"AN ACCESSIBLE CITY"

AN INVESTIGATION USING GIS INTO THE POTENTIAL FOR FURTHER DEVELOPMENT OF THE

PROPOSED MAJOR CYCLEWAYS NETWORK FOR CHRISTCHURCH, NEW ZEALAND

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Abstract

As the future of the world's oil reserves becomes progressively more uncertain, it is becoming increasingly important that steps are taken to ensure that there are viable, attractive alternatives to travel by private motor vehicle. As with many of New Zealand's major urban centres, Christchurch is still exceptionally reliant on private motor vehicles; although a significant proportion of the population indicate that they would like to cycle more, cycling is still an underutilised mode of transport. Following a series of fatal earthquakes that struck the city in 2010 and 2011, there has been the need to significantly redevelop much of the city's horizontal infrastructure – subsequently providing the perfect platform for significant changes to be made to the road network.

Many of the key planning frameworks governing the rebuild process have identified the need to improve Christchurch's cycling facilities in order to boost cycling numbers and cyclist safety. The importance of considering future growth and travel patterns when planning for transport infrastructure has been highlighted extensively throughout literature. Accordingly, this study sought to identify areas where future cycle infrastructure development would be advantageous based on a number of population and employment projections, and likely future travel patterns throughout the city.

Through the use of extensive GIS analysis, future population growth, employment and travel patterns for Christchurch city were examined in order to attain an understanding of where the current proposed major cycleways network could be improved, or extended. A range of data and network analysis were used to derive likely travel patterns throughout Christchurch in 2041. Trips were derived twice, once with a focus on simply finding the shortest route between each origin and destination, and then again with a focus on cyclist safety and areas where cyclists were unlikely to travel. It was found that although the proposed major cycleways network represents a significant step towards improving the cycling environment in Christchurch, there are areas of the city that will not be well serviced by the current proposed network in 2041. These include a number of key residential growth areas such as Halswell, Belfast and Prestons, along with a number of noteworthy key travel zones, particularly in areas close to the central city and key employment areas.

Using network analysis, areas where improvements or extensions to the proposed network would be most beneficial were identified, and a number of potential extensions in a variety of areas throughout the city were added to the network of cycle ways. Although it has been found that filling small gaps in the network can have considerable positive outcomes, results from the prioritisation analysis suggested that initially in Christchurch demand is likely to be for more substantial extensions to the proposed major cycleways network.

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List of Abbreviations

ARCM: Abley Route Choice Metric

BMP: Bicycle Master Plan

CAST: Christchurch Assignment and Simulation Traffic Model

CCC: Christchurch City Council

CCDU: Christchurch Central Development Unit

CCRP: Christchurch Central Recovery Plan

CTM: Christchurch Transport Model

GCTS: Greater Christchurch Transport Statement

GIS: Geographic Information Systems

GPS: Government Policy Statement

LINZ: Land Information New Zealand

MCN: Major Cycleways Network

NZTA: New Zealand Transport Agency

RLTS: Regional Land Transport Strategy

VPD: Vehicles per Day

1. Introduction

1.1 Cycling on a Global Scale

Cities around the world are reassessing the way in which their transport systems work; they are re-evaluating the ways in which their residents travel, and consequently reviewing their transport habits, patterns and needs. In recent years, many countries and cities around the world have taken various steps towards becoming more cycle friendly. Through the well planned development of suitable infrastructure, comprehensive urban and network design and awareness campaigns, levels of cycling throughout the world are beginning to rise. It has been identified that there is still a significant amount of inconsistency in the levels of cycle use in countries and cities around the world. Australia, Canada and the United States all still have relatively low levels of cycle use, where trips made by bicycle comprise a mere one percent share of all trips made; similarly, in the United Kingdom and Ireland, trips made by bicycle account for only two percent of all trips made (Pucher & Buehler, 2012).

When examining bike share figures, it is clear that European cities are the world leaders in the use of the bicycle. The percentage of trips made by bicycle vary significantly between countries (Figure 1.1.1); in the Netherlands cycle trips account for twenty six percent of all trips, followed by eighteen percent in Denmark and ten percent in Germany, Finland, Sweden, and Belgium (Pucher & Buehler, 2012). Pucher and Buehler (2012) suggest that the higher share of trips made by bicycle in European cities can likely be attributed to shorter trip distances than in many cities throughout America, Canada and Australia. Whilst factors such as higher levels of mixed-use development, less urban sprawl, and consequent higher population densities have been cited as reasons for this, it is also likely that well planned cycle infrastructure and urban design both play pivotal roles (Pucher & Buehler, 2012).
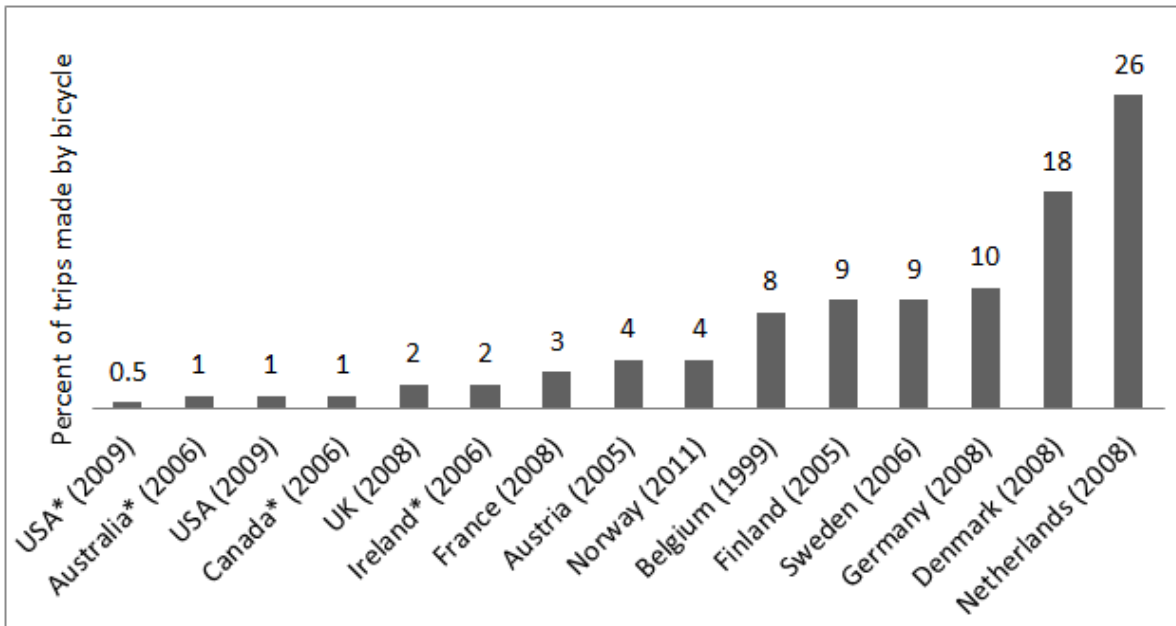
Figure 1.1.1: Cycle share of daily trips in Europe, North America and Australia, 1999 – 2008

Source: (Buehler & Pucher, 2012)

Note: Latest available travel surveys were used to collect data; the survey year can be seen in brackets above. The numbers shown above reflect all trips, with the exception of those marked with an asterisk (*), which represent journeys to work only, derived from each of the countries latest census.

Whilst European cities are making significant developments to their transport patterns, New Zealand is a nation still highly dependent on motor vehicles. The Ministry of Transport's 2012 vehicle fleet data shows that since 2007 New Zealand's vehicle fleet has grown by 2.7 percent in total, with the light vehicle fleet growing by 4.4 percent (Ministry of Transport, 2012). New Zealand has one of the oldest vehicle fleets in the world; the average light vehicle age within New Zealand is 13.21 years old, compared to Australia's 10 years and the United States' 11.1 years (Ministry of Transport, 2012).

Each year the Ministry of Transport conducts The New Zealand Household Travel Survey (NZHTS). NZHTS results from the period between 2009 – 2013 show that cycling in New Zealand accounts for two percent of total time travelled and a mere one percent of the number of trip legs[1] made (Ministry of Transport, 2013). Figure 1.1.2 presents the mode share results for the household travel surveys conducted in the years between 2009 and 2013. Results show that both car drivers and passengers in private vehicles still dominate both the share of total travel time and the share of trip legs, accounting for seventy nine and seventy eight percent respectively. Mode share results highlight how underutilised cycling is as a mode of transport, comprising only 1.8 percent of total travel time and 1.4 percent of trip legs (Ministry of Transport, 2013b).

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[1]A trip leg is defined as a section of travel that is made by a single mode with no stops. A full journey may consist of several trip legs.
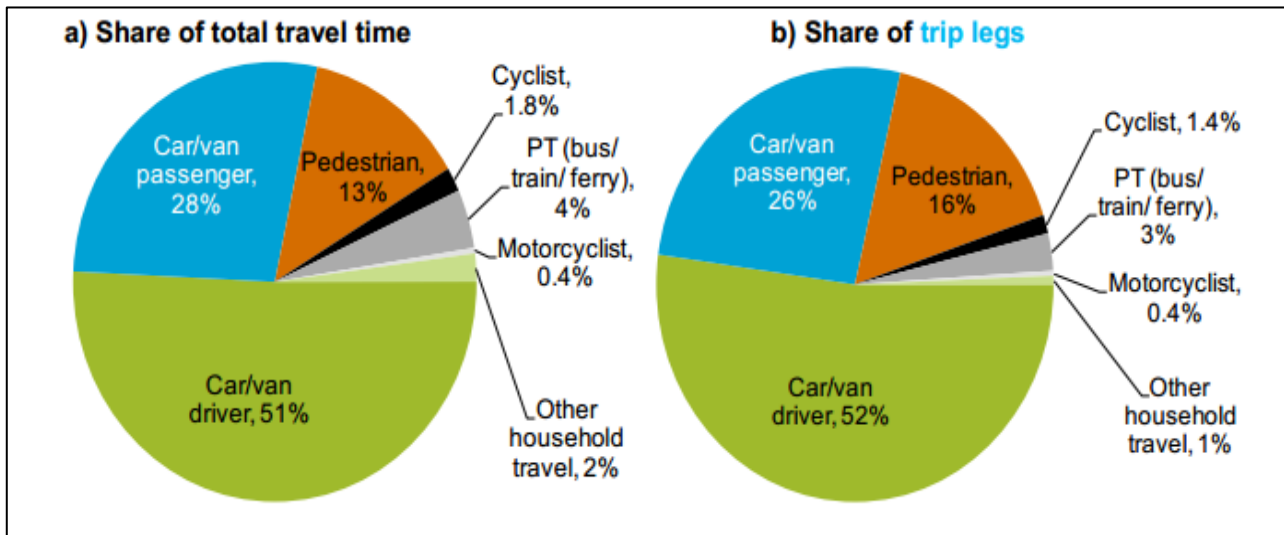
Figure 1.1.2: Mode share for all modes of travel analysed by share of total travel time and share of trip legs

Source: Ministry of Transport, 2013

1.2 The Christchurch Rebuild

As a result of the series of earthquakes that struck in 2010 and 2011, Christchurch has found itself in the unique position to completely "rethink, renew and revitalise central Christchurch"(Christchurch Central Development Unit, 2012). Whilst there had been growing interest in enhancing cycling culture and facilities throughout the city prior to the earthquakes, the central city rebuild and redevelopment has provided the perfect platform for this development to occur. In July 2012 the Christchurch Central Development Unit (CCDU) released the Christchurch Central Recovery Plan (CCRP). The plan acknowledged that Christchurch has a rich history that should not be forgotten during the rebuild, but rather incorporated into the future of the city (Christchurch Central Development Unit, 2012).

Included within the core goals for the central city redevelopment was making Christchurch a more accessible city; improving accessibility and the ability to reach key destinations for all people in the city. It was acknowledged that in order to improve accessibility, a functional multi-modal network was going to be required. Following the publication of the CCRP, "An Accessible City" was developed and released; a revised, more detailed version of the transport chapter in the CCRP. As well as further developing key transport goals for the city throughout the rebuild, An Accessible City highlighted how important features such as the proposed city wide cycle network, would be in terms of connecting the central city to the wider Christchurch urban area.

1.3 Purpose

The Christchurch City Council has acknowledged that they wish to enhance and encourage the cycling culture within the city, primarily through the implementation of a connected and functional cycle network. Currently there is a proposed plan for a $70 million, thirteen route, cycle network (see Appendix One). Whilst this is undoubtedly represents a significant step towards enhancing Christchurch's cycling culture, it is important that the network is accessible throughout all areas of the city.

