large trucks and buses	2	3	5
High speed motor vehicles	4	5	3
Parked car/s narrowing cycling space	1	1	4
Parking car	0	1	4
Narrow lane width	1	2	4

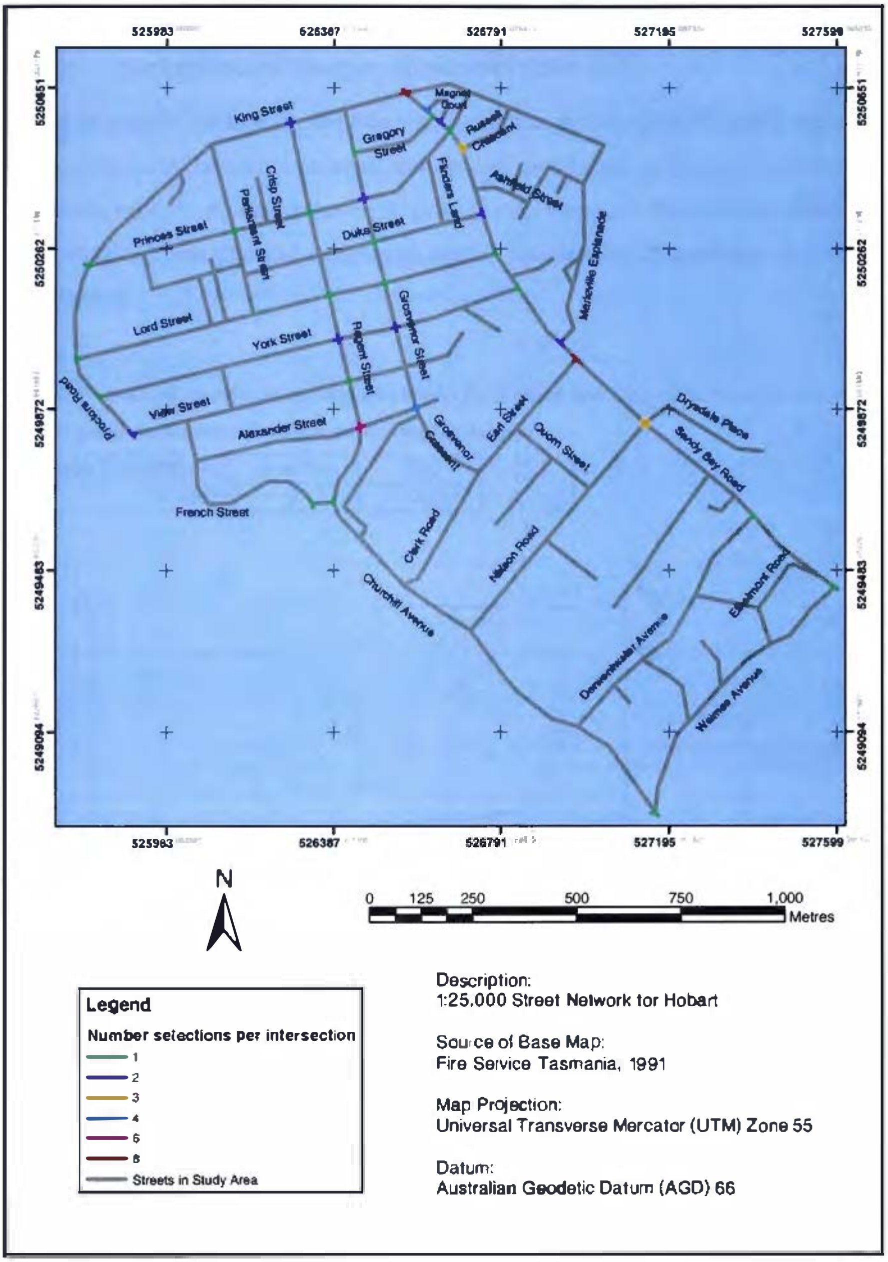

Figure 4.7: Street map of the study area illustrating the number of selections for each intersections that was perceived as dangerous to cycle through

4.3.3.3 Relationship between the number of accidents and cyclists' perception of danger at intersections

As can be seen in Table 4.15, the Pearson correlation is very small (0.1685), indicating that the number of accidents occurred and cyclists' perception of danger at intersections are weakly related. A small adjusted R^2 (0.0284) in Figure 4.8 indicates that around 3% of the cyclists' perception of danger can predict the nnmber of accidents occurring at intersections.

Table 4.15: Pearson correlation and significance levels (p-value and Sig.) of the number of accidents occurring and the number of cyclists perceiving the danger

Pearson Correlation	p-value	Sig.
0.1685	0.1371	0.2742

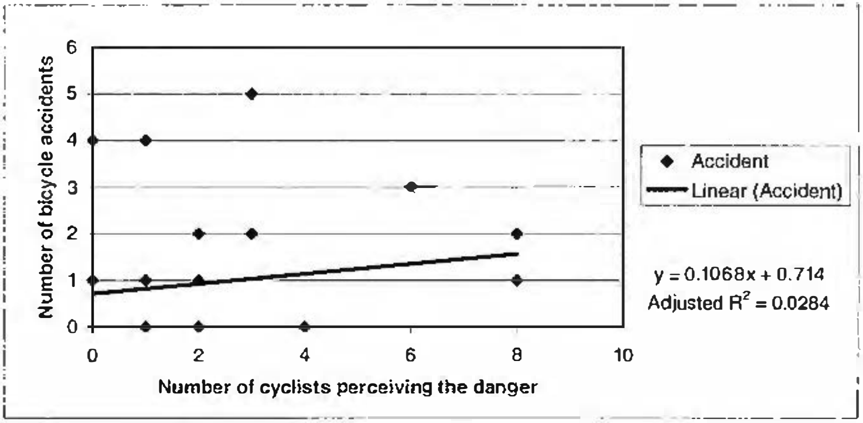

Figure 4.8: Linear regression showing the model and adjusted R^2 of the number of accidents occurring and cyclists' perception of danger at intersections

4.3.4 *Relationship between the total number accidents and the total list of cyclists' perceptions of danger*

The following combines the results from both intersections and the street sections. Table 4.16 shows the significance level for the above relationship is very small (less than 0.05): thus, the correlation is significant and the variables in question are linearly related. However, a Pearson correlation at 0.3360 shows a weak relationship between the number of accidents and cyclists' perception of danger. A small adjusted R^2 (0.1051) indicates that approximately 10% of the variation amongst accidents is related to cyclists' perception of danger (see Figure 4.9).

Table 4.16: Pearson correlation and significance levels (p-value and Sig.) of the number accidents and the number of cyclists perceiving the danger

Pearson Correlation	p-value	Sig.
0.3360	0.0001	0.0002

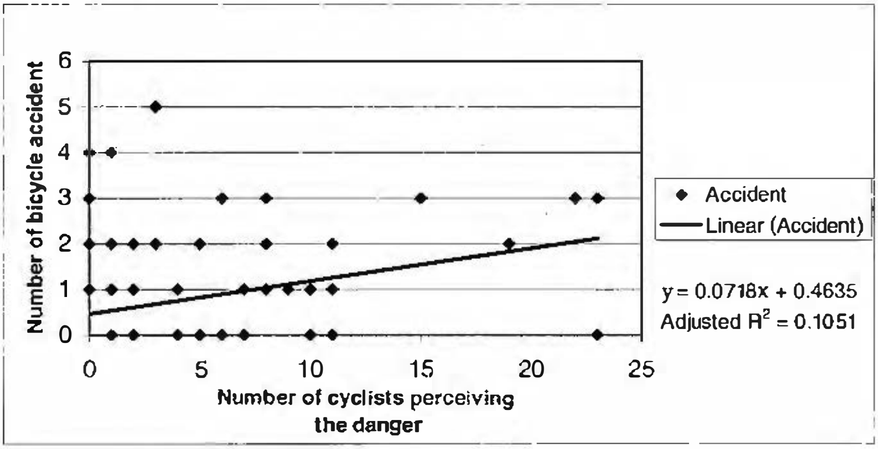

Figure 4.9: Linear regression showing the model and adjusted R^2 of the number of accidents and cyclists' perceptions of danger at both street sections and intersections

4.4 Recommendations from cyclists to improve cycling safety in the study area

From 75 cyclists providing recommendations for safer cycling (see Table 4.8), 102 suggestions were offered. Seventy-eight of these are general suggestions and 27 are related to specific suggestions. In Table 4.17 and Table 4.18 the 102 suggestions are classified into groups and the results were processed by frequency distribution and percentage (see Section 3.4.1). The two tables group data to show that the majority of cyclists provided general recommendations for the Sandy Bay areas as a whole (76.47%) rather than recommendations for particular streets (23.53%). Overall, the main recommendation given by cyclists (44.12%) to improve cycling safety in the Sandy Bay area was the creation of the bicycle way. The main streets targeted for infrastructure improvement were Sandy Bay Road (15.69%) and Regent Street (4.90%) (see Table 4.18).

Table 4.17: General suggestions for the Sandy Bay area as a whole to improve cycling safety, showing the number of cyclists making suggestions and the percentage of total suggestions

General suggestions	Number of cyclists	Percentage of total suggestions (120)
Dedicated bicycle route	45	44.12
Modify human behavior	16	15.69
Other Road and traffic engineering practices	16	15.69
Legislative matter	1	0.98
Total	**78**	**76.47**

Table 4.18: Specific suggestions in the Sandy Bay area for the improvement of particular streets for cycling safety, showing the number of cyclists making suggestions and the percentage of total suggestions

Specific suggestions	Number of cyclists	Percentage of total suggestions (120)
Sandy Bay Road	16	15.69
Regent Street	5	4.90
Churchill Avenue	2	1.96
Grosvenor Crescent	1	0.98
Total	**24**	**23.53**

4.4.1 General recommendations on cycling safety

The general recommendations from the respondents for cycling safety were divided into four main categories: Modify human behaviour, dedicated bicycle routes, road and traffic engineering, and legislative matter (see Table 4.19). The most popular recommendation was the establishment of bike lanes or paths (41.03%) (bicycle routes category). The second most popular was to increase driver awareness (19.23%). Reduction of speed limits to improve cycling safety within the Sandy Bay area was the most popular suggestion in the road and traffic engineering category. One cyclist suggested that cycling on footpaths should be allowed as a legislative matter.

Table 4.19: General recommendations to improve safety for cyclists in the Sandy Bay area as a whole, showing the number of cyclists making suggestions and the percentage of general suggestions

General suggestions to the Sandy Bay area		Number of cyclists	Percentage of general suggestions (78)
Modify human behaviour	Increase drivers' awareness	15	19.23
	Improve cyclists' riding skills and awareness	1	1.28
Dedicated bicycle route	Establish bike lane/path	32	41.03
	Establish waterfront bike path to Casino	6	7.69
	Establish bicycle route from city to University	3	3.85
	Establish now bicycle route from Inter-City Cycleway to University	3	3.85
	Establish bicycle route from New Town to University	1	1.28
Other road and traffic engineering practices	Reduce speed limits	6	7.69
	Install bicycle signs to warn drivers about cyclists	3	3.85
	Widen streets	2	2.56
	Establish roundabouts at intersections	2	2.56
	Remove potholos	1	1.28
	Install traffic lights for cycling	1	1.28
	Install traffic time for cycling	1	1.28
Legislative matter	Permission to ride bicycles on footpath	1	1.28
	Total	78	100.00

4.4.2 Specific recommendations for cycling safety

Cyclists thought that creating bike lanes on Sandy Bay Road (37.50%), Regent Street (12.50%) and Churchill Avenue (4.17%) was the major factor for improved safety for cycling in the Sandy Bay area (see Table 4.20). On Sandy Bay Road, the second highest recommendation was a reduction in motor vehicle speed limits (12.50%). One cyclist suggested allowing cycling against the traffic flow on Grosvenor Crescent as the way of improving cycling safety on this street.