1.4 Aims and Objectives

The key aim of this research was to investigate and identify areas in which further network development could occur to make the network more comprehensive and accessible for employment related commuting. This was achieved through the identification of areas where future cycle network development could occur throughout Christchurch following the development of the initial thirteen cycle routes, with a particular focus on the year 2041. A number of key objectives will be involved in completing this, including:

1. The identification of likely commuter travel patterns throughout Christchurch for the year 2041
2. Examine potential cycle trips in relation to the proposed major cycleways
3. Examining where future cycle infrastructure should be located based on 2041 commuter travel patterns
4. Make suggestions as to how development of this infrastructure should be prioritised based on likely demand and value
5. Develop a method for achieving the above objectives that could then be applied in various other contexts

In order to provide context and aid in interpreting this research and the results to follow, a map with the study area and named area units has been provided below.

Figure 1.4.1: Context map of the study area

Source: CCC Monitoring and Research Team

1.5 Thesis Outline

Whilst Chapter one has given a brief introduction to cycling as a mode of transport on a global level and the current situation in Christchurch, this will be discussed in much more detail in Chapters 2 through to 5. Examining everything from the importance of good planning for cycling, to planning frameworks in place to encourage further uptake of utility cycling, to the ways in which we can model cyclist route choice and travel patterns, Chapters 2 – 5 provide the all-important background and contextual information for the research to follow.

Chapter 6 then introduces the specific methods used throughout analysis. It begins by introducing Geographic Information Systems, and explaining their role in a planning environment. Following this, and outline of the data used throughout analysis is provided, with detail given about how the data was gathered and prepared for analysis. Finally, the steps that made up the 3 major analysis stages are discussed in detail.

The four chapters following the methods section present the results from analysis. The first, Chapter 7, examines population changes expected to occur throughout Christchurch in the next twenty to thirty years, along with areas where there are expected to be high levels of employment. Chapter 7 also presents the results from the first round of network analysis, where key commuter travel patterns in 2041 were modelled.

The results presented in Chapter 8 examine the fit of the proposed major cycleways network for the city come 2041. Proximity analysis was used to assess whether the network would be well placed to service key residential and employment destinations, along with the network's proximity to expected high demand travel zones.

Chapter 9 contains the results where cyclist's perceived safety was factored into analysis. It then discusses the implications that cyclist's perceived safety has on route choice, and how this can be expected to influence areas where cyclists choose to travel throughout Christchurch.

Finally, Chapter 10 examines key demand areas for future cycling infrastructure throughout Christchurch city. Areas where infrastructure could be implemented are suggested, and the impacts that they would likely have on cyclist route choice are investigated. Finally, some suggestions are made as to how the implementation of future infrastructure should be prioritised.

2. Planning for Cycling

2.1 Introduction

As we become increasingly aware of the many benefits associated with increased cycling uptake, a growing number of countries and cities throughout the world are developing cycle strategies with the key goals of improving liveability, sustainability and reducing traffic congestion. A number of key variables are associated with the development and implementation of a successful cycle strategy and network; these include accessibility, cycle safety and coherent network and infrastructure design. Chapter two examines these, and the role in which they play in further encouraging and enhancing cycle culture.

2.2 Accessibility

Accessibility has long been associated with all facets of planning, and while an exact definition is ambiguous at best, at a very simple level it can be described as the ease with which activities, either economic or social, can be reached or accessed by people. In 1959 accessibility was defined by Hansen as 'the potential of opportunities for interaction' (Hansen, 1959) and in the years following our understanding of accessibility, and the impacts it has on the choices individuals make on a day to day basis, has continued to develop. As the notion, and it's importance has continued to progress, so too has the way in which it is defined, with further popular definitions including: 'the ease with which any land use activity can be reached from a location using a particular transport system'; the freedom of individuals to decide whether or not to participate in different activities'; and 'the benefits provided by a transportation/land use system' (Abley & Halden, 2013).

The importance of the relationship between land use, transport and accessibility is widely discussed throughout the literature. Whilst there has been some debate surrounding the extent of the impact that land use has on transport and transit patterns (van Wee, 2002), it is clear that there is an influential relationship between the two. Geurs and Van Wee (2004) argue that accessibility should ultimately define the purpose of land use and transport systems, which is to give individuals the opportunity to participate in activities in a number of locations. They also suggest that accessibility is comprised of a number of different components, which can be identified in the various different definitions of and measures of accessibility. These have been identified as: the land use component, which reflects the land use system; the transportation component, which describes the land use

system, most commonly expressed as an individuals need or desire to traverse a distance between an origin and destination using a particular mode of transport; the temporal component which includes temporal constraints such as the availability of different activities at different times throughout the day; and finally the individual component which very basically represents the needs of an individual (Geurs & van Wee, 2004). No one of these components alone contributes to an individual's accessibility to opportunities, thus understanding the various relationships between them and how they contribute to accessibility is invaluable. These relationships can be seen further in Figure 2.2.1 below.
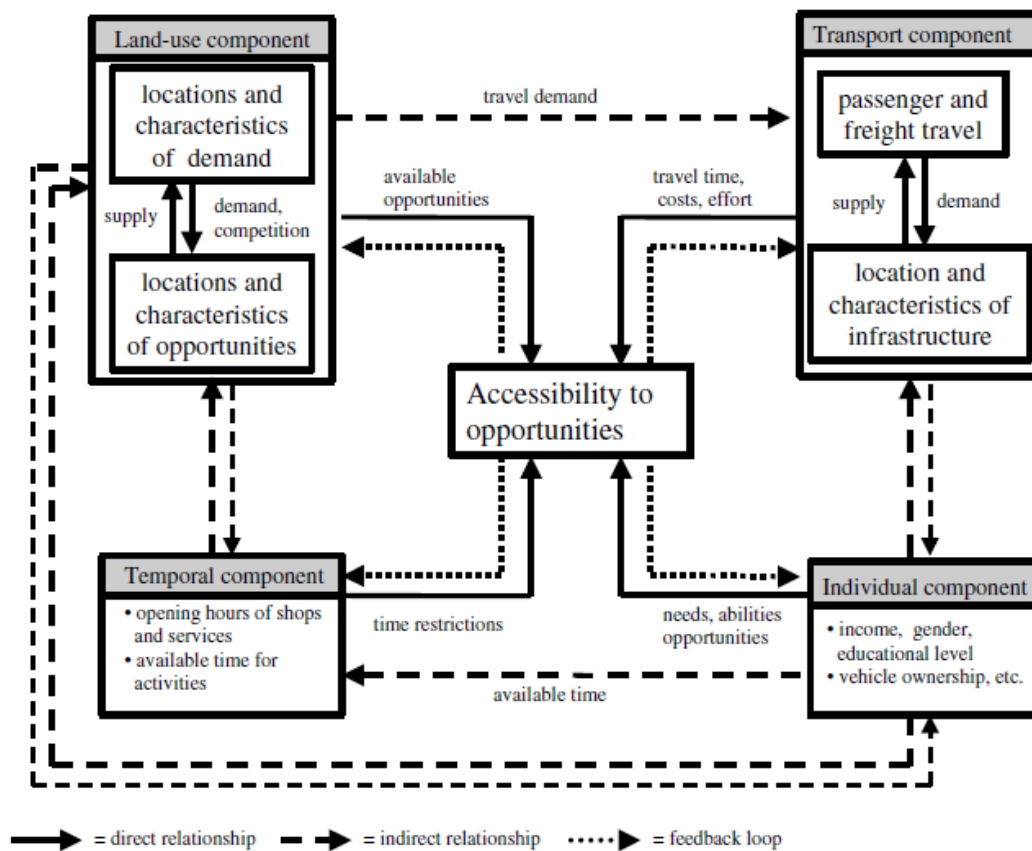
Figure 2.2.1: The relationships between the different components of accessibility

Source: Geurs & van Wee, 2004

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Transport has been said to provide for peoples desires to participate in different activities, such as living, shopping and employment, in different places (van Wee, 2002). Land use and density impact the distances between these destinations; higher density development and land use results in shorter trip distances between the destinations that people visit on a regular basis (van Wee, 2011). The mixing of land use categories during development, such as residential dwellings, employment centres, shops, schools, and services, into key activity centres supports a reduction in the distances that people need to travel between destinations as a result of improved locality. The development of key activity centres supports higher density development, thus reducing trip distances and supporting the use of alternative modes of transport through improved levels of accessibility.

It has been noted that factors which influence mode choice are based on two fundamental land use characteristics: (a) proximity and (b) connectivity, or the directness of travel (Frank, 2000). Proximity is linked to the distance between a trip origin and a trip destination and is subsequently heavily determined by the two land use concepts discussed above - density and mixed category land use (Saelens, Sallis, & Frank, 2003). Saelens, Sallis and Frank acknowledged that mixed use is characterised by a diverse range of land use within a relatively small area (2003). As aforementioned, the development of key activity centres of mixed use development reduces the distance people have to travel between origins and destinations, thus improving proximity, connectivity, and ultimately accessibility.

The New Zealand Transport Strategy outlines five major transport objectives for New Zealand to have reached by 2040; one of which is improving accessibility and mobility: "There are formidable challenges facing the transport sector. It needs to find affordable ways to support the economic transformation of New Zealand improve the health, safety, security and accessibility of New Zealanders, while at the same time addressing climate change and other environmental impacts" (NZ Transport Agency, 2008). When considering this and the disregard often given to non-motorised modes of transport, it becomes clear that further integrating alternative transport options, such as walking and cycling, into transport modelling would be a good way to achieve the transport objective outlined above. The strategy has acknowledged that in order to achieve improved access and mobility, measures need to be taken to increase the mode share of walking, cycling and other active modes to thirty percent of the total trips made in urban areas by 2040 (NZ Transport Agency, 2008).

It has been noted that European cities are largely healthier and more transport efficient as they are more accessible than those in countries such as New Zealand, Australia, Canada and the United Kingdom. As a result of increased accessibility people travel shorter distances to meet their needs, consequently leading to higher mode share for active modes of travel.

2.3 Cycle Safety

One of the key objectives included in almost every government transport policy is improving road safety. This is unsurprising as it has been identified that one of the key factors preventing people from cycling is the perception that cycling is unsafe (Geller, 2006). Cyclist perception of the environment has been recognised as being particularly important. Appropriate infrastructure and safety standards will help cyclists in feeling perceivably more secure, thus raising the profile of cycling through increased cyclist numbers (Land Transport Safety Authority, 2005).

The Ministry of Transport has acknowledged that cyclists face a number of risk factors that those who drive cars do not. Perhaps the most predominant is that a bicycle simply does not provide the same level of protection that a car can provide; additionally cyclists are also less visible to other road users, such as those in a car or truck (Ministry of Transport, 2013a). New Zealand crash statistics show that in 2012 there were 8 cyclists killed on New Zealand roads, 161 were seriously injured in crashes and 637 suffered minor injuries; this totals approximately six percent of all crash casualties from crashes that were reported to police in 2012 (Ministry of Transport, 2013a). Figure 2.3.1 provides an indication of cyclist deaths/injuries in comparison to those who travel by other modes.
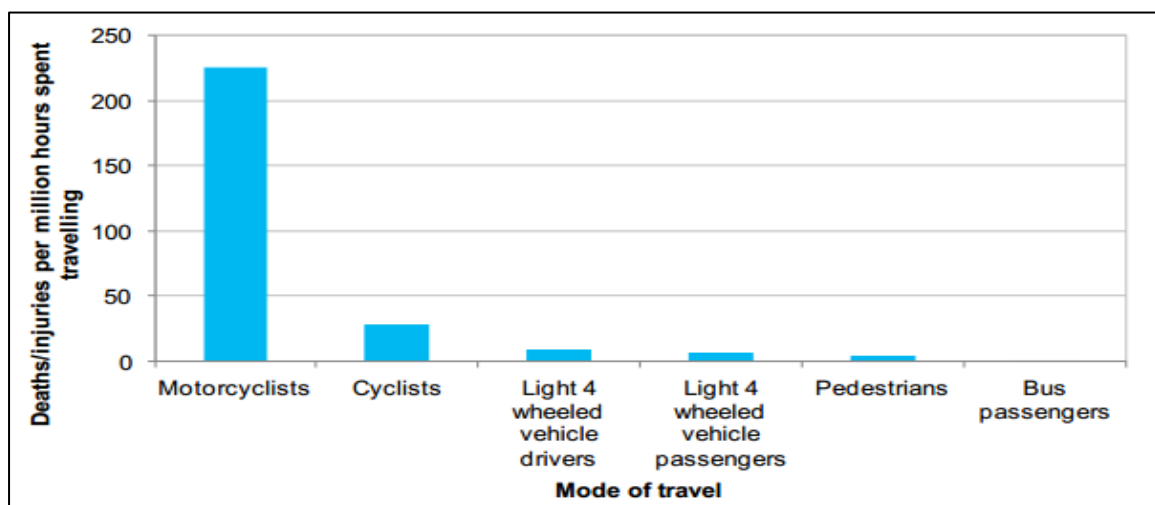
Figure 2.3.1: Deaths/injuries per million hours spent travelling, by mode of transport July 2008 – June 2009

Source: Ministry of Transport, 2013

Figure 2.3.2 indicates where these accidents are occurring; it can be seen that the majority of serious and minor injuries are occurring on urban roads with speed limits below 70 kilometres per hour. The 2012 crash statistic reported that for all cyclist casualties, approximately nine in every ten occurred on urban roads (Ministry of Transport, 2013a). The crash statistics also highlight that over half of all causalities are occurring on major urban arterial routes. This reinforces how important appropriate cycle infrastructure can be for cyclists in urban areas.
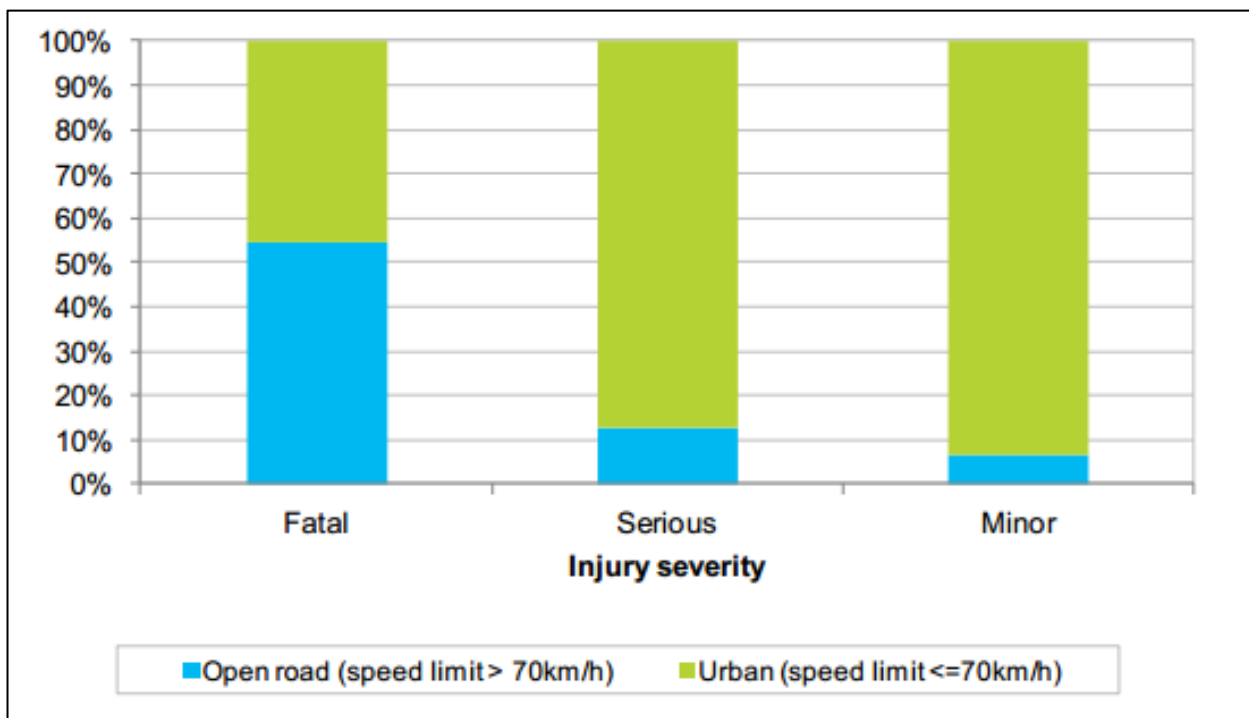
Figure 2.3.2: The percentage of cyclist death and injuries by road type 2008 – 2012

Source: Ministry of Transport, 2013

2.4 Infrastructure and Network Design

Infrastructure and network design is inherently important in the uptake of utilitarian cycling. Typically cyclists can be categorised into one of four cyclist groups: the strong and fearless; the enthused and the confident; the interested and concerned; and the no way no how group (Geller, 2006) . Geller's research (2006) identified that in Portland most of the city's citizens fell into the "interested but concerned" category (n = 300,000), representing over sixty percent of the city's population. Whilst these people may be interested in cycling, particularly for utilitarian purposes, the potential safety risks associated with having the share the same carriage way as motor vehicles is

enough to discourage them from cycling (Geller, 2006). It is in cases like this where access appropriate and functional cycle infrastructure becomes important.

Four Attitudes Toward Transportation Bicycling
Percentages based on data from Portland, Oregon

7%
Comfortably Confident
Prefer short to medium trip distances and may be willing to ride in traffic where there are bike lanes or other good facilities

60%
Willing But Wary
Not comfortable in traffic, even with conventional bike lanes, but will ride on low-traffic streets and paths

<1%
Fit & Fearless
Ride long distances without dedicated bike facilities

33%
No Way No How
No interest in bicycling — won't consider bicycling without major changes in social norms and street conditions

Source: www.portlandoregon.gov/transportation/article/158497; see also Dill J and McNeil N. "Four Types of Cyclists? Testing a Typology to Better Understand Bicycling Behavior and Potential." Portland State University, August 10, 2012. Available at: http://web.pdx.edu/~jdill/Types_of_Cyclists_PSUWorkingPaper.pdf.

Figure 2.4.1: A summary of the four types of cyclists and their attitudes towards cycling as a mode of transportation

Source: Geller, 2006

It has been noted that cycling can be liberating in a well - designed environment, but difficult and unpleasant if the environment has not been designed in a manner that successfully accommodates cycling (Parkin & Koorey, 2012). Various infrastructure requirements have been identified that contribute to making an environment cycle friendly; these include cohesion, directness, attractiveness, safety, and comfort (CROW, 2007). In terms of cohesion, connectivity is important in a network to allow cyclists to get from origins to destinations with ease. Consistency of infrastructure quality and the freedom to choose a route are also important; connectedness is particularly important for the latter. Attractiveness has been identified as being significant; cycle infrastructure should be well integrated into the surrounding environment. It must however be noted that perception is important; certain aspects of cycling that are attractive to one person may be considered less desirable by another. Cyclists are particularly vulnerable where no cycle infrastructure is provided as they are forced to share the same space as motor vehicles. Physically separating cyclists from other traffic has the potential to have significant positive impacts on cyclist safety (CROW, 2007).

As discussed above, Land Transport New Zealand and the New Zealand Road Safety Authority have provided a set of guidelines for cycle network and route planning in a New Zealand context. The

guide also outlines the general route requirements for a cycle network. These include: safety, comfort, directness, coherence and attractiveness; very similar requirements to those outlined in the CROW design manual (Land Transport Safety Authority, 2005). Once more, safety is highlighted as being the most important requirement, with it again noted that cyclist perception is particularly important. Appropriate infrastructure and safety standards will help cyclists in feeling more secure, thus raising the profile of cycling through increased cyclist numbers.

When designing cycle friendly infrastructure, the development of a well-planned, functional network is perhaps the most important consideration that needs to be made. Key factors that require attention during network design include cohesion, as discussed above; directness; and safety (CROW, 2007). Although the implementation of cycle infrastructure is undoubtedly a good step towards making a city more cycle friendly, if the network is not cohesive and lacks connectedness and directness then people are still less likely to utilise cycling than if they have been provided with a well-designed network. CROW's design manual for bicycle traffic (2007) proposes that if around seventy percent of a cycle journey can be made via a network of cycle routes, then it can be concluded that the network meets cohesion and directness requirements.

Copenhagen's cycle strategy for 2011 – 2025 has outlined a number of important infrastructure and network design elements that should be considered throughout network and infrastructure design and development. The three most predominant in the strategy are comfort, travel time and sense of security (The City of Copenhagen, 2011); three features that have already be identified as being fundamentally important for any functional cycle network. Copenhagen has recognised that a positive bicycle experience is important if more people are to be encouraged to cycle regularly. Consequently, the implementation of practical and functional bicycle parking and more attention given to the maintenance and quality of cycle tracks have been identified as areas of focus within the city. Similarly, if cyclist numbers are to remain high within the city of Copenhagen, then it is paramount that travel times via bicycle can compete with those of other modes. In order to ensure that the bicycle remains a competitive form of transport, the city has identified that their cycle network needs to allow for more people cycling further and quicker; have fewer missing links allowing for more direct routes; encourage contraflow cycling on one way streets; and provide effective and impressive shortcuts (The City of Copenhagen, 2011). Finally, Copenhagen has acknowledged that in order for people to make use of utilitarian cycling, they must first have the impression that cycling is safe. It has been noted in the strategy that many transport habits are developed at a young age as children; subsequently, the cycle network throughout the city needs to

be safe for not only adults, but also beginner cyclists to encourage them to develop a sense of security around cycling from a young age. As a result, room for diversity, more cycle tracks and encouraging small steps that can have large effects on cyclist numbers, have been identified as specific cyclist safety targets for Copenhagen throughout the life of the strategy (The City of Copenhagen,2011).

2.5 Build it and they will come: Portland, Oregon's experience

Research has shown that when provided with the appropriate infrastructure, cyclist numbers generally increase. As previously discussed, cycling can be liberating in a well - designed environment, but difficult and unpleasant if the environment has not been designed in a manner that successfully accommodates cycling (Parkin & Koorey, 2012). Following modest investment in cycle facilities in Portland, Oregon, the city has experienced increases in the use of cycling for transportation to rates that were much higher than the national average (Geller, 2011). Throughout the 1980s and early 1990s, prior to investment, Portland was just like any other United States (US) city with majority of daily trips made by car, accompanied by very little car use and negligible investment in cycle facilities (Geller, 2011).

The implementation of infrastructure such as bicycle lanes, bicycle boulevards and off street path led to significant changes in mode share figures in Portland, with growth in cyclist numbers relative to Portland's population exceeding 400 percent (Geller, 2011). Due to the substantial increase in cycle numbers, the road network in the city's downtown area has not required investment to accommodate an increased number of cars, despite and twelve percent increase in demand for mobility throughout the city. Following the success of Portland's investment in cycling, other US cities have begun to make similar investments, and are consequently seeing similar changes and benefits that Portland has been experiencing and benefiting from for many years.

2.6. Copenhagen "Cycle City"

Copenhagen is unarguably the world leader in utilitarian cycling having received the title of the world's first, and currently only, "Bike City"; similarly, in 2013 Copenhagen was voted the best city in the world for cyclists, along with the world's most liveable city (City of Copenhagen, 2012). Results from Copenhagen's 2012 Bicycle Account found that in 2012, of all trips made throughout the city to workplaces or education institutes thirty two percent were made by bicycle; fifty two percent of all

Copenhageners reported cycling to their place of work or education every day, even if it is beyond the city boundaries. As a result of these high mode share figures for cycling, 1.27 million kilometres are travelled by bicycle every working day in Copenhagen[2] (City of Copenhagen, 2012). Approximately thirty six percent of all commuter destinations within the city boundaries can be reached by bicycle (Nielsen, Skov-Petersen, & Agervig Carstensen, 2013).

In 2012, The City of Copenhagen released their bicycle strategy for 2011 – 2025 – "Good, Better, Best", with two important goals: to become the world's best bicycle city and to be carbon neutral by 2025 (The City of Copenhagen, 2011) . The strategy has recognised that people in Copenhagen choose to cycle because it is the fastest and most efficient way to get around. Therefore, if you are encouraging the number of people cycling to increase, then the next goal is to make cycling the fastest and easiest way to get around for even more citizens; ensuring that the bicycle still remains the most efficient mode of transport (The City of Copenhagen, 2011). In order to achieve this, it has been recognised that prioritisation and innovation are going to be important throughout the life of the strategy.

Neilson, Skov-Petersen and Carstensen have recognised that in order to both maintain and increase cyclist numbers in Copenhagen, cycle planning efforts in the city need to be multifaceted (2013). On the more strategic level, bi-annual cycle indicators have been produced since 1996. These provide information on both Copenhageners perception of cycling conditions in the city along with identifying issues that may be reducing the comfort of cyclists within the city, leading to decreased cycle numbers. Additionally, they provide information for the development of quantitative targets and investment plans (Nielsen et al., 2013). Planning for cycling within Copenhagen city is a collaborative process, where users and stakeholders are frequently consulted on cycling conditions in the city (Nielsen et al., 2013). The city has clear priorities and responsibilities when it comes to cycling, cycling infrastructure and cycling culture. The way in which these responsibilities and priorities have been addressed has led to what can only be described as an enormously successful cycle city.