Table 4.20: Specific recommendations to improve Sandy Bay Road, Regent Street Churchill Avenue, and Governors Crescent for cycling safety in the Sandy Bay area, showing the number of cyclists making suggestions and the percentage of specific suggestions

Specific suggestions to particular streets		Number ofcyclists	Percentage of specific suggestions (24)
Sandy Bay Road	Establish bike lane	9	37.50
	Reduce traffic speed limit	3	12.50
	Remove car parking	2	8.33
	Reduce traffic volume	1	4.17
	Improve intersection Earl Street & Sandy Bay Road	1	4.17
Regent Street	Establish bike lane	3	12.50
	Remove car parking	1	4.17
	Decrease footpath width for car parking	1	4.17
Churchill Avenue	Establish bike lane	1	4.17
	Improve intersection French Street & Churchill Avenue	1	4.17
Grosvenor Crescent	Allow riding against traffic	1	4.17
	Total	24	100.00

4.5 Measurement of road width in the study area

As the previous section shows, the introduction of bicycle lanes was the most recommended improvement suggested by cyclists. Thus, a measurement of the width of streets and footpaths in the study area was undertaken. The results, shown in Table 4.21, present the mean of street widths of the four main streets. Sandy Bay Road has both the widest street and footpaths. Churchill Avenue has the smallest footpath width. See Appendix 9 for the full details.

Table 4.21: Mean street and footpath widths (in metres) on Sandy Bay Road, Churchill Avenue, Regent Street and Nelson Road

Street names	Total street width	Footpath (city bound)	Footpath (outward bound)
Sandy Bay Road	16.51	2.37	2.59
Churchill Avenue	13.55	1.69	1.64
Regent Street	12.06	1.89	1.91
Nelson Road	9.91	1.79	1.86

4.6 Chapter summary

The questionnaires were returned with a response rate of 79%. Most of the respondents were men. Around 32% of cyclists had bicycle accidents in the Sandy Bay area and among them, around 77% had been involved in bicycle accidents in the study area. More than half of the cyclists thought that the study area contains dangerous places for cycling.

The results demonstrate that selected entire streets, namely, Sandy Bay Road and Regent Street are considered the most dangerous places for cycling in the study area. The high volume of cars and large vehicles were the predominant factors leading to risk for cycling. Street sections near the University of Tasmania and the shopping area have the highest number of bicycle accidents. Sandy Bay Road near the shopping area was considered the most dangerous section to cycle, followed by a Regents Street section. The relationship between the number of accidents and the perception of the dangers of bicycle riding is real but weak.

In the case of intersections, those along Sandy Bay Road and Regent Street have the highest number of bicycle accidents occurring. The perceptions of greatest danger when cycling at intersections were along five streets: Sandy Bay Road, Grosvenor Street, Regent Street, Princes Street and Proctors Road. There is no relationship between the number of bicycle accidents and the perceived risk of cyclists at those intersections.

Establishing bicycle routes was the most suggested improvement for safer cycling in the Sandy Bay area. Sandy Bay Road was most identified by cyclists as the street where improvements were required. Sandy Bay Road also proved to be the widest street in the study area.

Chapter 5 Discussion, Conclusion, and Recommendations

5.1 Introduction

The objective of this chapter is to discuss and interpret the main results, the effects of the particular methods chosen, what would be different if different methods had been applied, and the improvements for safer cycling suggested by cyclists and some recommendations from literature are also included. In addition, key findings are discussed with regard to whether they are similar to or different from those of previous researchers. The recommendations for further study are provided.

5.2 Bicycle accidents and cyclist perceptions of danger

This section will discuss results associated with the bicycle accidents, cyclists' perceptions of danger and the relationship between them.

5.2.1 Bicycle accidents

According to Boyle (1997) Sandy Bay Road and Regent Street had the highest bicycle accident rates between 1985 and 1995 (see Table 1.1). This statement is compatible to the bicycle accident data used in this thesis. The results show that intersections (see Section 4.3.3.1) and street sections (see Section 4.3.2.1) along Sandy Bay Road and Regent Street within the study area have the highest bicycle accident rates. These results indicate that the data manipulated by combining data from two sources (the questionnaire and HCC) did not have an effect on the results of the locations containing the highest bicycle accident rates. This could suggest that unreported bicycle accidents also occurred along these two streets.

5.2.2 Relationships between the number of accidents and cyclist perceptions of danger

Visually, Sections 4.3.1 (entire streets), 4.3.2 (street sections) and 4.3.3 (intersections) show that the dangerous locations identified by cyclists were along Sandy Bay Road and Regents Street. These results seem to indicate that cyclists' perceptions of danger are usable because they appear compatible to Boyle (1997), as stated in previous section.

Nevertheless, based on the analysis of the number of accidents and cyclists' perceptions of danger presented in Section 4.3.4, it was revealed that cyclists' perceptions could only explain 10% of the variation in bicycle accident rates occurring on both street figures: intersections and street sections. This suggests that cyclist's perceptions might not be good indicators for the incidences of bicycle accidents.

Interestingly, when the street characteristics were separated into two figures: intersections and street sections. Only 3% of cyclists' perceptions could predict the actual bicycle accident rates at intersections (see Section 4.3.3.3), while 26% could predict the actual bicycle accident rates on street sections (see Section 4.3.2.3). These show that cyclist's perceptions are better able to indicate the incidences of bicycle accidents on street sections than at intersection or in the combination of both street figures: intersection and street sections. In other words, around one quarter of cyclists' perceptions of danger seem to be a useful indicator in order to suggest locations of the actual bicycle accidents on street sections.

It is possible that the results of the relationships may be affected because cyclists become more careful when they feel that they are in a dangerous area and less careful when they safe. For examples, Figure 4.8, together with Table 4.13 presents some interesting points showing high rates of bicycle accidents but low number of cyclists indicating those areas as the dangerous intersections and vis versa. For example, at two intersections there were four accidents at each, but only zero and one cyclist perceived the danger. At two other places, only one or two accidents occurred but eight cyclists perceived the danger. Figure 4.6 and Figure 4.7 illustrate these four intersections that are located on the two most dangerous streets (see Sections 4.3.1): two on Regent Street (with Duke Street and Lord Street); and two on Sandy Bay Road (Earl Street and King Street).

Moreover, another instance is shown in Figure 4.5. Two points are particularly remarkable: on one street section, there were three accidents (the highest number of bicycle accidents recorded in one place), but none of the cyclists selected this street section in the questionnaire as dangerous, but another street section was selected by 25 cyclists (the highest number of cyclists perceiving the danger of one specific area) but there were no recorded accidents. These two street sections are shown in Figures 4.2 and 4.3 and are situated: 1) on Sandy Bay Road between Gregory Street and Lower part Magnet Court, and 2) on Dobson Road between Churchill Avenue and Grosvenor Crescent.

In addition, the results that reflect to the relationship analysis might be because cyclists may also have drawn the line on the map to cover more areas than they intended, which might be due to the small size of the maps in the questionnaire (see Appendix 1).

Another assumption associated with the low percentages of the relationships is that other factors have more influence in the incidence of bicycle accidents. For instance, cyclists have differing perceptions of the dangers of particular locations, thus explaining why 3%, 10% and 26% of the variations are explained by perceptions of danger. Cyclists face danger in a large variety of different road and traffic conditions at the one location (for example, the time of day they would regularly ride in a particular area). Cyclists' perceptions of danger are different depending on their riding experiences in the study area. The riding patterns of each cyclist are also different, so their feelings of risk in different places vary.

It is possible that the result of relationships might be an artefact of the questionnaire. Robinson (1998) stated that a survey is a reactive measurement. The cyclists may have felt that they were subjects in a study, so they may have exaggerated. The questionnaire allowed them to identify up to five dangerous locations, so the number of dangerous locations perceived presently were higher than the number of accidents occurring since 1984. The result would be different if cyclists had been allowed to identify only one place.

5.2.3 Other related studies

Importantly, the results of relationships do not reflect well on bicycle suitability criteria involving cyclists' perceptions and might not be able to be used for identifying black spots to the extent that researchers hoped. One suitability criteria, called RCI, was tested by Epperson (1994). He examined the relationship between the suitability results and bicycle accidents. Epperson (1994) found that the modified RCI could only explain 18% of the variation in bicycle accident rates, which is similar to this survey. This low percentage rate may mean that the bicycle suitability criteria, which include cyclists' perceptions (stated in Section 2.4), might not be usefil.

However, Lamm *et al.* (1999) stated that 3% of the causes of bicycle accidents are associated with defective bicycle trail design or dangerous road conditions – that is, with location dependent variables, unlike, for example, rider error or poor bicycle maintenance (see Section 2.2). Importantly, it might be thought that cyclists' perceptions in the survey should be a good indicator of *poor road conditions* at intersections, and even better at street sections and over street figures.

5.2.4 Data

The data used might have had an impact on the results because the bicycle accident data were from 1984 to 2002, but cyclists' perceptions of danger were those given on a short period in 2002. In other words, this study contained two time dimensions: cross-sectional research[22] and longitudinal research[23]. The cross-sectional research occurred when cyclists was asked to identify dangerous locations at the time of conducting the questionnaires. Two longitudinal studies (the time-series research[24] and the panel study[25]) occurred in this study. The time-series study occurred when the same type of accident information and data was collected on different cyclists across multiple time periods such as DIER data from 1988 to 2002. The panel study appeared when some respondents identified that they had experienced more than one bicycle accident in the

[22] Cross-section research is 'a study in which all observations are made at a single point of time' (de Vaus 1995, p 389).
[23] Longitudinal research is 'any research that examines more than one time point'(Neuman 2000, p 513).
[24] *'Time-series research is a longitudinal study in which the same type of information is collected on a group of people or other units across multiple time periods.'* (Neuman 2000, p 31)
[25] The panel study is 'A type of longitudinal study in which data are collected from the same sample (the panel) at several points in time.' (Babbie 1990, p 375)

study area and had given bicycle accident details. Because time dimensions of two data sets (bicycle accident places and dangerous locations) are different, these differentiations could have an effect on the results.

The result of the relationship analysis could be different if the bicycle accident data used were only those from 2002, or in the last five or ten years because the number of bicycle accidents would be smaller, compared to dangerous locations for the process of analysing the relationship. The result might also be different if the bicycle accident data had been from the survey only, not from the existing data as well. However, the bicycle accident data set would have been too small compared to the data set from cyclists' perceptions of danger. The results from the present study show that there were 401 dangerous locations for cycling selections, while there were 83 bicycle accidents.

It is also possible that the result would be different if the data arrangements were different (see Section 3.4.2.1). For example, if the entire streets were separated into street sections and included in the data analysis of street sections. This also applies to the intersections (from entire streets and street sections) where cyclists identified intersections as the locations associated with danger. However, the additional data would produce a data set, which would be too large to compare with the bicycle accident data.

The data collection method might have influenced the linear regression. The linear regression assumes that sampling is a random sampling method, but this study applied non-random sampling. The linear regression also assumes that the data is normally distributed, but the data used in the study might not have been normally distributed because of the effect of non-random sampling.

If near missing incidences were regarded as accidents and then included in the accident data set, this would affect the result of the relationship. Near misses do not involve direct contact between motor vehicle and bicycle, but occur when the cyclist perceives the proximity of the vehicle is such that they feel they are in danger. The result of a near miss may be that the cyclist will swerve or move up onto the verge or pavement which may cause injury, not through physical contact with a vehicle, but through a perceived danger of close proximity with a vehicle. The perception of a near miss will obviously vary between cyclists and may be difficult to ascertain in a questionnaire. A possible solution to partially climinating the different perceptions of what constitutes a near miss is in research into clearance distances between cyclists and vehicles (see Figure 5.2) when constructing bicycle lanes. Once a suitable clearance distance has been ascertained, the clear demarcation on the road between cyclist and vehicle, by way of a cycle lane, may serve to remove varying perceptions of proximity.

5.3 Recommendations on improvements for safety cycling

The recommendations to improve the safety of cycling discussed in this section are derived from the survey and literature review. The recommendations given do not consider financial constraints.

As the result shows in Section 4.2.3, 75 out of 79 participants have given their recommendations for improvements. The high rate of responses might be because a survey is the reactive measurement as mentioned earlier. Therefore, they may have exaggerated in providing ways to improve cycling safety. It also could be that the questionnaire did not provide a question asking the participants whether they thought that the Sandy Bay area needed to be improved for safer cycling. The results could be different if this question were provided.

Most of the general recommendations given by participants for safer cycling in the study area fall into two aspects of improvements: education (modifying human behaviour) and engineering (road and traffic engineering practices). These aspects are comparable to the two main focuses stated in *Australia Cycling 1999-2004: The National Strategy*: education and engineering (see Section 2.3.2).

5.3.1 Human awareness

Although the questionnaire required the road and traffic improvement recommendations (see Appendix 1), many cyclists have given comments on other issues such as modifying human behaviour and legislative matters (see Section 4.4.1), which are related to cycling safety. These two are associated with human awareness. These choices may reflect their personal concerns and should be regarded as real problems and more important than road and traffic conditions. Increasing the human awareness issue is significant, as Lamm *et al.* (1999) states that the major cause of accidents is related to human behaviour, and many strategies mentioned in Section 2.3 are related to improving human road behaviour.

In support of this statement, two causes of dangerous road and traffic environment were related to human behaviour: the high speed of motor vehicles, and parked cars with door opened and opening (see Section 4.3), both rated highly as causes selected by cyclists. These two factors of danger are associated with the lack of driver awareness of the existence of cyclists and the shared use of streets with cyclists. The high-speed factor is also related to enforcement issues.

A possible solution to modifying human behaviour is through education, together with encouragement such as wide spread advertisements on improving shared road use, road safety training, and educating school students. Some road and traffic engineering treatment could change driver awareness and behaviour. For example, warning signs about the existence of cyclists should be established on main streets such as Sandy Bay Road, Churchill Avenue, and Regent Street. A strict enforcement is also important in order to reduce speed, because the speed limit has a further significance in installing bicycle lanes (see Section 5.3.2) and traffic jams (see Section 5.3.4.3).

5.3.2 Bicycle lanes

Another interesting result from the recommendations given in the questionnaire, is the suggestion from cyclists to establish bicycle lanes. This suggests that the participants preferred the separation of bicycles from motor vehicles, which is compatible with results from European countries stated by Lamm *et al.* (1999) in Section 2.3.1 and similar to recommendations appearing in the "Hobart Bikeplan 1997", which are:

- A shared cycleway/ footpath along Sandy Bay road to Wrest Pont Casino,
- A segment of elevated cycle/walking along the foreshore to Wrest Point Casino, or
- Dedicated cycle lane along Sandy Bay road between Marieville Esplanade and Wrest Point Casino(Boyle 1997, p 27-28).

The first recommendation is possible. However, some sections of the footpath along Sandy Bay Road have been taken up by bus stops and signposts, which reduce the amount of space available for cycling. It would be difficult to relocate such obstacles given the current street design. Moreover, the existing curve should be flat and level to the road (a dropped kerb). The exiting curve treatment at some intersections such as Earl Street and Sandy Bay Road is not suitable because the cyclists are forced too close to the road and some of them do not line up with the opposite corner (see Figure 5.1). It would be better to change to the new treatment like the one at intersection between Grosvernor Street and View Street (see Figure 5.1), which would also be beneficial for wheelchairs.

Figure 5.1: Comparing corners between two intersections

The second recommendation would be of benefit to cyclists who go to the Wrest Point Casino and Hutchins school rather than commuting by bicycle to the university or elsewhere. The last recommendation would be practical, but the bicycle lanes are probably too short, which would be inappropriate for inclusion in a commuting route network.

5.3.2.1 Recommended streets for establishing bicycle lanes

The establishment of bicycle lanes/paths is the improvement most recommended by cyclists (see Section 4.4.1) with Sandy Bay Road, Churchill Avenue, and Regent Street being the main streets selected needing the creation of bicycle lanes (see Section 4.4.2). This section discusses the possibility and suitability of bicycle lanes in each of these three streets.

The bicycle lane measurements in this thesis are based on *Guide to Traffic Engineering Practice, Part 14 – Bicycles* of Austroads (1999b) and Boyle (1997), which is a practice guide for traffic engineering in designing roads for safe cycling. Based on street widths shown in Appendix 9, the basic calculation of the width needed, shown in Figure 5.2, taking into consideration the existing car parking area, shows that it would be possible to establish bicycle lanes on Sandy Bay Road and Churchill Avenue, but not on Regent Street (see Figure 5.3).

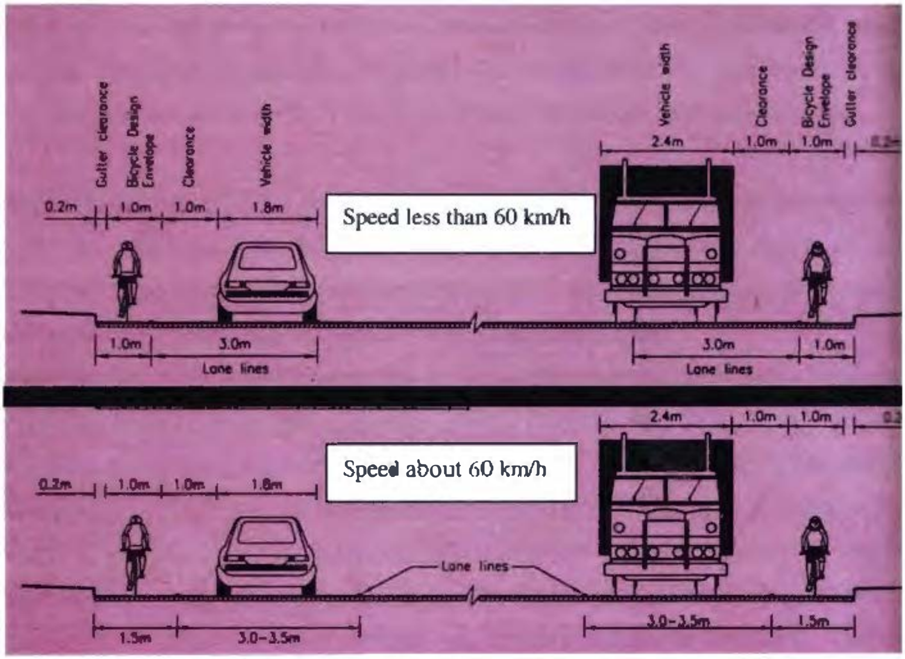

Figure 5.2: Bicycle lanes associated with vehicle positions on street with the speed environment less than and about 60 km/h, adapted from Austroads (1999b, p 22)

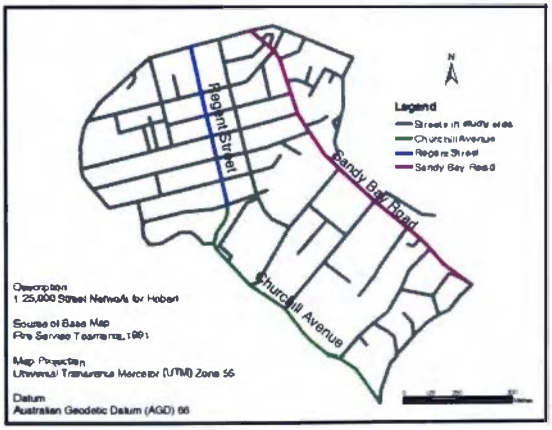

Figure 5.3: Churchill Avenue, Regent Street, and Sandy Bay Road recommended by cyclists for establishing bicycle lanes

Regent Street has narrow lanes and footpath, and permitted parking area. According to Boyle (1997), for adequate bicycle lanes in the permitted parking area, traffic lane widths should be rearranged to achieve a 7.2 - 7.5m kerbside lane width which would be unsuitable in the case of Regent Street. It might cause conflict with the needs of those living on or in the proximity of Regent Street for the provision of residential street parking. Any decisions regarding the removal of parking areas may also conflict with shop owners on Regent Street. This may interfere with the interest of shop owners.

According to Figure 5.2, if the speed environment could be reduced to less than 60 km/h, it would be practical to create a 1-metre bicycle lane on Sandy Bay Road and Churchill Avenue with no need to extend the width of the streets or reduce the footpath space. However, there might be a need to eliminate centre islands.
At present, the speed limit of Sandy Bay Road and Churchill Avenue is 60 km/h (except in school zones). Nevertheless, creating bicycle lanes on Churchill Avenue without widening the street or reducing the footpath width would still be feasible. In the case of Sandy Bay Road, at a speed limit of 60 km/h, there would be a need to increase the width of the road meaning either a reduction in footpath area or a reduction in vehicle lane width. If the speed limit on Sandy Bay Road were reduced to less than 60 km/h, the reduction in footpath area or vehicle lane width would not be necessary. One of recommendation stated in the "Hobart Bikeplan 1997" is to 'reduce the number of traffic lanes where the intent is to maintain kerbside parking (Boyle 1997, p 31).' This conld be implemented on Sandy Bay Road, but may be difficult to implement considering the views of other road users and the potentially increased traffic congestion. A reduction from two lanes to one lane of traffic along certain sections of the Sandy Bay Road, such as in and around the Sandy Bay shopping area, the Casino area, the University area and school areas, may further aggravate already congested sections of the road and other streets nearby. However, the creation of bicycle lanes on Churchill Avenue might lead to a conflict with street parking. In this case, pear period bicycle lanes might be a solution.

5.3.2.2 Required engineering solutions related to the establishment of bicycle lanes

The requirements for establishing bicycle lanes on Sandy Bay Road are; the elimination of car parking areas along both sides, the elimination of centre islands, the creation of alternative bus stop areas, the creation of bicycle lane signs (intermediate signs) and bicycle lane symbols (intermediate bicycle symbols, see Figure 5.4).

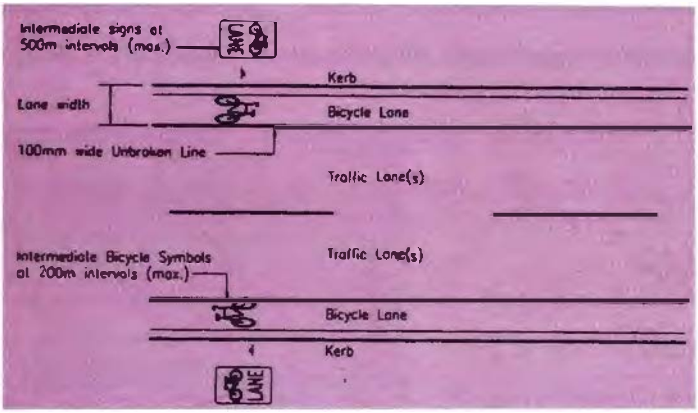

Figure 5.4: Bicycle lane layout adapted from Austroads (1999b, p 21)

Boyle (1997, p 31) recommended to 'use white stencilled bicycle pavement logos wherever it is necessary to denote commuting routes and recreational routes' and 'use white stencilled bicycle pavement logos wherever it is necessary to denote commuting routes and recreational routes.' These methods would be necessary to clearly demarcate cycle lanes and to raise the awareness of pedestrians, cyclists and vehicle users.

In the case of establishing bicycle lanes, advance stop lines (see Figure 5.5) and intersection treatments (see Figure 5.6) are needed. These stop lines are practical and easy to implement, as is the installation of contrasting coloured bike lanes travelling through all intersections with dedicated right or left turns (incorporating line marking and logos). The two advance stop lines are possibly suitable at the intersections with traffic lights such as the intersection: between Sandy Bay Road and: King Street, Russell Crescent, and Nelson Road; and between Regent Street and King Street (see Figure 5.7). The stop line 'b' can possibly be applied at these intersections without the existence of bicycle lanes (see Figure 5.5). The stop line 'a' is suitable at intersections between major streets and minor streets such as the intersections along main streets (Sandy Bay Road, Churchill Avenue and Regent Streets).

Figure 5.5: Two examples of advanced stop line, adapted from Austroads (1999b, p 56)

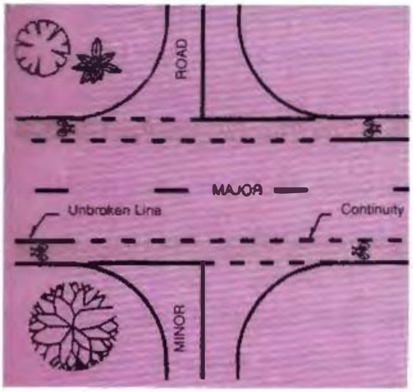

Figure 5.6: Intersection treatment for bicycle lanes, adapted from Austroads (1999b, p 56)

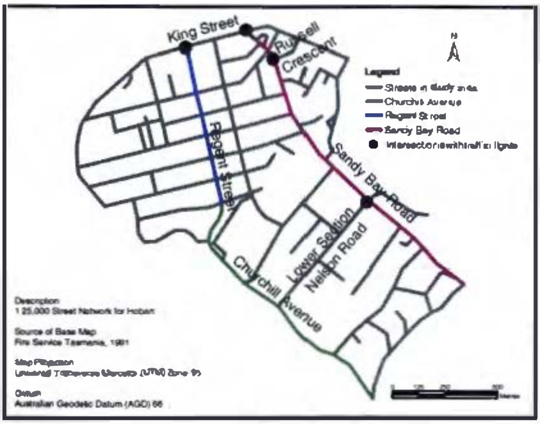

Figure 5.7: Intersections suitable to install advance stop lines between Sandy Bay Road and King Street, Russell Crescent and Lower Section Nelson Road; and King Street and Regent Street

Bike lanes are better than bike paths because drivers are more aware of the existence of and necessary integration of cyclists rather than bike paths where they are removed from the proximity of vehicular traffic. Bike lanes can allow for alternative, non-motorised forms of transport, such as rollerblades, scooters and skateboards, which would be safer for pedestrians and promote green transport. Unfortunately, there is no space along any of streets in the study area which could support a bicycle path without reconstruction.