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[2] Includes both Copenhagen residents and those who commute into the city

2.7 Seattle

Whilst Copenhagen is working towards maintaining their bicycle culture and continuing to make the city increasingly cycle friendly, Seattle is working towards a shift in the way the city accommodates people cycling to make the city more cycle friendly, but most importantly encourage a substantial increase in cyclist numbers. Seattle's 2013 Bicycle Master Plan (BMP) outlines the key cycling visions for the city over the coming years. Important themes throughout the master plan include: ensuring cycling is comfortable, which suggests that it will be a safe, convenient and attractive travel for both those living in and visiting the city; making cycling integral to daily life in Seattle, ensuring that it is not a niche activity to those who are experienced and therefore confident riders, but that it is instead an important component of the city's built environment and overall urban framework; and finally that cycling is available to those of all ages and abilities (Seattle Government, 2013). Consequently emphasis will be put on planning, designing and building a cycle network that is accessible and can be utilised by an extensive range of people throughout the city.

At present, Seattle is ranked third in the United States in terms of the percentage of people who use cycling for utilitarian purposes. Subsequently, the main purpose of the city's BMP is to provide an overarching planning framework for improving the bicycling environment throughout Seattle. Implementing new bicycle infrastructure, maintenance, enhanced end-of-trip facilities, and soft measures such as programs to enhance cyclist safety and encourage more people to utilise cycling have been identified as the main areas of cycling related investment for the city in the coming years (Seattle Government, 2013).

Seattle has recognised that simply providing infrastructure is not going to be enough to encourage a dramatic increase in cyclist numbers throughout the city. As a result, the BMP has identified that the planning process will need to be both a public and technical endeavour. It has been acknowledged that public engagement is an important part of any planning process, and that there is a need to reach out beyond the current cycling community in Seattle, instead targeting infrequent cyclists and potential new users of the cycle network (Seattle Government, 2013). Subsequently, the city has two significant public engagement and objective goals for the planning phase of the improved cycle network. The first is to "engage broad and diverse segments of Seattle residents, businesses, employees and property owners" and the second is to "update the BMP to reflect the priorities and interests of infrequent and potential riders, as well as avid users of the system" (Seattle Government, 2013). The inclusion of these goals in the city's major planning framework indicates

just how serious Seattle is about enhancing its cycling culture, and will hopefully go a long way in proving the importance of public engagement in the planning of cycle networks and infrastructure.

2.8 Conclusion

Drawing all of this together, it is clear that good planning for cycling is essential in encouraging people to being to reconsider their transport habits. The example provided above, Portland, Copenhagen and Seattle, have all been successful in enhancing their city's cycling culture through solid planning, and the implementation of functional and effective infrastructure. However, as noted in the Seattle example, it is important that the planning process is not simply just a legislative, policy building process, but rather a public and technical endeavour. If more of the population are going to be encouraged to take up utility cycling, then it is important that the facilities provided are attractive to both current, as well as potential cyclists.

3. New Zealand Transport Planning Frameworks

3.1 Introduction

As the significance of reducing car use throughout New Zealand has come to the forefront of people's attention, planning for cycling and other active forms of transport has become progressively more important. Consequently, provisions for increasing the mode share of active transport are being seen progressively more throughout planning frameworks and legislation in New Zealand. Chapter 3 will address the overarching planning legislation and frameworks that support the enhancement of the cycling facilities and culture throughout New Zealand.

3.2. New Zealand Transport Strategy

In 2008 the New Zealand Transport Strategy was updated, replacing that had been in use since 2002. The 2008 Strategy further developed that released in 2002, to "enable the transport sector to respond more effectively to the changing environment in which it must operate and to support New Zealand becoming a more sustainable nation" (NZ Transport Agency, 2008). Whilst the 2002 plan covered the years between 2002 and 2010, the 2008 plan has been developed to take a longer view, setting the direction for transport in New Zealand through until 2040.

One of the key objectives of the strategy is to "increase the availability and use of public transport, cycling, walking and other shared and active modes"; it is noted that increasing the use of public and active modes is an important component of reducing congestion, the use of fossil fuels and reducing greenhouse gas emissions from transport (NZ Transport Agency, 2008). An increase in the uptake of the use of active modes will also result in improvements in public health, and will contribute to the vibrancy of urban areas. An increase in the use of cycling could also be attributed to an increase in accessibility, consequently improving people's ability to participate in society (NZ Transport Agency, 2008).

3.3. Connecting New Zealand

Connecting New Zealand was created with the purpose of summarising the government's broad policy direction for transport in New Zealand for all interested stakeholders. Drawing together policy outlined in a number of government guidance documents (including the National Infrastructure Plan and the Government Policy Statement on Land Transport Funding 2012/13 – 2021/22), connecting New Zealand will assist stakeholders in better understanding the broad direction the Government sees New Zealand's transport system developing in throughout the life of the document (Ministry of Transport, 2011). The government has identified three key areas of focus for transport throughout the lifespan of these documents; these include a transport system that supports economic growth and productivity, getting the best value for money from investment in transport and finally further supporting and increasing awareness of road safety. Additionally, some likely challenges for transport in New Zealand throughout this period have been identified, including but not limited to: an aging population; changes in where people are living; increasing fuel prices that are likely to remain volatile.

Connecting New Zealand acknowledges that the government plans to invest funding into walking and cycling projects throughout the lifespan of the Government Policy Statement on Land Transport Funding 2012/13 – 2021/22. In order to maximise the potential benefits of funding investment, the government plans to direct funding to reducing congestion to support a safer pedestrian and cyclist environment. Investment will be targeted at encouraging more people to cycle more often in a safer environment, subsequently offering people more transport choice (Ministry of Transport, 2011). The government is aiming to further support groups with specific transport needs through improving both the efficiency and safety of the transport system, as well as supporting the development of built environments that are well designed to support walking and cycling.

3.4. Government Policy Statement on Land Transport 2012/13 – 2021-22

The Government Policy Statement on Land Transport Funding (GPS) sets out the governments priorities and expected outcomes from investment in land transport throughout the life of the GPS. The GPS describes: what the government expects to be achieved from its investment in land transport; how this expectations will be met through investment in various key transport sectors; how much funding will be provided and allocated to different areas; and finally how the funding will

be raised (Ministry of Transport, 2012a). The GPS is responsible for guiding the development and execution of a number of other key transport plans and policies.

A number of key transport goals for New Zealand have been outlined in the GPS. The overarching goal for transport is to provide "an effective, efficient, safe, secure, accessible and resilient transport system that supports the growth of our country's economy in order to deliver greater prosperity, security and opportunities to all New Zealanders". The GPS acknowledges that investment in walking and cycling will also likely make a contribution to economic growth and productivity. As noted in Connecting New Zealand, it has been recommended that government funding for active transport should be directed towards the reduction of congestion and improving pedestrian and cyclist safety (Ministry of Transport, 2012a).

3.5 Government Policy Statement on Land Transport 2015/16 – 2024/25

In December 2014 the Government Policy Statement on Land Transport 2015/16 – 2024/25 was confirmed. Unsurprisingly, the new GPs, set to take effect in July 2014, highlights the same 3 key areas of focus as the previous GPS; improving and supporting economic growth and productivity, improvements to road safety and the best value for money investment (Ministry of Transport, 2014a). The GPS recognises that transport is an essential part of daily life for all New Zealanders; it has been noted that effective transport enables travel to and from work places, supports social visits and finally supports businesses, regions and cities in being well connected and productive (Ministry of Transport, 2014a).

The GPS outlines a number of key objectives for improving transport throughout the life of the statement. One of the key objectives included in the 2015/16 statement highlights the importance of providing a transport system that offers a range of transport choices; it is acknowledged that the transport system needs to have the ability to support transport choices appropriate to users' needs (Ministry of Transport, 2015). One of the key outcomes hoped to be seen under this objective is increased safe cycling through the investment in cycle infrastructure. It is highlighted that cycling provides an alternative to motor vehicle for shorter journeys and single purpose trips – such as commuting to school and work, and there is plenty of opportunity to increase the transport system capacity in urban areas.

Interestingly, whilst there is increasing knowledge of the many health benefits that increased levels of utility cycling can have, the GPS highlights the need for infrastructure in eliminating safety as a

barrier to cycling uptake. It is noted that whilst there are health benefits associated with the increased levels of physical activity, safety continues to be a concern for many potential cyclists and represents a significant barrier to cycling reaching its transportation potential (Ministry of Transport, 2015). Consequently the 2015 GPS is set up support an increase in safe cycling through increasing levels of investment in cycle infrastructure, with further investment in safe cycling infrastructure in main urban areas, including improvements to suburban routes for cyclists.

The importance of cycling safety was widely discussed in Chapter 2.3, particularly the issue of safety as a barrier to cycling. Whilst New Zealand has a long way to go to reach the levels of cycling participation many European cities and countries have, increased investment in appropriate infrastructure in main urban areas represents a significant step and commitment towards making New Zealand more cycle friendly.

3.6 Cycle Network and Route Planning Guide

In 2005, the NZ Transport Agency released the 'Cycle network and route planning guide'; a guide produced by the Land Transport Safety Authority that aims to promote a consistent approach to cycle planning throughout New Zealand. Through providing guidance on all aspects of cycle network and route planning, it is hoped that consistent and high quality cycle infrastructure will begin to become more apparent throughout the country. The guide acknowledges that network planning is a process of improving community mobility and accessibility through providing interconnected routes and facilities based on the needs of bicycle users. The guide encompasses and covers all aspects of network and route planning, including planning and policy context, the principles of cycle network planning and the cycle network planning process (Land Transport Safety Authority, 2005).

3.7 Conclusion

As can be seen in the summary of New Zealand's transport planning frameworks and legislation above, New Zealand is gradually becoming more committed to reducing car use and automobile dependency throughout the country. The government and New Zealand Transport Association have acknowledged in the New Zealand Transport Strategy that the transport sector must acknowledge that it is now operating in a changing environment, and consequently needs to respond appropriately to further assist New Zealand in becoming a more sustainable nation. This has paved the way for alternative, more sustainable modes of transport to be considered and supported by not

only central government and government departments, but also the wider population. When considering the other pieces of legislation and planning documents explored in this chapter, it becomes clear that there is a substantial amount of attention being put into addressing and reducing traffic congestion issues, a problem that could certainly be relieved through more of the population utilising more active modes of transport, such as utility cycling.

4. Developing Cycling in Christchurch

4.1 Introduction

As Christchurch City and the Greater Christchurch area continue to develop throughout the rebuild period, it is excepted that in the next 35 years, it can be expected the Greater Christchurch area will grow by an additional 135, 000 people. The Greater Christchurch Urban Development Strategy[3] acknowledges that the decisions people make about where they are going to live have much wider flow on effects (Greater Christchurch UDS Partners, 2010). Where people decide to live will likely influence where they work, where children attend school, how they choose to travel and the kinds of community facilities and services they require. Presented with the rare opportunity of rebuilding, Christchurch City has prioritised cycling as a key component of the rebuild, a key step towards encouraging people to travel by modes other than private motor vehicle or public transport. Cycling features heavily in the transport chapter of the Central City Recovery plan. Amongst the key transport targets for the rebuild are the increased use of cycling, walking, and public transport for trips into and around the city centre; increased opportunities for the use of active and passive forms of transport within the city; and improving transport safety within the central city, particularly for cyclists and pedestrians (Christchurch Central Development Unit, 2012). Chapter four outlines the overarching planning legislation and frameworks that support the enhancement of the cycling facilities and culture in both Christchurch City and the wider Christchurch and Canterbury areas.

4.2 Canterbury Regional Land Transport Strategy 2012 – 2042

The Canterbury Regional Land Transport Strategy (RLTS) 2012 – 2042 sets out the strategic direction of transport throughout the Canterbury region throughout the 30 year lifespan of the strategy. Designed to contribute towards the government's vision of achieving an integrated, safe, responsive and sustainable transport system, a number of key goals for transport in Canterbury have been outlined in the RLTS; these include but are not limited to: maintaining and enhancing accessibility, providing transport options, managing private vehicle traffic growth, improving road safety for all users, meeting the transport needs of dispersed communities and managing the transport impacts

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[3] The Greater Christchurch Urban Development Strategy is a joint project between Christchurch City Council, Waimakariri District Council, Selwyn District Council, Environment Canterbury, NZ Transport Agency and Ngai Tahu that provides guiding principles and strategic direction to support the overall vision for the Greater Christchurch Community.

of anticipated population change (Environment Canterbury, 2012). Consequently a number of key objectives for transport in Canterbury have also been identified, including: ensuring Canterbury is provided with a resilient, environmentally sustainable and integrated transport system; increasing transport safety for all users; protecting and promoting public health; assisting in economic development and growth; and finally improving levels of accessibility for all (Environment Canterbury, 2012).

The RLTS acknowledges that different transport modes will all have different roles in providing Canterbury with an integrated, safe, responsive and sustainable transport system. It has been recognised that whilst transport does represent a means to an end, a quality transport system can also provide a more liveable region for both individuals and the population through enabling individuals, families and communities to actively participate in and contribute to society due to improved accessibility (Environment Canterbury, 2012). Consequently, the RLTS outlines that the strategic direction for transport in Canterbury over the medium to long term, is to move to a more multi – modal transport system, in which the appropriate roles of each mode are utilised to their best advantage (Environment Canterbury, 2012).

Region wide cycling is set to play an important role throughout the 30 year lifespan of the RLTS. The planning and development of increased cycle lanes, off - road paths and cycle parking in urban areas is set to support the increased use of cycling, which has many health, efficiency, affordability and environmental benefits (Environment Canterbury, 2012). Cycling has been identified as an effective and affordable mode for making short to medium distance trips throughout the greater Christchurch area. An increase in cycling would support a decrease in congestion throughout the city, and it is hoped that the development of a city wide cycle network will make cycling more attractive, thus encouraging a mode shift. Work places throughout the greater Christchurch area will be encouraged to adopt cycle-supportive policies and measures, such as providing facilities for cyclists such as changing rooms, showers and lockers.

4.3 Greater Christchurch Transport Statement 2012

Acknowledging that the redevelopment of the Canterbury region is going to be a complex process, the Greater Christchurch Transport Statement (GCTS) was developed with the intentions of ensuring key transport providers throughout Canterbury are working together to provide the greater Christchurch area with a seamless transport system. Goals include supporting the earthquake recovery and growth of Canterbury and connecting people and places with a variety of both

affordable and sustainable transport options (Greater Christchurch, 2012). In order to achieve this integrated transport planning and decision making is going to be essential, as well as aligning transport investment across the board to ensure investments going to represent the best value for money(Greater Christchurch, 2012).

Looking forward to 2041 both the population and number of daily person trips made in the greater Christchurch area are expected to undergo substantial increases. Population is expected to grow by twenty six percent, reaching 550,000 by 2041; similarly, numbers of daily person trips are expected to increase by twenty seven percent, reaching 2,360,600 by 2041 (Greater Christchurch, 2012). Consequently, whilst the greater Christchurch area may be working through an undoubtedly important period of recovery at present, it is also essential that transport planning solutions implemented now are designed to respond to the key economic and social drivers of travel demand likely to occur over the next 30 years.

4.4 Christchurch Transport Strategic Plan

The Christchurch Transport Strategic Plan for 2012 – 2042 sets out all the key transport related goals for the city, over what will be the main rebuild period. Once again, the importance of transport and well-designed networks are discussed within this document; the main focus being to improve access and choice when it comes to different modes of transport. The vision of making Christchurch a "cycle city" is also predominant throughout the plan. It has been identified that this will involve improving access and choice, creating and encouraging the development of safe, healthy, and liveable communities, creating opportunities for environmental enhancement (Christchurch City Council, 2012).

The Christchurch City Council (CCC) has recognised that through creating a city - wide cycle network that includes shared pathways and "flagship cycleways", they will be able to make a strong statement about Christchurch's status as a "cycle city"(Christchurch City Council, 2012) . Of all the journeys made by car in Christchurch, forty percent are less than two kilometres long; thus making them ideal for the use of alternative modes of transport, such as cycling(Christchurch City Council, 2012).

4.5 Christchurch Central Recover Plan & "An Accessible City"

In July 2012 the final copy of Christchurch's Central Recovery plan was released, outlining key goals and visions for the city. Among these key visions was the desire to transform Christchurch into a green city; promoting healthy, sustainable and active living through the effective use of the natural environment and various green technologies. Cycling and active transport feature heavily in the transport chapter of the plan (Christchurch Central Development Unit, 2012). Amongst the key transport targets for the rebuild are the increased use of cycling, walking, and public transport for trips into and around the city centre; increased opportunities for the use of active and passive forms of transport within the city; and improving transport safety within the central city, particularly for cyclists and pedestrians (Christchurch Central Development Unit, 2012)

In October 2013 the "Accessible City" plan was finalised; a revised version of the transport chapter in the Central City Recovery plan, outlining, in detail, the proposed transport network for the city. As improved accessibility and safety have been cited as important targets for the rebuild, a functional, well designed transport network is incredibly important. The cycling chapter of the Accessible City plan recognises the importance of offering good connections between the central and wider city if cyclists are to be encouraged back into the central city. "Main streets" have been identified where speed limits will be restricted to 30 kilometres per hour, with the goal of making the city centre an appealing and safe environment for cyclists and pedestrians. Urban design features, such as physically separated cycle lanes and cycle parking facilities have been considered within this plan, and it has been recognised that urban design is going to be an important component of fostering the city's cycle culture (Christchurch Central Development Unit, 2013).

4.6 Conclusion

Throughout the last 4 years as the rebuild has progressed, Christchurch has become more interested in enhancing the city's cycling culture. As can be seen above, cycling has been at the forefront of both city officials, as well as the wider populations, attention as the rebuild and planning frameworks have been developed for the city. As outlined in both the Christchurch Central Recovery Plan, as well as An Accessible City, creating a green, sustainable city is one of the key goals of the rebuild, a crucial component of which will be encouraging the city's population to reassess their transport habits and decisions, getting more people out of their cars and onto bikes. Whilst encouraging and providing the infrastructure to support this change is going to be an important

element of the rebuild, ensuring that an increased level of cycling is supported in the long term has also been considered, with sustainable transport networks that provide transport choice mentioned throughout almost all of the frameworks discussed in this chapter.

5. Transport and Route Choice Modelling

Travel and route choice modelling play an integral part in the planning and implementation of successful transport systems. It has been acknowledged that while route choice modelling can be complex and problematic, it is an essential component of evaluating people's perceptions of different route characteristics and features, forecasting the different ways in which people may travel based on hypothetical scenarios, predicting future transport and traffic patterns and understanding how the population will adapt to accommodate these changes and conditions (Prato, 2009). This chapter investigates the importance of transport and route choice modelling, and examines different examples of methods of utilised for modelling.

5.1 Transport Modelling

As the world continues to change, so too do transport systems, consequently making it extremely important to understand how and why this development transpires to adequately provide for development in the future. Transport is still facing many of the same problems it has historically, including: congestion, pollution, accidents, financial deficits and poor accessibility (Ortúzar & Willumsen, 2011). However, flawed planning in the past, including a lack of trust in strategic modelling and decision making, has highlighted the importance of transport modelling, ensuring that it is now an fundamental constituent of good transport planning.

A model provides a simplified representation of a real life situation, with a specific focus on certain elements considered to be important from a particular point of view (Ortúzar & Willumsen, 2011). Thus, transport models provide us with a simplified representation of a transport system, allowing us to focus on a small component of the system, and understand the impacts it has on a larger scale.

5.2 Trip Generation

Trip Generation is a key component of transport modelling. Generally, a trip is defined as (unless otherwise specified) a one-way movement, by one or more modes of travel, between an origin and a destination, for a specific purpose. The purpose of a trip is most often described in terms of the nature of the origin and destination, with the origin and destination of a trip most commonly defined using land use patterns and zoning. The classification of trip generating activities (origins and

destinations) is most commonly done based on the nature of the activity using typical land use classes, such as residential, industrial, commercial, educational, recreational, and health related activities. It is important to note that trips can often be multimodal, suggesting that the trip was comprised of a number of linked trips, where there was a change to the mode of travel, but no change in trip purpose. Mode combinations can include either combinations of multiple public transport modes, multiple private modes, or a combination of both public and private modes.

Ortúzar and Willumsen (2011) acknowledged that in a traditional transport model, the trip generation phase aims to predict the number of trips originating in and ending in each zone of a specific study area; generally this is achieved through examining the trips and travel patterns of either the individuals or households within each zone, along with demographic data such as population, employment and the number of cars in each zone. From a geographic perspective, travel is seen as a derivative demand, where the frequency and distribution of trips are a consequence of the distribution of both land use and socio-economic activity in a metropolitan area (Taaffe, Gauthier, & O'Kelly, 1996). Accordingly, the number of trips generated in a zone, or any geographic area, is likely to be strongly associated to the land use and economic activities within that zone.

5.3 Route Choice Modelling

As discussed in earlier chapters, there are a number of influences that impact both how people travel and the route they chose to take. Route choice modelling takes these influences and decisions into account, and generates predictions of likely travel routes for a variety of different modes. Whilst route choice modelling can be problematic and challenging given the complexities of modelling human behaviour and decision making, it is a fundamental component of planning a successful transport network.

Prato (2009) suggested that route choice models not only contribute to the understanding and analysing of peoples travel behaviour, but also constitute an essential component of traffic assignment models. Route choice models come in a variety of different forms, including simple route choice models, which assume that all travellers have perfect knowledge of path costs and thus will chose the route that has the lowest travel cost, and probabilistic route choice models, which instead assume that travellers have imperfect information about the cost of taking a path, and will chose a route that minimises the cost of their trip (Prato, 2009).

As the benefits of commuter cycling become increasingly well known, encouraging more of the population to cycle, the importance of planning for cycling, and providing quality cycle infrastructure continues to develop. Route choice modelling plays a key role in this planning, allowing some assumptions to be made on where the best location will be for new infrastructure. It is important to note that a route will not always be chosen on a least cost basis, as perception and preference play a large role in route selection.

5.4 Abley Route Choice Metric

The Abley Route Choice Metric (ARCM) research was undertaken with the aim of developing an improved impedance measure for cycling that takes into account the preferences cyclists have for different types of facilities. It was acknowledged that in typical network models, cyclists are assumed to select the route between an origin and destination that has the shortest travel time. However, in reality a number of factors are likely to influence the route a cyclist selects, most notably - safety. Consequently, the ACRM weights the time taken to traverse certain links based on cyclist preference. As a result, the metric was used to scale the route cyclists are likely to take between various origins and destinations throughout Christchurch.

The ARCM was modelled off a similar metric developed for Portland, Oregon. The Portland model developed a series of relative distance variables based on factors that were found to be important to cyclist route choice, including trip type, slope, intersections, cycle facilities and vehicle volumes on roads that do not have cycle facilities (Rendall, Rose, & Janssen, 2012). The Christchurch model was developed with similar factors in mind, using data collected by Beca Infrastructure Ltd in 2007; 400 cyclists were asked to record their cycling activity for a week, with a total of almost 4,000 cycling trips made by the participants. The results from the exercise were then processed, cleaned and digitised into a GIS format. Of the original 4,000 trips, only 1,527 were used in analysis after the following trips were removed from the initial data:

1. Recreational trips or trips with no specified destination/purpose
2. Trips that did not have a unique identifier
3. Circular Trips
4. Trips that went outside of the network
5. Trips that had obvious mistakes or digitising errors

The time scaling factors developed for New Zealand can be found in Figures 6.5.1 and 6.5.2. The values can be used to scale the initial link travel time, resulting in the perceived cyclist travel time increasing when a cyclist has to traverse through undesirable conditions, such as links that have high traffic volumes and no cycle facilities. Consequently, the scaling factors in Figure 6.5.1 were used to scale the derived trips across Christchurch City based on cyclist preference.

| Facility description | Time delay (s) | | | |
| | Portland | | New Zealand | |
	Commute	Non-commute	Commute	Non-commute
Traffic signal*	6.1	10	3.1	5.3
Stop sign	1.4	2.6	0.7	1.3
No signal, Right turn; 10,000-20,000 vpd	26	47	13	24
No signal, Right turn; 20,000+ vpd	67	130	34	64
No signal, Left turn; 10,000+ vpd	11	19	5.6	9.9
No signal, crossing*; 5,000-10,000 vpd	12	21	6.1	11
No signal, crossing*; 10,000-20,000 vpd	17	30	8.7	15
No signal, crossing*; 20,000+ vpd	93	180	48	91

* excluding Left turns

Figure 5.4.1: ARCM route choice scaling factors based on different road and cycling facilities

Source: Rendall, Rose, & Janssen, 2012

| Facility description | Time scaling factor | | | |
| | Portland | | New Zealand | |
	Commute	Non-commute	Commute	Non-commute
Bike lane	1.00	1.00	1.00	1.00
No bike lane; 10,000-20,000 vpd	1.37	1.22	1.19	1.11
No bike lane; 20,000-30,000 vpd	2.40	2.37	1.71	1.70
No bike lane; 30,000+ vpd	8.16	7.19	4.65	1.46
Bike path	0.84	0.74	0.92	0.87

Figure 5.4.2: ARCM route choice scaling factors based on a roads average VPD

Source: Rendall, Rose, & Janssen, 2012

5.5 Conclusion

It is clear that transport and route choice modelling are integral components of sound transport planning, particularly when planning for the future. The importance of good planning for cycling has been widely discussed throughout this research; so often good planning requires having the ability to predict and understand future transport plans - something that is certainly achievable through the implementation of transport modelling. The importance of comprehensive transport planning in Christchurch has been highlighted a number of times already throughout this research, and following the discussion of the merits of transport and route choice modelling, as well as they ways

in which it can be applied, it is clear that both of these will play a key role in providing Christchurch with a robust transport system that functions both presently, as well as in the years to come.