5.3.3 Car parking

Many cyclists regarded issues concerning car parking areas as a problem (see Section 4.3). Many cyclists also pointed out in the questionnaire that removing car parking areas along Sandy Bay Road and Regent Street would be a possible solution and an improvement, giving rise to safer cycling (see Section 4.4.2). This suggestion would be possible on Sandy Bay Road, but would be difficult to implement on Regent Street as the parking areas comprise street parking for residents, as mentioned before. However, the issue related to car parking that cyclists were most concerned with was associated with opening or opened doors of parked cars, which is related to driver awareness rather than the existence of car parking areas. Conversely, it can be argued that if there were no car parking, there would be no problem of opening or opened doors.

5.3.4 Road and traffic engineering improvements according to the literature

There are many references in the literature, ranging from international[26], national[27] and local, which provide road and traffic engineering practice specifically for cycling which could be applied to the study area. It would be more appropriate to first discuss the local practices for improving cycling safety from the local literature.

[26] Such as *Sign up for the bike: Design manual for a cycle-friendly infrastructure* of the Netherlands (CROW 1996b) and *Guide for the development of bicycle facilities* of the United States of America (AASHTO 1999), and *Cycle friendly infrastructure- guidelines for planning and design* of the United Kingdom (Bicycle Association 1996).
[27] *Guide to Traffic Engineering Practice, Part 14 – Bicycles* of Austroads (1999b)

5.3.4.1 Recommendations in the "Hobart Bikeplan 1997"

The "Hobart Bikeplan 1997" is a primary source providing many recommendations to improve road conditions for safer cycling, which could be applied to the study area. Some recommendations from Boyle (1997, p 31 - 34) have been selected and the possibility and suitability of each are discussed:

- 'Replace drainage grates with "bike friendly" grates' (see Figure 5.8). This is good for all current drainage grates, such as two that are near the intersection of French Street and Churchill Avenue, shown in Figure 5.9. This would be a simple procedure.

Figure 5.8: Two examples of drainage grates with bike friendly gates: left adapted from Boyle (1997), and right adapted from Austroads (1999a)

Figure 5.9: Current drainage grate type used and the condition of the one near the intersection between French Street and Churchill Avenue

- 'Extend orange phase of traffic lights across wide multi-lane intersections with uphill grade.' This can be done simply and applied to the intersection between King Street and Regent Street; and between Sandy Bay Road and Russell Crescent.

- 'Reduce general urban speed limit to 40 km/hr throughout the entire municipality.' This would be practical on all streets in the study area. However, in Tasmania a state-wide urban speed limit for non-arterial roads is 50 km/h (LTSD 2001). In applying a 40 km/h speed limit, campaigning and advertising would be necessary. Nevertheless, a 30 km/h speed limit would be better (see Section 5.3.4.3).
- 'Extend clearway zones and times.' Clearway zones and times already exist along the Sandy Bay Road, Regent Street, and Churchill Avenue where car-parking areas exist. In spite of this, there is a need to extend clearway times if the peak-period bicycle lane will be established on these three streets.
- 'Publish specific bicycle route maps showing on road commuting and recreational routes.' There is *Hobart Bike Map* (see Figure 5.10. However, the current map shows three levels of bike road route. However, the map does not clearly indicate comfort or safety levels. According to Broadley (2002), the route levels on the map were created using cyclists' perceptions. It is recommended that one of bicycle suitability criteria. For example, BCI is applied in order to produce a suitable bicycle map. In addition, it would be advantageous to identify the code-coloured levels and give adequate explanation of what the levels refer to.

Figure 5.10: Code-coloured levels in Hobart Bike Map, adapted from ILS (2002)

5.3.4.2 Bicycle signs

Even though only three participants thought that installing bicycle signs to warn drivers about cyclists would help to improve their road safety, this kind of warning sign is related to increasing driver awareness of the existence of cyclists, which was the second highest recommendation selected by the participants (see Section 4.4.1). According to Austroads (1999b), traffic control devices improve safety in the movement of bicycles and motor vehicles. Bicycle warning signs help in the provision of the safety. For example, if shared use paths between cyclists and pedestrians occur as mention in Section 5.3.2, shared use path signage is used at the beginning and the end of paths. "Watch for Bicycle" signage provides motorists with an indication at locations where it is critical to look out for cyclists. Providing bicycle signs is a cheap method of increasing driver awareness and therefore cyclist safety.

5.3.4.3 30 km/h speed limit

According to Krag & Lehner-Lierz (2000), 'international experience shows that an urban speed limit of 30 km/h is not only better for road safety and noise, but also gives smoother traffic flow and improves the quality of urban life.' Collisions between cars and unprotected road users such as cyclists and pedestrian fall to only 5% at 30 km/h, and accident injuries are considerably less serious At lower speeds, road safety is substantially improved, and the traffic is less congested. In order to create a 30 km/h speed limit zone, it is necessary to construct traffic signs, road markings, humps or other changes in the infrastructure to remind motor vehicle drivers about the existence of a 30 km/h zone. Krag & Lehner-Lierz (2000) found that traffic speeds have a great effect on cyclists' perceived level of safety. The present study also found that high motor vehicle speed was perceived as a major cause of danger (see Section 4.3). Such a change would encourage walking and cycling, which would mean more physical exercise and better long-term public health. However, this might be difficult when the Tasmania urban speed limit of the area is 50 km/h (LTSD 2001), which is far removed from 30 km/h.

5.3.4.4 Other possible improvements

The author found that 'in accordance with Austroads *Road Safety Audit* guide, it is appropriate that audits of bicycle routes and other facilities are conducted at various stages from planning through to construction, and in relation to existing infrastructure

(Austroads 1999b, p 143; Austroads 2002). Therefore, *Road Safety Audit* is the first step in identifying road and traffic treatments for cycling safety.

From the author's observations, in the study area many streets (such as Grosvernor Street, Earl Street and Alexander Street) have insufficient lighting for cycling at night time. However, a small number of bicycle accident occurred at night (see Appendix 3 and 5), and 'not enough street light' was selected by the small number of participants (see Appendix 6, 7 and 8). This might be because most cyclists do not ride at night, they might feel that is not safe, or they may ride only short distances, so they do not tend to ride at night. However, increased street lighting on many streets would be desirable.

5.4 Constraints on the present study and recommendations for further research

This section describes how the study could have been improved if some measures had been taken to overcome constraints, and gives recommendations for further research.

5.4.1 Questionnaire

This section provides some comments on the limitations of the questionnaire and suggestions to improve the questionnaire.

5.4.1.1 Maps in the questionnaire

The amount and type of information shown on the map used in the survey may have affected the level of detail and information received. More detail and accuracy could have been achieved in a number of different ways that were not considered in the early stages of research. Some improvements s could include the following.

- The maps for locating bicycle accidents and identifying dangerous areas should be a smaller scale (such as 1:1,000) and of a larger size (such as one full A4 page), and the maps presented should be the same as the GIS-T map version. This would show more detail, making it easier for both participants to pinpoint and the author to position the accurate locations of bicycle accidents or dangerous locations.

- Maps should show both lanes on two-way streets when the streets have two directions of traffic flow as riding conditions will vary depending on which direction the cyclist is heading. For example, riding up hill into the city is very different from riding downhill out of the city, even on the same stretch of road. Another example is that T-intersections have an influence on both sides of the traffic ways, but in different ways.
- The maps should include roundabouts, speed humps and other traffic regulation features on the map.
- The extent of the intersections should be defined on the map for the participants. The extent could be the physical intersection, or include the road within 10 meters of the intersection as the DIER does (or even both options).

5.4.1.2 Written questions

Including more questions that relate to other factors not considered in this study could increase the depth of understanding surrounding the core data. Some ideas for further questions include:

- The ranges for cyclists riding frequency at the time of the survey should be: every day; most days of the week; on 1-3 days a week; 1-3 times a month; and less often than once a month based on Costley (2002). Additionally, the time that the bicycle accidents occurred ought to be recorded.
- Experience at location where bicycle accident occurred.
- Was the cyclist using the footpath? If yes, why? (Safer? More space?). If not, why? (Safer? Space issues? Conflict with pedestrians?)
- Does the cyclist want to use the footpath? Why/ why not?
- Does the cyclist avoid particular places/ streets? Why?
- Has the cyclist avoided particular areas in the past, which they now use? Why?
- Inclusions of "near misses" as well as actual accidents.
- Did accident or "near miss" experiences change the cyclists' riding habits or routes?
- Do the cyclists have any disabilities? For example, poor eyesight.

- Was the cyclist on a familiar route when an accident occurred?
- Include a general question on what the cyclist thinks makes it cycling dangerous.
- Inclusion of a scale for the perceived danger of road sections and intersections questions. For example, low, medium, high, and very high.
- Inclusion of a similar scale to rate the perceived level of danger from road conditions and traffic factors.
- Information about the involvement of other road users in bicycle accidents.

These listed additional questions are also for further investigation.

5.4.2 Survey population and study area

The survey participants in this study were specifically targeted because they rode and parked bicycles on campus at the University of Tasmania. This bias may not have led to universally applicable results. In addition, the survey sampling method is availability sampling, which is used as a preliminary study such as pre-test and pilot test (Babbie 1990) rather than the actual survey. Some ideas for future studies include:

- A similar survey could be conducted with a larger number of participants from the entire study area, not just those who ride to the University, ensuring that the results can be statistically analysed.
- Conducting the survey with only university members (staff and students) including the city campuses, in order to identify the improvement on road and traffic engineering for them to ride to university.
- A similar survey could be conducted based on a random sample of the entire population in an area, rather than targeting current cyclists.
- A similar survey could be conducted in other areas of Hobart or in other cities as a comparison between areas.
- A similar survey could be conducted over larger or smaller population areas such as all of Hobart, or just Sandy Bay road.
- A similar survey could be conducted to cover different groups of cyclists such as elderly, youth or experience to find out the differences between their perceptions and bicycle accidents and improve the cycling safety to satisfy only one particular group or all groups.

- A similar survey could be conducted based on the entire population rather than only the cyclists. Such a survey could find out what other road users (such as pedestrian and motorist: bus and truck drivers and car drivers) think about the suggested improvements, the dangerous locations and the differences between these in relation to cyclists. This might be useful when the suggestions for improvement could compromise the safety of other road user groups.

5.4.3 Other data sources and environmental issues

Other data sources for this study included research into previous surveys and measuring in the field. Although every effort was made to locate other sources of relevant data, the police records to DIER were the only data compatible with this study. For further studies it may be possible to design the questionnaire in order to incorporate the data from the sources not used with this survey.

The field measuring of street and footpath widths would be more accurate if a tape measure were used instead of a measuring wheel. Also, the width data alone is not enough, the traffic volume is also needed. Other environmental information that would be helpful is visibility, especially at intersections and on hilly or overly curved roads.

5.4.4 GIS application and data

This study could have used GIS in the basic level. GIS was applied to help in data analyse and displaying the results rather than actually analyse data. Ideally, future research would use GIS packages for a greater depth of analysis. Some ideas for further and future analysis, which may or may not use GIS include:

- Separate analysis for two-way and one-way streets and for both lanes on two-way streets.
- Combine many different factors (For example, accident data, perceived dangerous locations, levels of perceived danger, road conditions, road widths, etc.) or applying bicycle suitability criteria in different combinations to produce safety level maps.
- Use "GIS Safety Analysis Tools" (see Section 2.7.3.2) to analyse the study area, and compare it with the results from this or similar future surveys.

- Develop GIS bicycle accident database from the DIER database and develop the data collection method with the use of GPS in recording accident positions.