6. Methodology

This chapter introduces, and summarises the methods used throughout this research to answer the four key questions outlined in Chapter 1 namely:

1. Identify likely commuter travel patterns throughout Christchurch for the year 2041
2. Examine potential cycle trips in relation to the proposed major cycleways
3. Examining where future cycle infrastructure should be located based on 2041 commuter travel patterns
4. Suggest how development of this infrastructure should be prioritised based on likely demand and value

A summary of how these key questions were addressed can be found in the sub-sections that follow. This includes both detail about the methods used to answer the questions, as well as particulars surrounding the steps that were required, and undertaken to complete the analysis.

6.2 Geographic Information Systems

Geographic Information Systems (GIS) have become a fundamental tool used throughout the many facets of urban planning and development. Most commonly utilised for their modelling, analysis, data management and visualisation abilities, urban planning is now one of the key applications of GIS technologies. It has been acknowledged that one of the key functions of planning is the prediction of future population and economic growth, both of which can be modelled using GIS tools (Yeh, 1999).

As one of the key aspects of this research is to predict likely transport patterns based on future population and economic growth, GIS has been the main method utilised. The use of GIS has allowed the visualisation of likely transit patterns throughout the Christchurch urban area in 2041, as well as providing a platform on which to undertake in-depth analysis of where future cycle infrastructure would be best located. The key research questions outlined in Chapter 6.1 have been answered through the use of various GIS and network analysis tools.

6.3 Data Sources

A substantial amount of quantitative data from a number of different sources has been used throughout this research. All data was obtained from secondary sources (Table 6.3.1).

Table 6.3.1: A summary of the data used for analysis and its source

Name	Description	Source
Rapid 2041	Modelled population and employment predictions for 2041	CCC
CAST Zones	Zones from the Christchurch Assignment & Simulation Traffic Model. Similar to meshblocks in size	CCC
CTM Zones	Zones from the Christchurch Transport Model. Similar to meshblocks in size	CCC
NZ Property Titles	Provides title information for all primary parcels throughout New Zealand	LINZ
Street Centrelines	Christchurch road network. Includes both active and planned streets and roads	CCC
Averages Vehicles Per Day	Number of vehicles per day for all Christchurch streets and roads as recorded at intersections	CCC
Major Cycleways Network	The proposed cycle network that is currently being implemented throughout Christchurch	CCC
Existing Cycleways	All existing cycle infrastructure throughout Christchurch, including both on and off road infrastructure	CCC
Projected Population Data	Statistics New Zealand population projections by area units for 2031	Stats NZ

6.4 Data Preparation

The variety of secondary data sources meant that much of the data required at least some preparation to remove potential sources of error from the analysis. This cleaning process was particularly important for the Rapid 2041 data obtained from the Christchurch City Council. The household data had been modelled for a number of different types of households, ranging from households with single occupants of either working or retirement age, family households, through to non-family households; the employment data had been modelled for each employment sector, as well as total employment. This level of aggregation was not suitable for the network analysis used, thus in order to aggregate the data to a level that would be acceptable for analysis, household data was combined to simply produce the number of households in each zone and only included the relevant household categories. Similarly employment data was also combined to provide an indication of how many places of employment can be expected in each zone.

Network analyst's Closest Facility analysis requires origin and destination point data; creating this data involved deriving population weighted centroids for each of the CAST zones that is expected to contain residential and employment activity in 2041. In order to do this, New Zealand property title polygons were used; whilst they did not include any information about whether the property was

used for residential or business activity, the dataset did include information on every property in the country. The initial dataset was cropped to only include Christchurch City, and centroids were generated from each of the property title polygons. The centroids that had been generated were spatially joined to the CAST zones, with a count field containing the sum of all the centroids in each CAST zone added to the attribute table. The ArcGIS mean centre tool was then used to create population weighted centroids for each of the CAST zones based on the number and distribution of property centroids in each CAST zone. Whilst this method did not allow for differentiation between residential and business activity in each zone, it did provide an indication of where activity will likely be happening, which was deemed sufficient for use in this analysis.

A substantial amount of the analysis undertaken required a road network that included vehicle per day (VPD) data. Due to this data only being available on a road by road basis, with inconsistencies in when the data was collected, the average vehicle per day data from the CCC's traffic management road level classifications was used. For each road segment the VPD count was attached through a table join, although a substantial number of segments required manual entry. As roads with vehicle volumes of less than 500 were not included in the CCC data, for the purpose of this research it was simply assumed that these roads had a VPD count of 500. The ARCM presented in Chapter Five does not provide a scaling factor for any road with less than 10,000 vehicles per day; thus for the purpose of this research it can be presumed that roads with 500 vehicles or less are relatively safe for cycling. The assumption that roads not included in CCC's traffic management classification document have VPD counts of 500 should not have any major impacts on analysis. It is however important to note that as the rebuild and redevelopment of Christchurch central continues, there are likely to be changes to these daily volumes for many roads.

Owing to the substantial size of the dataset used throughout much of the analysis, the origin (household centroids) data was split into 100 subsets and batch processed using a number of models created using the ArcGIS Model Builder to iterate through each subset. Splitting the data into small subsets meant that processing was more efficient, both in terms of time taken to complete analysis and ensuring that the computer hardware was able to manage the large volume of data.

6.5 Deriving Potential Trips

The ArcGIS Network Analyst extension was used to derive potential trips throughout Christchurch City for the year 2041. Using modelled population and employment projections (Rapid 2041) provided by the CCC and zones from the Christchurch Assignment & Simulation Traffic (CAST)[4] Model, some conclusions were able to be drawn as to where the general population is likely to be living and working in 2041.

Network Analyst's 'Closest Facility Analysis' (Figure 6.5.1) was used to calculate the 'least cost' route between each origin (household centroids) and every potential destination (employment centroids). The least cost route is determined by a specified impedance; whilst there are a number of impedances that can be used, in this instance network distance measured in metres was chosen. Due to a number of software and hardware limitations, an iterator was used in the model to process each of the data subsets. There are a number of iterators available within ArcGIS, all of which allow the process in the model to be automatically repeated for a number of different data or settings. In this case the iterator was used to perform the same closest facility analysis on each of the 100 data subsets. The road network used for analysis included both the road network, as well as the proposed major cycleways network; consequently, where it was the least cost option the algorithm had the option of using the major cycleways network to complete part of, or the entire trip.

The network analysis results provided a substantial amount of additional data; as a result of routes being derived between each origin and every possible destination, a total of 1,508,456 potential trips throughout the city were generated. However, as the network analysis had been completed using 100 subsets, the results were also generated in 100 subsets, making the rest of the analysis process much more efficient.

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[4] The CAST zones used are very similar to Statistics New Zealand meshblocks in size
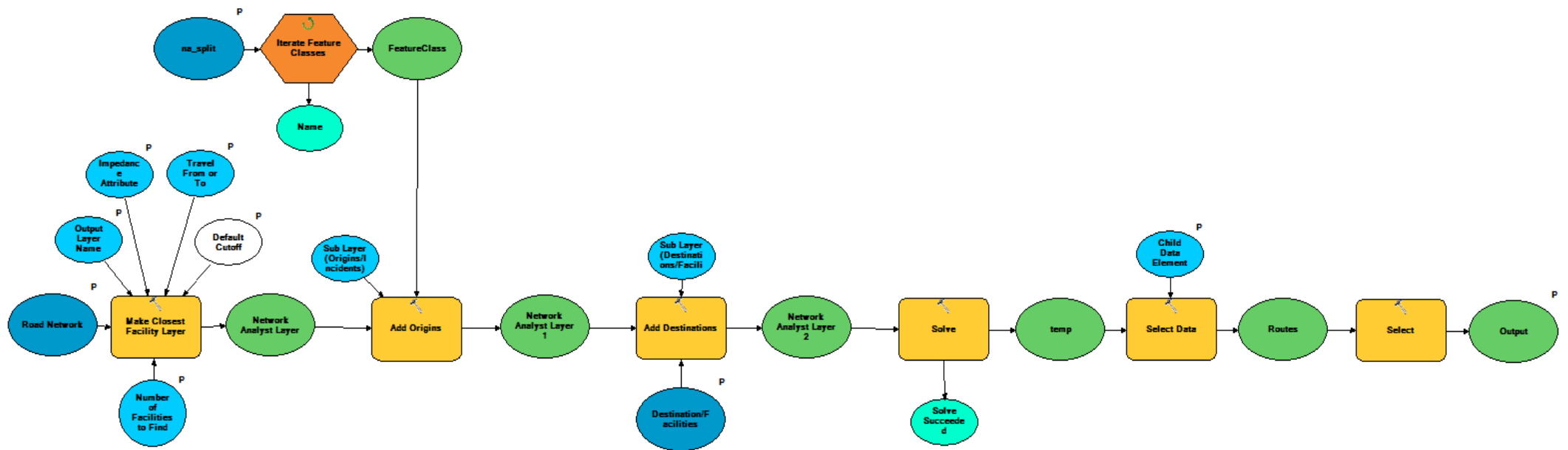
Figure 6.5.1: The model built in ArcGIS Model builder to undertake closest facility network analysis

6.6 Calculating Route Saturation

In order to ascertain where new investment in Christchurch is going to represent the best value for money, it is important to understand which parts of the city will likely see the most traffic passing through them. To determine areas in which infrastructure should be located based on likely demand, route saturation throughout Christchurch was examined.

To understand the distribution of the derived trips throughout the city, a spatial join was performed to join the trips to the CAST zones. A spatial join simply joins one feature to another, based on their spatial location; in this case the derived trips were joined to the CAST zones. The model in Figure 6.6.1 was used to complete the join, again using the iteration described above to iterate through each of the 100 trip result subsets. Following the completion of the spatial join, a new field could be found in the CAST zone attribute table, with a sum of how many of the derived trips had passed through each zone.   Finally the 100 subsets were combined to obtain an overview of the entire city, allowing some conclusions about demand for infrastructure to be drawn.

The two 'Select' data must be set as original files, then their common 'Value' changed. this is necessary so that the 'Field Map' can be populated.
I know, totes annoying.

Figure 6.6.1: The spatial join model used during analysis to calculate route saturation