5.4.5 Other further analysis

There are other types of analysis that could have been conducted with the data used in the study such as the survey data, the DIER data, or a combination of both. This study suggests the analysis of the relationship of two variables or bivariate analysis, which could be undertaken by applying cross-tabulation and contingency tables. This further analysis could help in understanding more about the relationship between two variables.

- Examples of bivariate analysis include the relationship between bicycle accidents and cyclist characteristics such as gender, age, age at accidents, cycling experience, cycling experience at accidents, cycling experience in the Sandy Bay area, cycling experience at accidents in the Sandy Bay area, and riding frequency.
- Another bivariate analysis could be between the bicycle accidents and each bicycle accident detail (Question 10), each cyclist's detail when they had bicycle accidents (Question 11), and each road and traffic condition (Question 12).
- Based on cyclists who were involved in bicycle accidents, bivariate analysis of the relationship between accident locations and the dangerous locations could be conducted.

5.4.6 Other further investigations

It is recommended that the further investigation could be taken to gain insight into the issues related to cycling safety. The potential investigations could be as followed.

- The investigation about collision (if any) of cyclists with other road users such as motor vehicles, pedestrians, and animals could help to find real causes of each collision. The outcome of this might be able to help in the management.
- The investigation of the present road and traffic conditions in comparison to the reason given by the participants.
- The study of the relationship between cyclists' route patterns and the occurrence of bicycle accidents.

- The study of the relationship between the number of bicycle accidents and the number of cyclists using that route such as Sandy Bay Road. There might be a relationship between the high number of accidents and the high number of cyclists using that cycling route.
- The investigation of the reasons behind the differences between the relationship results of intersections and street sections (see Section 5.2.2).
- The in-depth knowledge of cyclists' perception of danger and the causes of bicycle accidents can be gained from the qualitative study like a study done by Analysis and Development of New Insight into Substitution (ADONIS 1998).
- The examination of the relationship between bicycle suitability criteria listed in Section 2.4 and the incidence of bicycle accidents in the study area or larger areas like Hobart to find the suitable criteria for bicycle planning in areas the examination conducted.
- The study of the use of the each bicycle suitability criteria to the study area or other areas.
- The examination of the relationships between the results of applying each bicycle suitability criteria and the bicycle accident rates within the study area or other areas.

5.5 Conclusions

Cycling is beneficial for various reasons. Along with the environmental benefits, cycling is beneficial for leisure, community interaction and maintained mobility for elderly people. Thus many responsible authorities recognise the importance of encouraging people to cycle. It is evident that road improvement is central to the success of any strategy that is devised to encourage cycling because without such improvements, people will not adopt this form of transport. There have been many attempts to develop bicycle suitability criteria for bicycle planning and decision-making. However, it is still questionable that all criteria are useful to identify places where bicycle accidents are likely to occur, when criteria do not take bicycle accident locations into account. The criteria might therefore be only used for making road and traffic conditions more comfortable for cyclists.

In the light of these benefits and considering the importance of road improvements and the potential use of bicycle suitability criteria for the improvement for commuting by bicycles, the aims of this thesis were to provide recommendations for improving safety cycling in the study area and examine the relationship between the number of bicycle accidents and cyclists' perception of danger.

In order to fulfil these aims, a questionnaire was devised to assess participant perceptions regarding dangerous locations in the study area and accident data together with the DIER data were used. The results revealed that there is the real relationship between the number of bicycle accidents and cyclists' perceptions of danger, but it is a weak relationship. This might be due to variety of factors, especially when human factors are the main cause of accidents not road environments. Nevertheless, when considering only the road environment, the cyclists' perceptions can be good indicators in identifying the bicycle accident locations based on road environment factors.

It is obvious that cyclists think the study area contains dangerous spots for cycling. The majority of cyclists would prefer the establishment of bike lanes, especially on Sandy Bay Road, Regent Street and Churchill Avenue. From the street-based fieldwork, the lane width of Sandy Bay Road and Churchill Avenue can accommodate bicycle lanes. Due to the potential conflict with residential parking along Churchill Avenue, the most suitable options for establishing bicycle lanes within the study area, with only small changes to the street and traffic conditions; is firstly to reduce the speed limit to less than 60 km/h on Sandy Bay Road followed by constructing bicycle lanes on both sides of the road between King Street and Waimea Avenue.

Another effective way to reduce bicycle accidents from international experiences is to reduce the speed limit to 30 km/h throughout the study area (Krag & Lehner-Lierz 2000, see Section 5.3.4.3). This practice should be applied to all urban areas in Tasmania. However, it might not work in practice due to the current practice of the 50 km/h speed limit (LTSD 2001). In addition, as the human factors play a major role in the incidence of accidents, there is a need for education and training on better-shared road uses.

GIS in this study is simply a tool to help in better spatial data presentation rather than part of data analysis. The spatial data can simply be done by colour highlighting on hard copy maps. The advantages in the use of GIS need further consideration and development such as the work of Transportation Division engineers in San Leandro, northern California. The engineers use GIS to find accident information on locations, cause, date, time of day and type of vehicle in order to investigate traffic collisions in order to prioritise traffic areas in most need of improvement (Lang 1999).

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Appendix 1:
Questionnaire form

Questionnaire Survey for Cycling <u>ACCIDENTS</u>

UNIVERSITY OF TASMANIA

This survey is designed to provide information on any cycling accidents you have had whilst cycling on public streets in the Sandy Bay area.

1 Please enter your gender: ☐ Male ☐ Female

2 Please enter your age: __________

3 How long have you been cycling? __________

4 How long have you been cycling within the Sandy Bay area? __________

5 How often do you cycle within the Sandy Bay area?

☐ Regularly ☐ Occasionally

6 Have you been involved in any cycling accidents (such as falling or collision) within the Sandy Bay area?

☐ Yes (go to **Question 7**) ☐ No (go to **Question 13**)

7 Have any of these cycling accidents occurred within the boundary on **Map 1**?

☐ Yes (go to **Question 8**) ☐ No (go to **Question 13**)

8 How many accident(s) have occurred? ________

9 From **Question 8**, please indicate the accident location(s) on **Map 1**, by

9.1 Marking **(X)**

9.2 Assigning a number **(1, 2, 3,...)** for each accident

9.3 Indicating with an arrow (➡) the direction of travel

10 For each accidents from **Question 9** and based on the assigned numbers on **Map 1,** please complete and tick (✓) the relevant information concerning the **accident details**

Accident Number(s)	Time	Day/ Month/ Year	Reported: Yes, to whom (Police, Insurance Company, Clinic or Hospital)?	Reported: No	Weather Condition (at least one): Clear	Raining	Fog	Windy	Surface Condition: Wet	Dry	Light Condition: Daylight	Dawn or Dusk	Dark <u>with</u> Street Light	Dark <u>without</u> Street Light	Road Alignment: Straight	Curve	Road Slope: Level	Gentle slope	Steep
1																				
2																				
3																				
4																				
5																				

11 From **Question 9,** and based on the assigned numbers on **Map 1,** please tick (✓) the relevant information concerning **your personal details**

Accident Number(s)	Were you? Riding	Stationary	Giving Signal Turns (If you were turning) Yes	No	Wrong Way on One-way Road Yes	No	Riding Against Traffic Yes	No	Riding at High Speed Yes	No	Riding Competition Yes	No	Doing Trick(s) Yes	No	Feeling ill Yes	No	Wearing Helmet Yes	No	Light Colour Clothing Yes	No	Bicycle in Good Mechanical Condition Yes	No
1																						
2																						
3																						
4																						
5																						

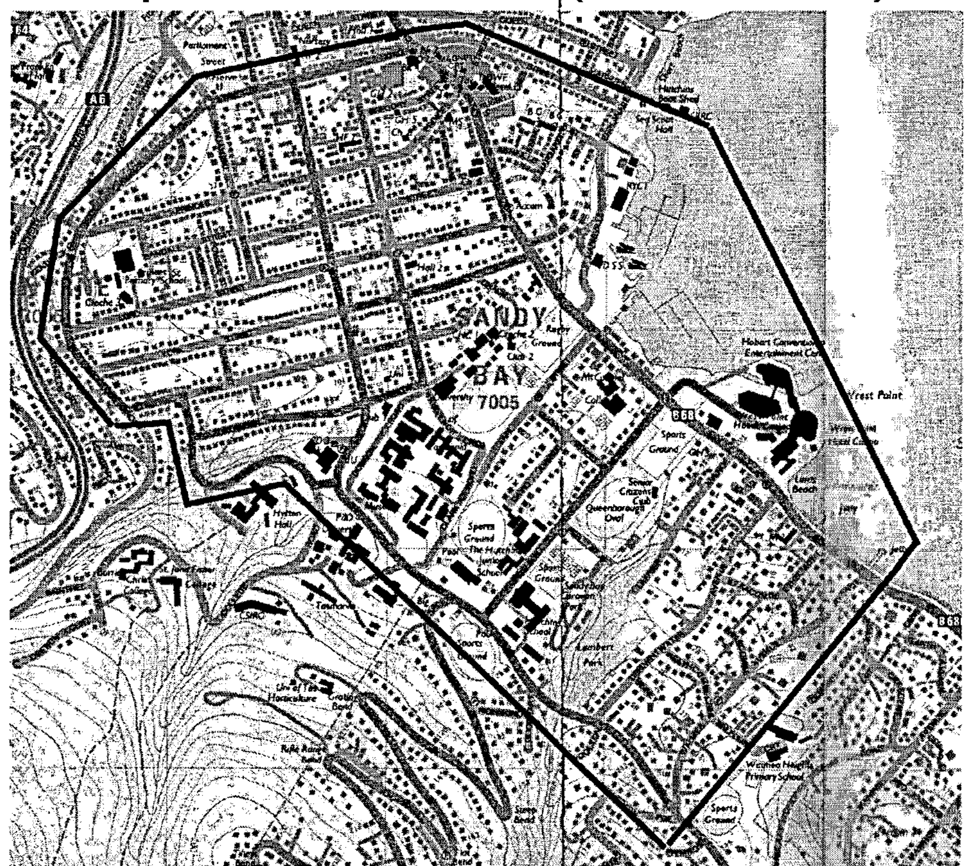
12 From **Question 9** and based on the assigned numbers on **Map 1,** what were the associated **reasons** and **levels of severity** for each accident? Please tick (✓) <u>any</u> relevant information concerning **road and traffic environment**

Factors applicable to accidents	Accident Number(s) 1	2	3	4	5
Personal error – lost balance (<u>unrelated</u> to traffic conditions and road conditions)					
Personal error – inattention (<u>unrelated</u> to traffic conditions and road conditions)					
Personal error – judgement (<u>unrelated</u> to traffic conditions and road conditions)					
Mechanical fault/condition of bicycle					
High volume of cars					
High volume of large vehicles such as large trucks and buses					
High speed cars or trucks					
Parked car with door opened or opening					
Parked car/s narrowing cycling space					
Parked car/s reducing visibility					
Parking car					
Narrow lane width					

Continued

Factors applicable to accidents (continued)	Accident Number(s) 1	2	3	4	5
Intersection					
Dark streets with poor street lighting					
Road obstructions such as rubbish, glass, grit, other debris and pot hole					
Wet and slippery surface					
Gutters					
Kerb					
Curve/Corner/Bend					
Road hump/island					
Steep slope					
Riding on footpath prohibited					
Building on corner blocking visibility					
Other (Please specify)					
1					
2					
3					
4					
5					
Severity Level					
Major property damage (Bicycle and other belongings)					
Minor property damage (Bicycle and other belongings)					
First aid at scene					
Non hospitalised injury, additional medical treatment					
Hospitalised injury, additional medical treatment					

Map 1: Accident Locations (Question 7 to 12)



Map adapted from ILS (2001)

<u>Please turn over</u>

UNIVERSITY OF TASMANIA

Questionnaire Survey for Cycling DANGEROUS Locations

UNIVERSITY OF TASMANIA

This survey is designed to provide information about any location(s) where you think is/are dangerous for cycling on public streets.

13 Do you think anywhere in the identified area on the **Map 2** is dangerous for cycling?
❒ Yes (go to **Question 14**) ❒ No (go to **Question 16**)

14 In your opinion, which areas on the **Map 2** do you consider dangerous at present?
14.1 Marking **(X)** and/or drawing a line on an intersection(s) and/or section(s) of a street(s)
14.2 Assigning a number **(1, 2, 3,...)** of each dangerous location

15 For what reason(s) did you identify the areas on **Map 2** as dangerous? Please tick (✓) any relevant factors for each dangerous location)

Factors applicable to danger	Dangerous Location(s)				
	1	2	3	4	5
High volume of cars					
High volume of large vehicles such as large trucks and buses					
High speed motor vehicles such as cars and trucks					
Parked car with door opened or opening					
Parked car/s narrowing cycling space					
Parked car/s reducing visibility					
Parking car					
Narrow lane width					
Intersection					
Dark streets with poor street lighting					
Road obstructions such as rubbish, glass, grit, other debris and pot hole					
Wet and slippery surface					
Gutters					
Kerb					
Curve/Corner/Bend					
Road hump					
Steep slope					
Riding on footpath prohibited					
Building on the corner blocking the visibility					
Other (Please specify)					
1					
2					
3					
4					
5					

16 What do you think would be the best road and traffic improvement(s) for cycling safety in the Sandy Bay area?

____

____

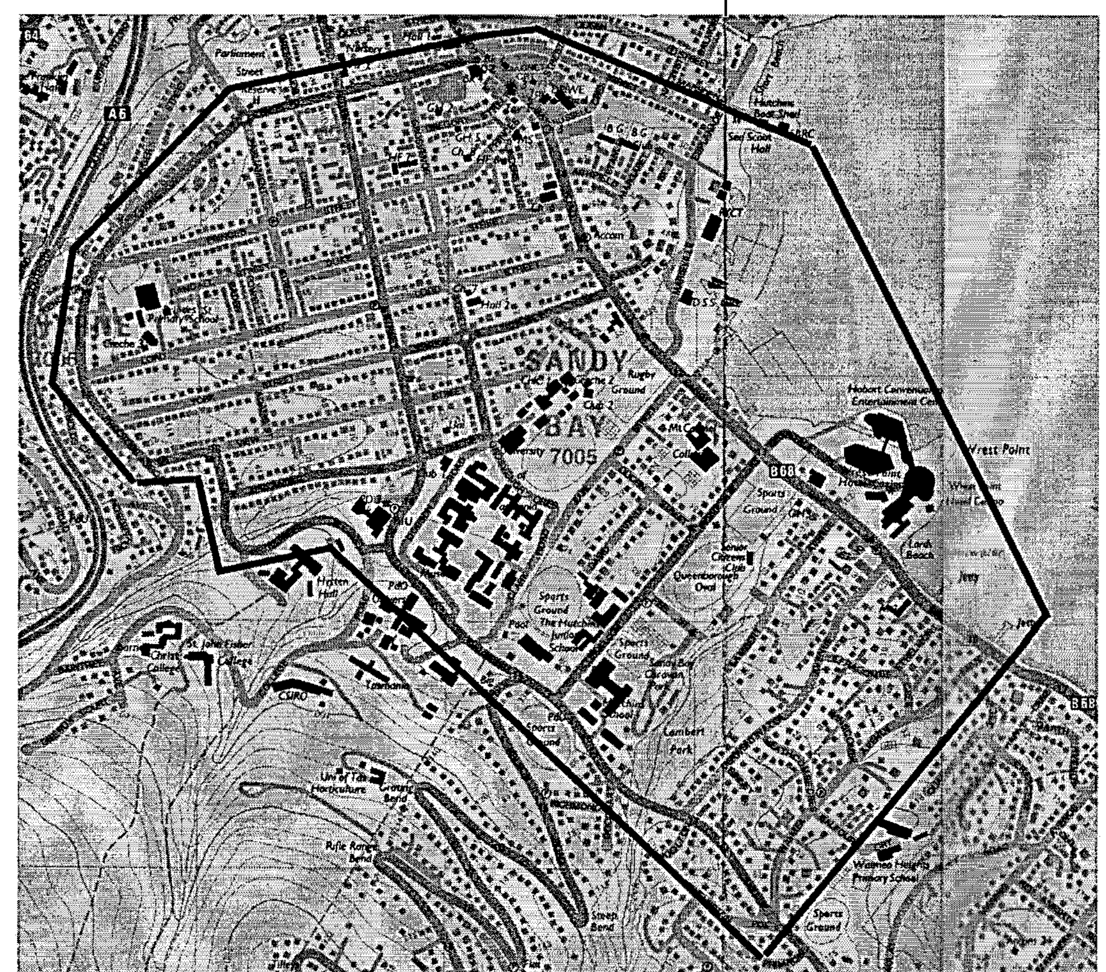
____

____

____

Thank you for your time.

Map 2: Dangerous Locations (Question 13, 14, and 15)



Map adapted from ILS (2001)

Appendix 2:
Questionnaire design

Questionnaire design

A questionnaire was designed to be able to obtain the useful data from participants for this study. The questionnaire could facilitate not only participants but also the author. Its structured was based on the following sections below.

Questionnaire sections

The questionnaire used in this study consisted of two sections, categorised into two groups based on whether they were fact or opinion. The fact is a section on accident while the opinion is a section on dangerous location.

- The accident section asked for the fact on the cyclists' characteristics and behaviours: gender, age, cycling experience, cycling frequency and accident involvement, which consists of accident details, personal details, road and traffic environments, and a map.
- The dangerous location section requested dangerous locations and improvement: relevant factors, improvement on road and traffic improvement, and a map.

Question types

This study applied both closed-ended and open-ended questions to gather data and information. The choice of using both the closed-ended and open-ended questions was based on the aims, the objectives and the practical limitations of a study project (Neuman 2000). The proper type of questions was the closed-ended questions because it can gain the same categories of data as the existing data from DIER. These also give a consistency of answers (Babbie 2002). In order to avoid the overlook of some responses, the closed-ended questions added "Other (Please specify)".

Details of questionnaire

The details of the questionnaire include the titles, the introductions and the questions, which needed to be clear to respondents of the questionnaire. The titles and the introductions of the two sections clearly tell the participants about the purpose of each section in the questionnaire.

The information to develop the questions was derived from many sources. The recorded new data should be able to provide a similar sort of information to the DIER database. Therefore, the questions about bicycle accidents were first developed using the bicycle accident data from DIER (2002). The information concerning cyclists' details on bicycle accidents were based on the information from DIER (2002), Burden (1978), New York State Department of Motor Vehicles (2002), and Department for Planning and Infrastructure (2002). For better understanding of the accident situations, the study added the relevant information from Burden and Burgess (1978) and Safe Routes to Schools Information Service (2000) to the questionnaire. The author focused on the road and traffic environment related to bicycle accidents as the main theme of the study. This sort of information was obtained from Austroads (1999).

In order to avoid replication to the DIER data, the participants who were involved in bicycle accidents were asked to identify whether they reported or not and to whom.

Appendix 3:

Information concerning the accident details

Accident numbers	Time	Day/Month/Year	Year	Report or No	Report to who	Weather	Surface	Light	Alignment	Slop
1	2:00 PM			No		Clear and Windy	Dry	Daylight	Straight	Level
2	9:00 AM	Dec-00	2000	No		Clear and Windy	Dry	Daylight	Curve	Steep
3		Jan-95	1995	No		Clear	Wet	Daylight	Straight	Level
4	1:00 PM	Mar-02	2002	No		Clear	Dry	Daylight	Straight	Level
5	6:00 PM	Mar-99	1999	No		Clear	Dry	Dawn or Dusk	Straight	Level
6	3:00 PM	Jun-02	2002	No		Clear	Dry	Daylight	Straight	Gentle slope
7	8:45 AM			No		Clear	Dry	Daylight	Straight	Level
8	8:00 PM	Feb-02	2002	No		Clear	Dry	Dark without street light	Straight	Level
9	4:00 PM	Nov-95	1995	No		Raining	Wet	Daylight	Straight	Gentle slope
10	8:45 AM	5-Jul-02	2002	Yes	General practitioner	Raining	Wet	Daylight	Curve	Gentle slope
11	6:00 PM	Apr-02	2002	No		Raining	Wet	Dark with Street Light	Straight	Steep
12	12:00 PM	Aug-01	2001	Yes		Clear	Dry	Daylight	Straight	Level
13	2:00 PM			No		Raining	Wet	Daylight	Curve	Steep
14	9:00 AM			No		Clear	Dry	Daylight	Straight	Gentle slope
15	5:00 PM	Apr-02	2002	No		Clear	Dry	Daylight	Straight	Level
16	10:00 AM			No		Raining	Wet	Daylight	Curve	Gentle slope
17		Mar-02	2002	No		Raining	Wet	Daylight	Curve	Level
18	5:00 PM	Aug-84	1984	No		Raining	Wet	Dawn or Dusk	Straight	Level
19				Yes	HCC	Clear	Dry	Daylight	Curve	Steep
20				Yes	General practitioner	Clear	Dry	Daylight	Straight	Gentle slope
21	10:00 AM	Sep-02	2002	No		Clear	Dry	Daylight	Straight	Gentle slope
22	11:00 PM	2000	2000	No		Raining	Wet	Dark with Street Light	Straight	Gentle slope
23	10:00 AM	2000	2000	No		Clear	Dry	Daylight	Straight	Level
24	5:00 PM	22-Sep-01	2001	No		Raining	Wet	Daylight	Straight	Level
25	5:00 PM	10-Jan-00	2000	No		Windy	Dry	Daylight	Straight	Level
26	9:00 AM	5-Nov-02	2002	Yes	Police	Clear	Dry	Daylight	Straight	Gentle slope
27	10:00 AM	Mar-02	2002	No		Clear	Wet	Daylight	Curve	Steep
28	6:30 PM	Jun-97	1997	Yes	Police and Insurance	Clear	Dry	Dark with Street Light	Straight	Gentle slope
29	11:00 AM	May-98	1998			Clear	Dry	Daylight	Straight	Steep
30	3:00 PM	Aug-00	2000			Clear	Dry	Daylight	Straight	Steep
31	12:00 PM	Apr-98	1998	Yes	Insurance	Clear	Dry	Daylight	Straight	Level

Appendix 4:

Cyclists' details when they had bicycle accidents

Accident numbers	Doing	Turing	Wrong Way	Against Traffic	High Speed	Competition	Trick	ill	Helmet	Light Clothing	Bicycle condition
1	Riding		No	No	Yes	No	No	No	Yes	Yes	Yes
2	Riding	Yes	No	No	Yes	No	No	No	Yes	Yes	Yes
3	Riding	No	No	No	Yes	No	No	No	Yes	Yes	Yes
4	Riding	Yes	No	No	No	No	No	No	Yes	Yes	Yes
5	Riding		No	Yes	No	No	No	No	Yes	Yes	Yes
6	Riding	No	No	No	No	No	No	No	Yes	No	Yes
7	Riding		No	No	No	No	No	No	Yes		Yes
8	Riding	No	No	No	Yes	No	No	No	Yes	No	Yes
9	Riding		No	No	No	No	No	No	Yes	Yes	Yes
10	Riding	No	No	No	No	No	No	No	Yes	Yes	Yes
11	Riding	No	No	No	No	No	No	No	Yes	No	No
12	Riding		No	No	No	No	No	No	Yes	No	No
13	Riding	Yes	No	No	No	No	No	No	Yes	Yes	Yes
14	Riding	No	No	No	Yes	No	No	No	Yes	Yes	Yes
15	Riding		No	No	No	No	No	No	Yes	Yes	Yes
16	Riding	No	No	No	No	No	No	Yes	Yes	No	Yes
17	Riding	No	Yes	Yes	No	No	No	No	Yes	Yes	Yes
18	Riding	No	No	No	No	No	No	No	No	No	Yes
19	Riding		No	No	Yes	No	No	No	Yes	No	Yes
20	Riding		No	No	Yes	No	No	No	Yes	No	Yes
21	Riding		No	No	Yes	No	No	No	Yes		Yes
22	Riding		No	No	Yes	No	No	No	Yes		Yes
23	Riding		No	No	No	No	No	No	Yes		No
24	Riding		No	No	No	No	No	No	Yes		Yes
25	Riding		No	No	No	No	No	No	Yes		Yes
26	Riding		No	No	No	No	No	No	Yes	Yes	Yes
27	Riding		No	No	No	No	Yes	No	Yes	Yes	Yes
28	Riding	No	No	No	Yes	No	No	No	Yes	No	Yes
29	Riding		No	No	No	No	No	No	Yes	No	Yes
30	Riding		No	No	Yes	No	No	No	Yes	No	Yes
31	Riding		No	No	No	No	No	No	Yes	Yes	Yes

x

Appendix 5:
Road and traffic conditions associated with all accidents

Road and traffic conditions (n = 20)	Number of cyclists	Percentage
High volume of cars	9	29.03
Narrow lane width	8	25.81
Wet and slippery surface	8	25.81
Intersection	6	19.35
Parked car with door opened or opening	5	16.13
Parked car/s narrowing cycling space	5	16.13
Road obstructions such as rubbish, glass, grit, other debris and pot hole	5	16.13
Curve/Corner/Bend	5	16.13
Personal error – lost balance	4	12.90
Personal error – judgment	4	12.90
Personal error – inattention	3	9.68
Mechanical fault	3	9.68
High volume of large vehicles such as large trucks and buses	3	9.68
High speed cars or trucks	3	9.68
Parked car/s reducing visibility	3	9.68
Parking car	3	9.68
Gutters	2	6.45
Kerb	2	6.45
Dark streets with poor street lighting	1	3.23
Road hump/island	1	3.23
Steep slope	1	3.23
Riding on footpath prohibited		0.00
Building on corner blocking visibility		0.00
Other (Please specify)	3*	9.68