6.7 Route Choice Metric

As discussed in earlier chapters, cyclist preference and perceived safety play a significant role in how a cyclist selects the route they will take, not just how long the trip will be. The Abley Route Choice Metric (as outlined in Chapter 5.1) was used here as a number of route choice and level of service calculations developed on a global scale were reviewed, and then considered to develop a cyclist route choice model that was relevant to cyclists in New Zealand. The scaling factors developed for the metric were applied to the derived trips in order to assess which routes would be perceived as the most and least safe to a cyclist. In order to gain an understanding of areas that are likely to experience high cyclist numbers in the future, the closest facility analysis was undertaken again, this time using a weighted road network that had 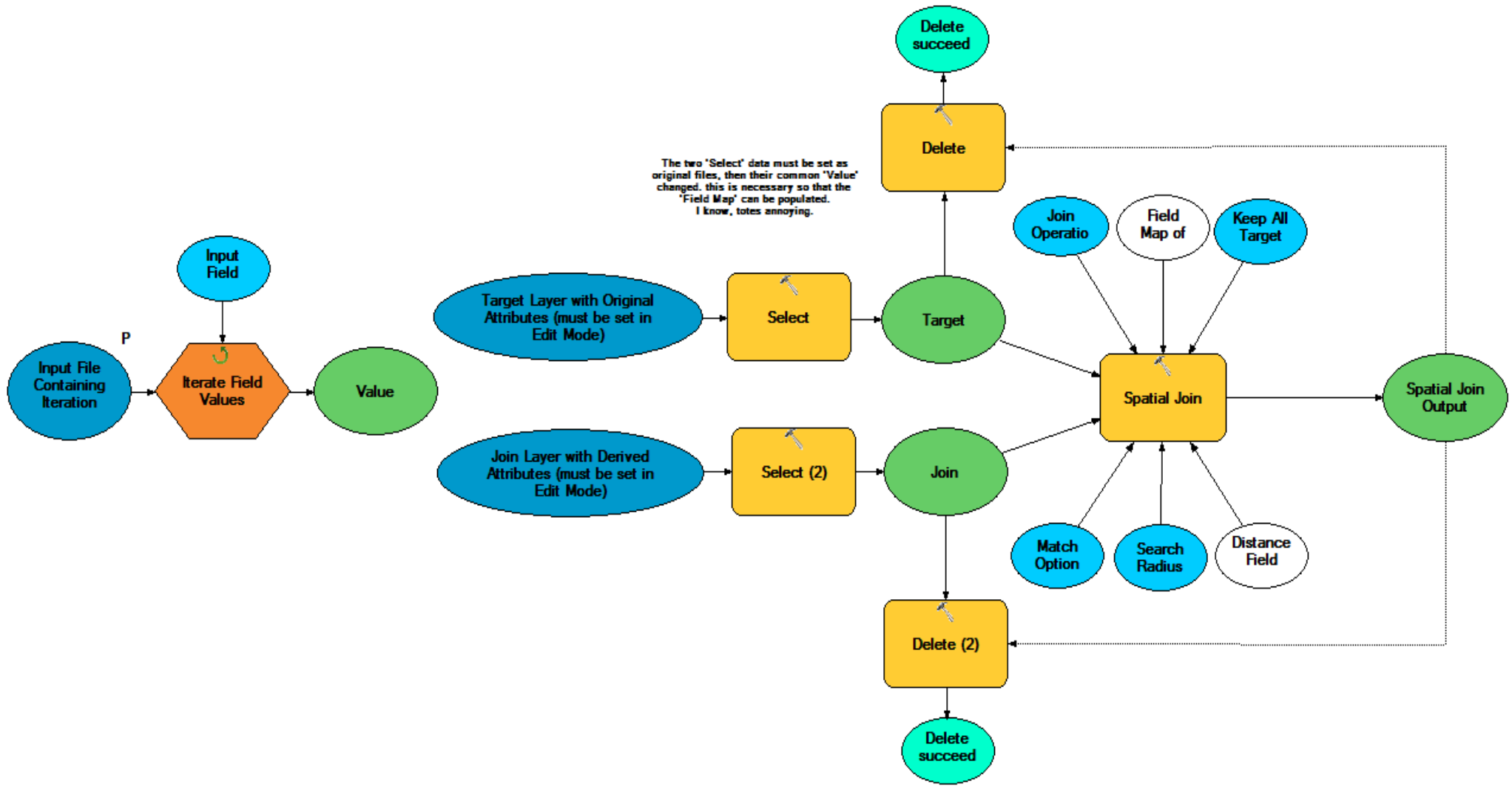been scaled using the route choice metric scaling factors. Whilst off road bike paths are undoubtedly an important cycling infrastructure asset, as this research is focused on trips made using the road network, the bike path category was not needed for analysis. Consequently, the road network was scaled based on the following four facility groups; Bike Lane; No Bike Lane 10,000 – 20,000 VPD; No Bike Lane 20,000 – 30,000 VPD; and No Bike Lane 30,000+ VPD.

| Facility description | Time scaling factor | | | |
| | Portland | | New Zealand | |
	Commute	Non-commute	Commute	Non-commute
Bike lane	1.00	1.00	1.00	1.00
No bike lane; 10,000-20,000 vpd	1.37	1.22	1.19	1.11
No bike lane; 20,000-30,000 vpd	2.40	2.37	1.71	1.70
No bike lane; 30,000+ vpd	8.16	7.19	4.65	1.46
Bike path	0.84	0.74	0.92	0.87

Figure 6.7.1: The ARCM scaling factors applied to the road network to weight analysis based on cyclists' perceived safety

Weighting the road network used for analysis based on the ARCM scaling factors in Figure 6.7.1 and then using it for analysis, meant that instead of simply generating the shortest route between an origin and destination, the algorithm would instead come up with the safest shortest route between an origin and destination. As the route choice scaling factors are a time scales, a travel time needed to be assigned to each piece of the road network. Travel times were calculated as distance divided by velocity (speed), with an average cyclist speed of 20 kilometres per hour assumed (Rendall et al., 2012). Once the road network had been assigned a travel time, the route choice scaling could be

applied to the road network; the scaled travel times were then used as the new impedance for further network analysis.

As with the initial network analysis, the results from the ARCM network analysis were joined to the CAST zones using a spatial join in order to ascertain how many of the trips passed through each zone. Whilst the count results from the first round of analysis provided an indication of areas where there is likely to be a large number of trips passing through in years to come, the count results from the ARCM analysis instead indicate areas that are likely to be attractive to cyclists, as well as areas that are likely to require some attention.

6.8 Examining Demand

The results from both sets of network analysis provided a good basis on which to assess demand for future infrastructure. In order to further identify areas where development would be best located, it was important to ascertain zones which already have a sufficient level of service from the proposed major cycleways network.

In order to gain a better understanding of which zones are likely to have a sufficient level of service, buffers were used. A 500 metre buffer was applied around the major cycle network. This distance was chosen as it has been suggested that if a person lives, works or travels within 500 metres of cycle infrastructure that person has reasonable access to suitable infrastructure (Macbeth, Allen, & Barton, 2007). Following the application of the buffer, the zones that did not have an adequate level of service were easily identifiable. It is important to note that a number of zones were partially serviced by the proposed major cycleways network and therefore is reasonable to suggest that extensions in these areas could significantly contribute to improving network accessibility.

In order to identify key demand areas throughout the city, it was important to first identify areas that would already have a sufficient levels of service from the initial 13 route network. Consequently, to ascertain which areas of the city would require attention in the future, the projected population and employment data, as well as the results from network analysis were overlayed with the major cycleways data. To gain an understanding of which areas would be serviced by the initial 13 routes, a 500 metre buffer was again created around the major cycleways network. Following this, the CAST zones that fell within the 500 metre buffer were selected using ArcGIS's "select by location" tool. Whilst selecting zones that intersected the 500 metre buffer would have given the initial network a wider service area, it would have been difficult to identify

which parts of the zone fell outside of the 500 metre buffer area. Consequently only those that were within the buffer area were selected; the selected zones were then exported. As a result, it was very easy to see which zones and areas of the city should receive priority when making suggestions as to where future infrastructure could be best located.

6.9 Prioritising Future Infrastructure

As with any new development, when considering the implementation of new cycling facilities there needs to be some thought given to where there is the largest demand for infrastructure, and how the implementation of facilities should be prioritised; in this case demand forecasting has been used. A case study that examines how new cycling infrastructure should be prioritised in Auckland, New Zealand, highlighted that existing cyclists who already cycle frequently are likely to use a new facility if it is constructed close to where they live or work, thus estimates of the demand for new infrastructure can be measured based on counts from the areas surrounding the new infrastructure (Raith, Nataraj, Ehrgott, Miller, & Pauw, 2011). When estimating new cyclists (those who may change to cycling from another mode of transport due to the construction of the new facility) demand, the number of new cyclists can be estimated based on population density and the distance to the new facility using buffer zones (Raith et al., 2011).

In order to determine the impacts that network extensions would have on route choice, the network analysis process outlined in sections 6.7 and 6.8 was once again undertaken, this time building network extensions into the road network and assigning them the same weighting as the rest of the proposed major cycleways network.

Once network analysis was completed, a 500 metre buffer zone was applied to the extensions to assess demand; 500 metres was selected again based on the 500 metre reasonable accessibility assumption discussed previously (Macbeth et al., 2007). It is important to note that whilst existing cyclist demand was measured in Auckland, due to the proposed major cycleways network not yet having been implemented, demand has been measured based only on new cyclist demand using the derived trip results. Select by spatial location was used to identify and isolate those zones that were both within 500 metres of the proposed extensions, or intersected the 500 metre buffer; once the zones had been selected they were exported as a new shapefile. Selecting the zones that were both within 500 metres of the proposed extensions, as well as those zones that intersected the 500 metre buffer meant that the impacts the extensions would have on both the areas they provided a full level of service to, as well as those that were partially serviced.

In order to suggest how the implementation of the infrastructure could be prioritised based on demand, the difference between the expected number of trips passing through the selected zones before, and after the application of the extensions was calculated. From here the extra trips per kilometre of infrastructure could be calculated.

7. A Changing Christchurch

This chapter aims to provide an introduction into current and predicted population changes throughout Christchurch. This is particularly important in providing some context for the findings to follow. In order to provide advice and recommendations on where future transport infrastructure of any kind should be located, it is important to first understand what shape, both physically and demographically, the city is going to take in the years to come. Through examining changes in demographic trends, including where the city's population will be both living and working, along with expected growth trends, it is hoped this important level of understanding will be established.

7.1. Usually Resident Population 2006 - 2013

The seven years between the 2006 and 2013 censuses saw an unprecedented amount of change in the distribution of Christchurch's residential population (Figures 7.1.1, 7.1.2, and 7.1.3). As a result of the series of large earthquakes that struck Christchurch in 2010 and 2011, there has been a significant amount of change to the city's residential configuration. Eastern suburbs such as Avondale, Bexley, Dallington and Burwood have experienced the largest decreases in their usually resident population, whilst northern suburbs such as Belfast and Bishopdale have seen accelerated levels of growth. Christchurch city experienced an overall population decline of 3.89 percent between 2006 and 2013 – though it is important to acknowledge that a substantial proportion of the city's population has chosen to relocate to areas on the city's peripheral, including Waimakariri and Selwyn. Greater Christchurch saw population growth of 2.6 percent between 2006 and 2013; Selwyn experienced the largest growth, up 32.6 percent, while Waimakariri was up 16.7 percent (Statistics New Zealand, 2014a).

As mentioned previously, Christchurch's eastern suburbs experienced the most significant decline in their usually resident population, reaching levels of decline between 42.2 and 62.9 percent (Statistics New Zealand, 2014a). These high levels of decline indicate that when future planning is being undertaken, attention needs to be focused in the city's major growth areas, which currently include northern suburbs such as Belfast and Bishopdale, as well as areas further towards the city's peripherial, particularly in the western and south western areas of the city.