*Car turned without indicating, can not give way and rubbish bin obstacle every Monday

Appendix 6:
Road and traffic environments
of entire streets causing the danger for cycling

Street	Number of cyclists	High volume of cars	High volume of large trucks and buses	High speed motor vehicles	Parked car/s with door opened or opening	Parked car/s narrowing cycling space	Parked car/s reducing visibility	Parking car	Narrow lane width	Intersection	Dark streets with poor street lighting
Churchill Avenue	4	4	2	2	3	3	2	1	3	1	
French Street	1	1	1		1	1			1		
Grosvenor Street	2				1	1	1		1	1	1
Lower Part Nelson Road	2	1	1	1	2	2	2	2	2		
Proctors Road	1	1	1		1	1			1		
Randall Street	1				1						
Regent Street	9	9	3	4	8	7	6	3	4	3	1
Sandy Bay Road	16	12	8	8	9	9	6	3	5	3	1

Street	Road obstructions	Wet and slippery surface	Gutters	Kerb	Curve/ corner/ bend	Road hump	Steep slope	Riding on footpath prohibited	Building on the corner blocking visibility	Other
Churchill Avenue							2			1*
French Street										
Grosvenor Street							1			
Lower Part Nelson Road							1			
Proctors Road										
Randall Street										1**
Regent Street	1	2	1	1	3					
Sandy Bay Road	3	1	2	2	1			2	2	4***

* Indifference/intolerance towards cyclists
** Learner drivers often on this street
*** Lack of car driver awareness of bikes
*** Narrow bike types will get stuck when traffic force to ride in the gutter
*** Use of mobile phones while driving
*** No cycling facilities lanes along street and bad road surface

Appendix 7:

Road and traffic environments

of street sections causing the danger for cycling

Street section locations	Number of cyclists	High volume of cars	High volume of large trucks and buses	High speed motor vehicles	Parked car/s with door opened or opening	Parked car/s narrowing cycling space	Parked car/s reducing visibility	Parking car	Narrow lane width	Intersection	Dark streets with poor street lighting	Road obstructions	Wet and slippery surface	Gutters
Churchill Av between Alexander St and French St	8	6	5	7	1	2	1	1	4	3				
Churchill Av between French St and Dobson Rd	7	7	4	5	3	5	3	2	3	2				
Churchill Av between Clard Rd and Upper Section Nelson Rd	4	4	2	3	3	3	2	2	2	1				
Churchill Av between Clark Rd and Dobson Rd	7	7	3	4	3	4	3	2	3	2				
Churchill Av between Derwentwater Av and Goodheart Pl	1	1		1	1	1	1	1						
Churchill Av between Goodheart Pl and Lower Section Nelson Rd	1	1		1	1	1	1	1						
Churchill Av between Lower Section Nelson Rd and Upper Section Nelson Rd	4	4	2	3	3	3	2	2	2	1				
Clard Rd between Churchill Av and Earl St	1													
Duke St between Parliament St and Regent St	1													
Earl St between Clark Rd and Quorn St	1										1	1		
French St between Churchill Av and College Rd	5	2	1	2					1	3	2	1	1	
Grosvenor Cres between Dobson Rd and Earl St	1				1	1	1							1
Grosvenor St between Lord St and York St	1										1			
Grosvenor St between View St and York St	1										1			
King St between Greenlands Av and Regent St	2	2	2	1	2	2	1		2				1	1
King St between Grosvenor St and Regent St	2	2	2	1	2	2	1		2				1	1
King St between Grosvenor St and Sandy Bay Rd	2	2	2	1	2	2	1		2				1	1
King St between Princes St and Pillinger St	1	1	1		1	1			1					
King St between Lasswade Av and Pillinger St	1	1	1		1	1			1					
King St between Lasswade Av and Parliament St	1	1	1		1	1			1					
King St between Greenlands Av and Parliament St	2	2	2	1	2	2	1		2				1	1
King St between Kendrick Ct and Lynton Av	1	1			1	1								
Lord St between Baden St and Powell St	1													
Lord St between Parliament St and Regent St	1													
Lord St between Parliament St and Powell St	1													
Lord St between Baden St and Proctors Rd	1													
Lower Section Nelson Rd between Peel St and Quorn St	1								1					
Marieville Esp between Marganet St and Sandy Bay Rd	1											1		
Parliament St between Duke St and Lord St	1													
Parliament St between Duke St and Randall St	1													
Parliament St between King St and Princes St	1													
Parliament St between Princes St and Randall St	1													
Princes St between Crisp St and Parliament St	1													
Princes St between Crisp St and Regent St	1													
Princes St between Flinders La and Grosvenor St	1				1	1	1	1	1					
Princes St between Flinders La and Sandy Bay Rd	1				1	1	1	1	1					
Princes St between King St and Princess St	1													
Princes St between Parliament St and Princess St	1													
Proctors Rd between Kendrick Ct and Lord St	1	1			1	1								
Proctors Rd between Lord St and Upper Section Reynolds Ct	1								1					
Proctors Rd between Lower Section Reynolds Ct and View St	1								1					
Proctors Rd between Lower Section Reynolds Ct and York St	1								1					
Proctors Rd between Upper Section Reynolds Ct and York St	1								1					

Street section locations	Kerb	Curve/ corner/ bend	Road hump	Steep slope	Riding on footpath prohibited	Building on the corner blocking visibility	Other	
Churchill Av between Alexander St and French St		4		3			1	Bike speed down hill
Churchill Av between French St and Dobson Rd		2		1	1		1	Many cross streets
Churchill Av between Clard Rd and Upper Section Nelson Rd		1		1	1			
Churchill Av between Clark Rd and Dobson Rd		2		1	1		2	Many cross streets, Difficult turning right to University
Churchill Av between Derwentwater Av and Goodheart Pl								
Churchill Av between Goodheart Pl and Lower Section Nelson Rd								
Churchill Av between Lower Section Nelson Rd and Upper Section Nelson Rd		1		1	1			
Clard Rd between Churchill Av and Earl St							1	Cars leaving parking can't see cyclists
Duke St between Parliament St and Regent St							1	Learner drivers often on this street
Earl St between Clark Rd and Quorn St							1	Lack of traffic island for bikes
French St between Churchill Av and College Rd	1	2		3		1		
Grosvenor Cres between Dobson Rd and Earl St	1		1					
Grosvenor St between Lord St and York St				1				
Grosvenor St between View St and York St				1				
King St between Greenlands Av and Regent St	1						2	Use of mobile phones while driving, Poor bicycle awareness
King St between Grosvenor St and Regent St	1						2	Use of mobile phones while driving, Poor bicycle awareness
King St between Grosvenor St and Sandy Bay Rd	1						2	Use of mobile phones while driving, Poor bicycle awareness
King St between Princes St and Pillinger St								
King St between Lasswade Av and Pillinger St								
King St between Lasswade Av and Parliament St								
King St between Greenlands Av and Parliament St	1						2	Use of mobile phones while driving, Poor bicycle awareness
King St between Kendrick Ct and Lynton Av								
Lord St between Baden St and Powell St							1	Learner drivers often on this street
Lord St between Parliament St and Regent St							1	Learner drivers often on this street
Lord St between Parliament St and Powell St							1	Learner drivers often on this street
Lord St between Baden St and Proctors Rd							1	Learner drivers often on this street
Lower Section Nelson Rd between Peel St and Quorn St								
Marieville Esp between Marganet St and Sandy Bay Rd				1				
Parliament St between Duke St and Lord St							1	Learner drivers often on this street
Parliament St between Duke St and Randall St							1	Learner drivers often on this street
Parliament St between King St and Princes St						1		
Parliament St between Princes St and Randall St							1	Learner drivers often on this street
Princes St between Crisp St and Parliament St				1			1	Really bumpy and some potholes
Princes St between Crisp St and Regent St				1			1	Really bumpy and some potholes
Princes St between Flinders La and Grosvenor St								
Princes St between Flinders La and Sandy Bay Rd								
Princes St between King St and Princess St				1			1	Really bumpy and some potholes
Princes St between Parliament St and Princess St				1			1	Really bumpy and some potholes
Proctors Rd between Kendrick Ct and Lord St								
Proctors Rd between Lord St and Upper Section Reynolds Ct								
Proctors Rd between Lower Section Reynolds Ct and View St								
Proctors Rd between Lower Section Reynolds Ct and York St								
Proctors Rd between Upper Section Reynolds Ct and York St								

Street section locations	Number of cyclists	High volume of cars	High volume of large trucks and buses	High speed motor vehicles	Parked car/s with door opened or opening	Parked car/s narrowing cycling space	Parked car/s reducing visibility	Parking car	Narrow lane width	Intersection	Dark streets with poor street lighting	Road obstructions	Wet and slippery surface	Gutters
Regent St between Alexander St and View St	11	9	4	4	9	8	4	2	4	3	1	1	2	
Regent St between Duke St and Lord St	9	7	2	3	8	7	3	1	3	2	1	1	2	
Regent St between Duke St and Princes St	11	9	4	4	9	8	4	2	4	3	1	1	2	
Regent St between King St and Princes St	10	8	2	3	8	7	3	1	3	2	1	2	2	
Regent St between Lord St and York St	10	8	3	4	9	8	3	1	4	2	1	1	2	
Regent St between View St and York St	11	8	3	4	10	8	4	2	4	3	1	1	2	
Sandy Bay Rd between Ashfield St and Duke St	9	9	8	6	9	8	6	7	4	6				1
Sandy Bay Rd between Ashfield St and Russell Cres	15	14	11	9	14	12	10	12	6	8			1	1
Sandy Bay Rd between Derwentwater Av and Ethelmont Rd	5	4	2	3			1	1	2					
Sandy Bay Rd between Derwentwater Av and Plimsoll Pl	5	4	2	3			1	1	2					
Sandy Bay Rd between Drysdale Pl & Lower Section Nelson Rd and Lambert Av	5	4	2	3	1	1	2	2	2	1				
Sandy Bay Rd between Duke St and Lord St	7	7	6	5	7	6	4	5	3	4				1
Sandy Bay Rd between Earl St and Drysdale Pl & Lower Section Nelson Rd	5	5	2	2	2	1	2	2	1	2				
Sandy Bay Rd between Earl St and Marieville Esp	4	4	2	3	3	2	2	3	1	2				
Sandy Bay Rd between Ethelmont Rd and Waimea Av	5	4	2	3			1	1	2					
Sandy Bay Rd between Gregory St and Lower Section Magnet Ct	23	21	12	11	21	18	12	14	8	10			1	1
Sandy Bay Rd between Gregory St and Upper Section Magnet Ct	22	20	10	10	20	17	10	13	7	10	1		1	1
Sandy Bay Rd between King St and Upper Section Magnet Ct	22	20	10	10	20	17	10	13	7	10	1		1	1
Sandy Bay Rd between Lambert Av and Plimsoll Pl	5	4	2	3			1	1	2					
Sandy Bay Rd between Lord St and Sayer Cres	6	6	5	4	6	5	3	5	3	4				1
Sandy Bay Rd between Lower Section Magnet Ct and Princes St	23	21	12	11	21	18	12	14	8	10			1	1
Sandy Bay Rd between Marieville Esp and York St	5	4	2	3	3	2	2	3	1	2		1		
Sandy Bay Rd between Princes St and Russell Cres	19	18	12	11	17	15	11	13	8	8			1	1
Sandy Bay Rd between Sayer Cres and York St	6	6	4	5	5	4	4	5	2	3				1
View St between French St and Proctors Rd	1	1	1		1	1			1					

Street section locations	Kerb	Curve/ corner/ bend	Road hump	Steep slope	Riding on footpath prohibited	Building on the corner blocking visibility	Other	
Regent St between Alexander St and View St		1		1	2		2	Use of mobile phones while driving, Poor bicycle awareness
Regent St between Duke St and Lord St					1		2	Use of mobile phones while driving, Poor bicycle awareness
Regent St between Duke St and Princes St		1			2		3a	
Regent St between King St and Princes St					1		2	Use of mobile phones while driving, Poor bicycle awareness
Regent St between Lord St and York St					1		3b	
Regent St between View St and York St		1		1	1		2	Use of mobile phones while driving, Poor bicycle awareness
Sandy Bay Rd between Ashfield St and Duke St		1			2	1	2c	
Sandy Bay Rd between Ashfield St and Russell Cres		2			3	2	3d	
Sandy Bay Rd between Derwentwater Av and Ethelmont Rd							3e	
Sandy Bay Rd between Derwentwater Av and Plimsoll Pl								
Sandy Bay Rd between Drysdale Pl & Lower Section Nelson Rd and Lambert Av					1		3f	
Sandy Bay Rd between Duke St and Lord St		1			1	1	2c	
Sandy Bay Rd between Earl St and Drysdale Pl & Lower Section Nelson Rd					1		4g	
Sandy Bay Rd between Earl St and Marieville Esp					1		1	Indifference/intolerance towards cyclists
Sandy Bay Rd between Ethelmont Rd and Waimea Av								
Sandy Bay Rd between Gregory St and Lower Section Magnet Ct		2		1	3	2	6h	
Sandy Bay Rd between Gregory St and Upper Section Magnet Ct		2		1	3	2	5i	
Sandy Bay Rd between King St and Upper Section Magnet Ct		2		1	3	2	5i	
Sandy Bay Rd between Lambert Av and Plimsoll Pl							3e	
Sandy Bay Rd between Lord St and Sayer Cres		1			1	1	1	Indifference/intolerance towards cyclists
Sandy Bay Rd between Lower Section Magnet Ct and Princes St		2		1	3	2	6h	
Sandy Bay Rd between Marieville Esp and York St					1		2j	
Sandy Bay Rd between Princes St and Russell Cres		2		1	3	2	3b	
Sandy Bay Rd between Sayer Cres and York St					1	1	2j	
View St between French St and Proctors Rd								

a Use of mobile phones while driving, Poor bicycle awareness, Cars coming over the curve reducing visibility
b Use of mobile phones while driving, Poor bicycle awareness, Trees Narrow space
c Large buses not providing enough space, Indifference/intolerance towards cyclists
d Poor bicycle awareness, Large buses not providing enough space, Indifference/intolerance towards cyclists
e Squeeze point and unnecessary 2nd lane, Indifference/intolerance towards cyclists, Transition in road surface to concrete asphalt
f Vehicles cut cyclists off by over taking and turning into service station abruptly, Indifference/intolerance towards cyclists, Transition in road surface to concrete asphalt
g Indifference/intolerance towards cyclists, Transition in road surface to concrete asphalt, Traffic from the school, Parked buses reducing visibility
h Large buses not providing enough space, Lack of traffic island for bikes, Pedestrians not looking for giving way and bike, Cross over of cycle car traffic in left turn, Indifference/intolerance towards cyclists
i Poor bicycle awareness, Lack of traffic island for bikes, Pedestrians not looking for giving way and bike, Cross over of cycle car traffic in left turn, Indifference/intolerance towards cyclists
j Indifference/intolerance towards cyclists, Transition in road surface to concrete asphalt

Appendix 8:

Road and traffic environments

of intersections causing the danger for cycling

Intersection locations	Number of cyclists	High volume of cars	High volume of large trucks and buses	High speed motor vehicles	Parked car/s with door opened or opening	Parked car/s narrowing cycling space	Parked car/s reducing visibility	Parking car	Narrow lane width	Intersection	Dark streets with poor street lighting	Road obstructions	Wet and slippery surface	Gutters	Kerb	Curve/ corner/ bend
Alexander St & Grosvenor Cres & Grosvenor St	4	1	1	1						4	1			1		1
Alexander St & Regent St	6	4	2	4	1	1	1		1	6	1	1	1	1	1	1
Cheverton Pde & Churchill Av & Waimea Av	1	1		1			1			1						1
Churchill Av & French St	1	1								1						
College Rd & French St	1	1		1						1						
Derwentwater Av & Sandy Bay Rd	1	1	1	1	1	1	1	1	1	1						1
Drysdale Pl & Lower Section Nelson Rd & Sandy Bay Rd	3	3	2	2	1	1	1	1	2	3	1			1		1
Duke St & Grosvenor St	1									1	1					
Duke St & Sandy Bay Rd	2	2	2	2	1	1	1	1	1	2						
Earl St & Sandy Bay Rd	8	8	3	5	1	1	1	1	2	8	1					1
Gregory St & Grosvenor St	1	1	1		1	1			1	1						
Gregory St & Sandy Bay Rd	1	1	1	1	1				1	1						
Grosvenor St & Lord St	1	1	1		1	1			1	1						
Grosvenor St & Princes St	2									2	1					
Grosvenor St & York St	2	1		1		1	1		1	2						1
King St & Lynton Av & Princes St	1		1	1						1					1	
King St & Regent St	2	1	1	1	1	1	2	2		2						
King St & Sandy Bay Rd	8	7	5	3	2	4	2	4	4	8	1			1	1	1
Lord St & Proctors Rd	1									1						
Lord St & Regent St	1									1						
Lord St & Sandy Bay Rd	1	1	1	1	1	1	1	1	1	1						1
Lower Section Magnet Ct & Sandy Bay Rd	2	4	2	3	4	2	2	1	3	2						
Marieville Esp & Sandy Bay Rd	2	1		1						2						
Parliament St & Princes St	1									1	1					
Princes St & Regent St	1									1						
Princes St & Sandy Bay Rd	1	1	1		1	1		1	1	1						
Proctors Rd & View St	2	1	1	2			1			2				1		1
Proctors Rd & York St	1									1						
Regent St & View St	1			1	1					1						
Regent St & York St	2	2	1	1	1	1			1	2			1	1	1	
Russell Cres & Sandy Bay Rd	3	3	2	1	3	2	1	2	2	3						
Sandy Bay Rd & Upper Section Magnet Ct	4	4	2	3	4	2	2	1	3	4						
Sandy Bay Rd & York St	1	1	1	1	1	1	1	1	1	1						
Waimea Av & Sandy Bay Rd	1	1	1	1	1	1	1	1	1	1						

Intersection locations	Road hump	Steep slope	Riding on footpath prohibited	Building on the corner blocking visibility	Other	
Alexander St & Grosvenor Cres & Grosvenor St		1			3	Cars not indicate, Cars not giving way, Hard to read traffic
Alexander St & Regent St	1	3	2	1	1	Use of mobile phones while driving, Poor bicycle awareness
Cheverton Pde & Churchill Av & Waimea Av						
Churchill Av & French St						
College Rd & French St						
Derwentwater Av & Sandy Bay Rd						
Drysdale Pl & Lower Section Nelson Rd & Sandy Bay Rd					1	Difficult turning into Sandy Bay Rd
Duke St & Grosvenor St						
Duke St & Sandy Bay Rd						
Earl St & Sandy Bay Rd					2*	
Gregory St & Grosvenor St						
Gregory St & Sandy Bay Rd						
Grosvenor St & Lord St						
Grosvenor St & Princes St					1	Street splits and a rail obscures the view
Grosvenor St & York St						
King St & Lynton Av & Princes St						
King St & Regent St		1				
King St & Sandy Bay Rd		1	2		5**	
Lord St & Proctors Rd		1				
Lord St & Regent St						
Lord St & Sandy Bay Rd						
Lower Section Magnet Ct & Sandy Bay Rd			1			
Marieville Esp & Sandy Bay Rd					1	Lack of traffic island for bikes
Parliament St & Princes St				1		
Princes St & Regent St						
Princes St & Sandy Bay Rd			1		1	Storm water grates should go across road, Drivers not look when pulling out form curve, Restrictive area for bikes
Proctors Rd & View St		2			1	People in cars taking off from a stationary position at high speed
Proctors Rd & York St		1				
Regent St & View St		1				
Regent St & York St					1	Narrow footpath
Russell Cres & Sandy Bay Rd			2		1	Storm water grates should go across road, Drivers not look when pulling out form curve, Restrictive area for bikes
Sandy Bay Rd & Upper Section Magnet Ct			1		1	Cars turn into Magnet Ct but back-up onto Sandy Bay Rd
Sandy Bay Rd & York St						
Waimea Av & Sandy Bay Rd						

* Cars turning into Eart St in moving looks for the break in city bound traffic not the cyclist,
* Dangerous crossing from outside lane to centre lane to turn onto Marieville Esp
** Poor bicycle awareness
** Use of mobile phones while driving, Poor bicycle awareness
** Cross over of cycle and car traffic in left turn
** Cars pulling out without noticing cyclist
** Storm water grates should go across road, Drivers not look when pulling out form curve, Restrictive area for bikes

Appendix 9:

Width of street, lanes, and footpaths

ID	Locations of intersection for measurement	Streets, measuring taken	Total road width	Lane width (city bound)	Lane width (outward bound)	Centre Island	Footpath (city bound)	Footpath (outward bound)
1	Earl Street & Sandy Bay Road	Sandy Bay Road	14.33	7.16	7.16	-	2.95	2.8
2	Lord Street & Sandy Bay Road	Sandy Bay Road	13.71	6.86	6.86	-	2.16	2.57
3	Russel Cresent & Sandy Bay Road	Sandy Bay Road	15.09	7.54	7.54	-	2.16	1.8
4	Magnet Court & Sandy Bay Road	Sandy Bay Road	17.07	8.53	7.19	1.35	2.64	3.56
5	King Street & Sandy Bay Road	Sandy Bay Road	23.64	11.82	11.82	-	3.66	3.86
	King Street & Sandy Bay Road	King Street	12.32	6.16	6.16	-	2.11	1.7
6	Grosvenor Street & King Street	Grosvenor Street	10.8	5.4	5.4	-	1.65	1.73
	Grosvenor Street & King Street	King Street	10.49	5.25	5.25	-	2.29	1.83
7	King Street & Regent Street	King Street	11.02	5.51	5.51	-	1.83	2.26
	King Street & Regent Street	Regent Street	12.32	6.16	6.16	-	2.01	1.78
8	Princes Street & Regent Street	Princes Street	8.36	4.18	4.18	-	1.63	1.7
	Princes Street & Regent Street	Regent Street	12.01	6.01	6.01	-	1.63	1.78
9	Duke Street & Regent Street	Regent Street	8.66	4.33	4.33	-	1.75	1.96
10	Regent Street & York Street	Regent Street	15.24	6.4	6.53	2.31	2.16	2.11
	Regent Street & York Street	York Street	14.55	7.28	7.28	-	2.67	2.16
11	Alexander Street & Regent Street & Churchill Avenue	Alexander Street	10.67	5.33	5.33	-	1.83	1.88
	Alexander Street & Regent Street & Churchill Avenue	Churchill Avenue	14.71	6.6	6.53	1.57	1.75	1.91
12	Churchill Avenue & French Street	French Street	17.68	7.09	3.4	7.19	1.3	2.03
	Churchill Avenue & French Street	Churchill Avenue	14.55	8.18	5.64	0.72	1.39	1.62
13	Churchill Avenue & Nelson Road	Churchill Avenue	11.38	5.69	5.69	-	1.93	1.4
	Churchill Avenue & Nelson Road	Nelson Road	9.63	4.81	4.81	-	1.24	1.68
14	Nelson Road & Sandy Bay Road	Nelson Road	10.19	5.09	5.09	-	2.34	2.03
	Nelson Road & Sandy Bay Road	Sandy Bay Road	18.54	9.27	9.27	-	1.6	2.26
15	Sandy Bay Road & Waimea Avenue	Sandy Bay Road	14.79	7.4	7.4	-	1.82	1.99
16	Sandy Bay Road & Derwentwater Avenue	Sandy Bay Road	14.87	7.44	7.44	-	1.99	1.84