Usually Resident Population 2006

- 204 - 1348
- 1349 - 2491
- 2492 - 3635
- 3636 - 4778
- 4779 - 5922
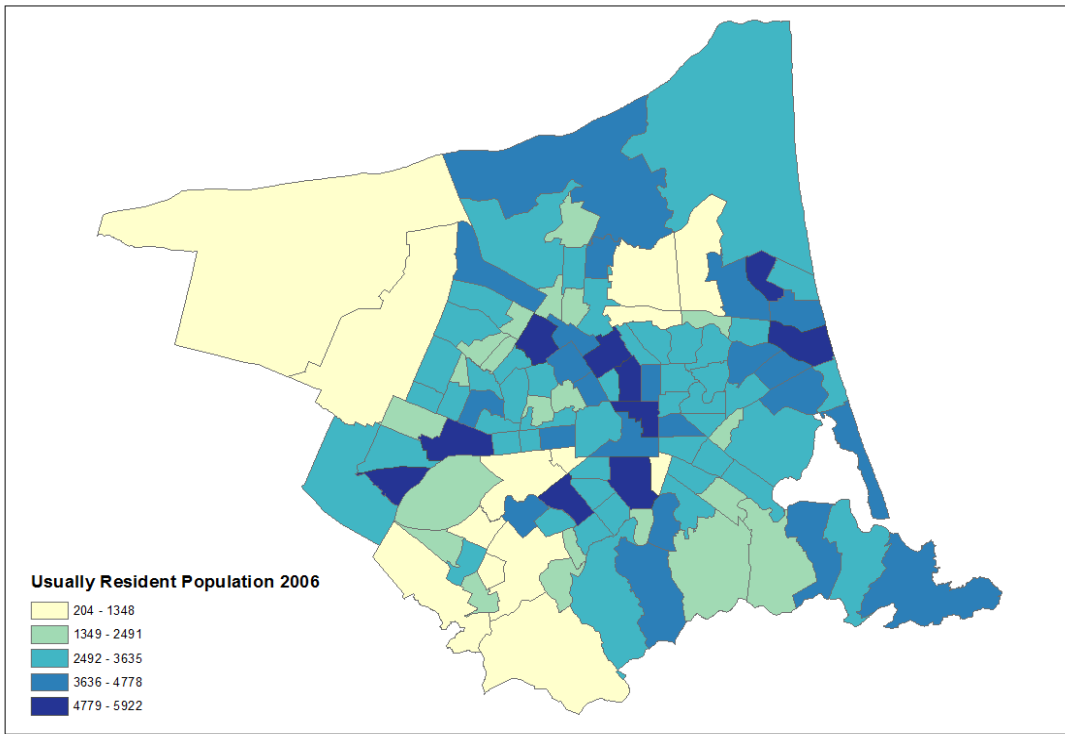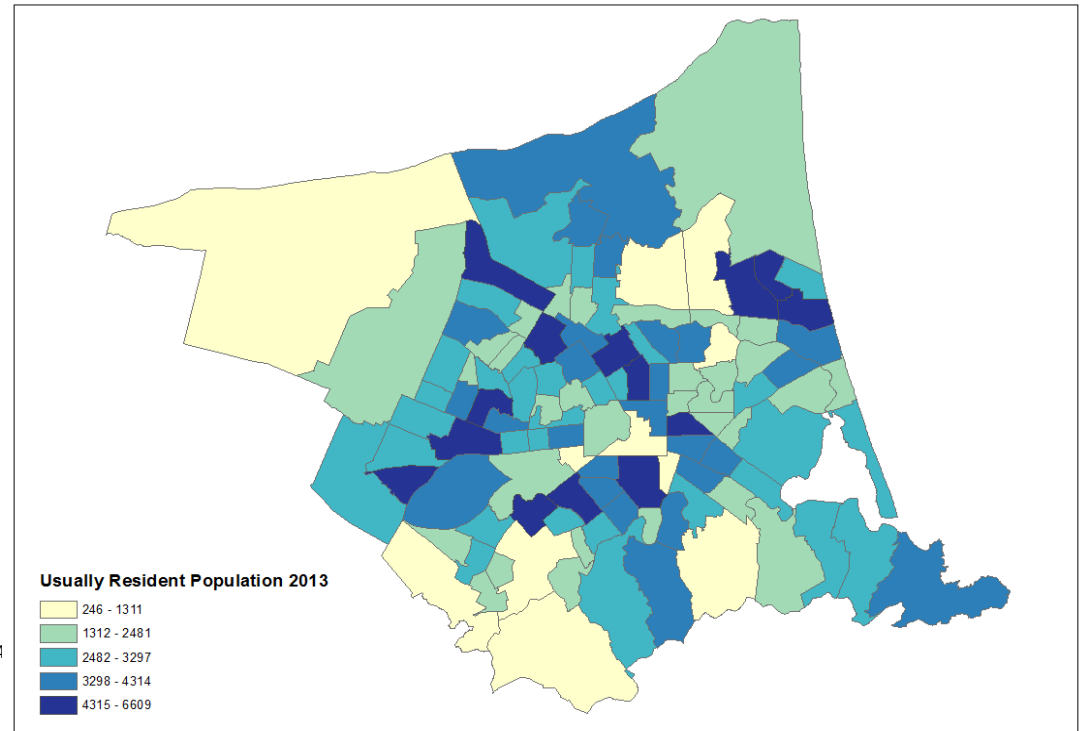
Figure 7.1.1: Usually resident population, 2006

Data source: Statistics New Zealand

Usually Resident Population 2013

- 246 - 1311
- 1312 - 2481
- 2482 - 3297
- 3298 - 4314
- 4315 - 6609

Figure 7.1.2: Usually resident population, 2013

Data Source: Statistics New Zealand

4

As noted previously, Christchurch saw an unprecedented amount of change in the distribution of the city's usually resident population between 2006 and 2013. Not surprisingly, the most earthquake affected areas in the east have largely experienced the highest rates of population change between 2006 and 2013 (Figure 7.1.3). Areas on the western edge of the city and city fringe, such as Halswell, Yaldhurst and Wigram, have also seen large rates of change between 2006 and 2013; in this case the variation in usually resident population can be attributed to accelerated levels of growth, as opposed to decline.

Usually Resident Population Percentage Change 2006 - 2013

Perc_Chang
- 0 - 10
- 11 - 30
- 31 - 50
- 51 - 180
- 181 - 566
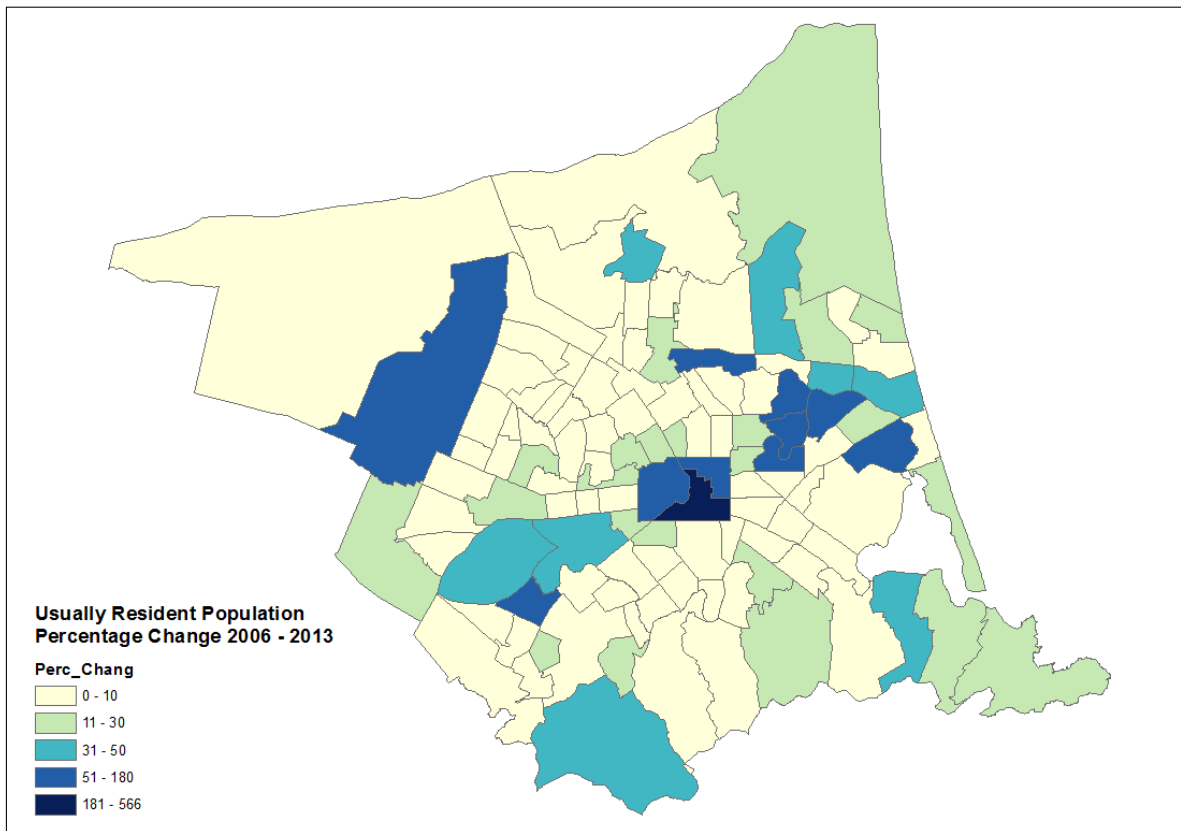
Figure 7.1.3: Percentage change in usually resident population, 2006-2013

Data Source: Statistics New Zealand

Should the city continue to grow the way it currently is, planning for future infrastructure needs to ensure that effective links between the major residential growth areas (such as Belfast and Halswell) and key employment destinations are provided. As deliberated earlier, it has been found that effective and attractive infrastructure plays a key role in encouraging the use of cycling as an attractive mode of transport (Geller, 2011). Christchurch City Council has acknowledged that one of their key goals throughout the rebuild is further enhancing the city's cycle culture, a goal in which well-designed and attractive cycle network plays a key role in achieving.

7.2 Expected Population Growth (2031)

As the rebuild progresses and Christchurch continues to recover, the city's population is predicted to grow (Statistics New Zealand, 2014b). With changes in the distribution of the city's population comes a change in infrastructure and service requirements; this makes being able to predict and understand where these changes will occur critical to effectively planning for the future.

There have been a number of predictions made as to how Christchurch will develop, and the changes that can be expected with regard to population growth. Figures 7.2.1 and 7.2.2 provide a summary of forecasts made by Statistics New Zealand as to how Christchurch may grow in the years to come. Figure 7.2.1 highlights that the largest proportion of residential growth is expected to continue in the city's northern, western and south western suburbs. Prestons, Highfield Park and Hendersons Basin are expected to have the largest increase in their usually resident population; however areas such as Belfast, Bishopdale, Halswell, Wigram, Sockburn and Yaldhurst are also expected to undergo substantial growth.
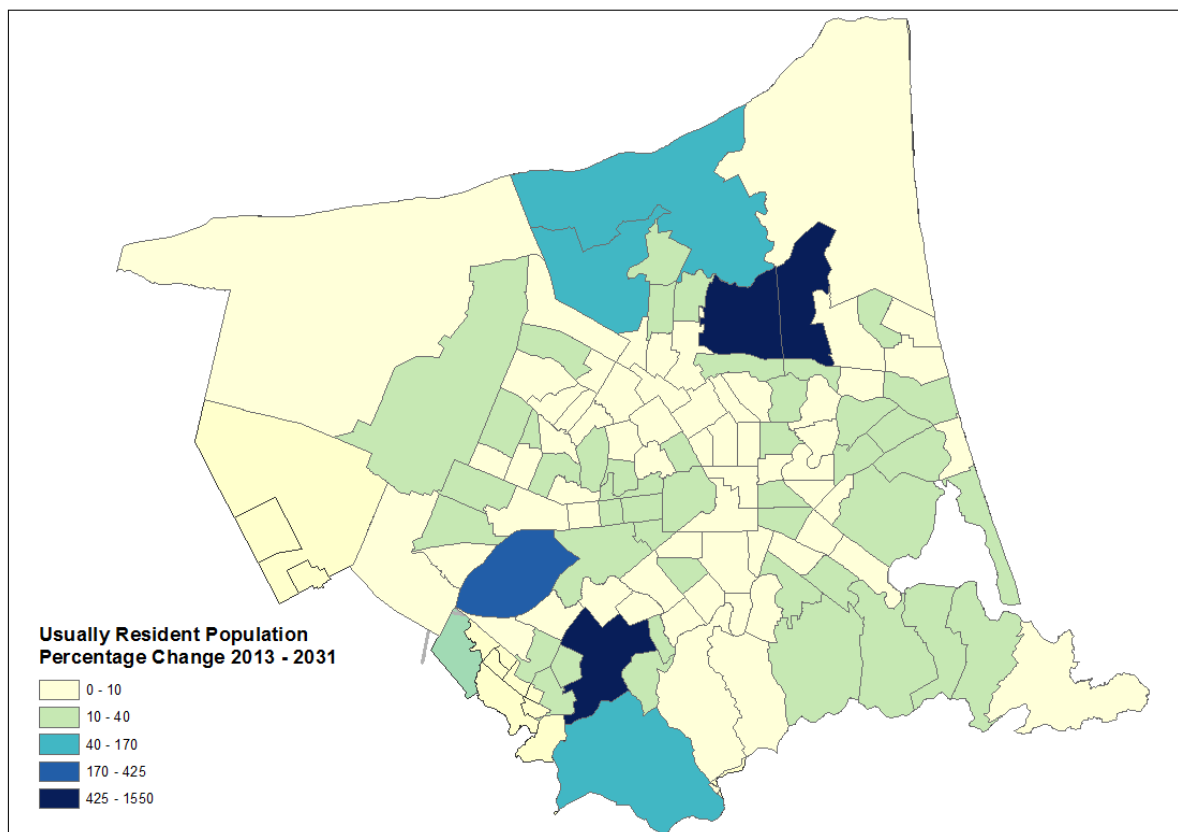
Figure 7.2.1: Projected population growth (percentage change) in usually resident population by area unit, 2013-2031

Data Source: Statistics New Zealand

Christchurch saw significant change to the distribution of the city's usually resident population between 2006 and 2013, and this is not a trend that is expected to diminish as recovery continues (Statistics New Zealand, 2014b). Figure 7.2.2 provides an overview of how the city is expected to look in terms of population distribution by 2031. Overall, Christchurch's residential population is expected to increase from that recorded in the 2013 census; the largest increase in residential population is expected in Belfast, growing from 6609 to 10,550 (62%). Along with changes to population density, it is also anticipated that the distribution of the population will undergo some change. Areas such as Belfast, Halswell, Sockburn and Yaldhurst are expected to continue growing, however it is expected that in the years leading up to 2031, Styx Mill, Sawyers Arms, North Beach and Sydenham, among others, will also see expansive growth to their usually resident population. Similarly, areas that underwent population decline between 2006 and 2013 are expected to see further reductions in their population; these principally include the most earthquake damaged eastern suburbs, including Linwood East, Travis, Burwood and Richmond South.
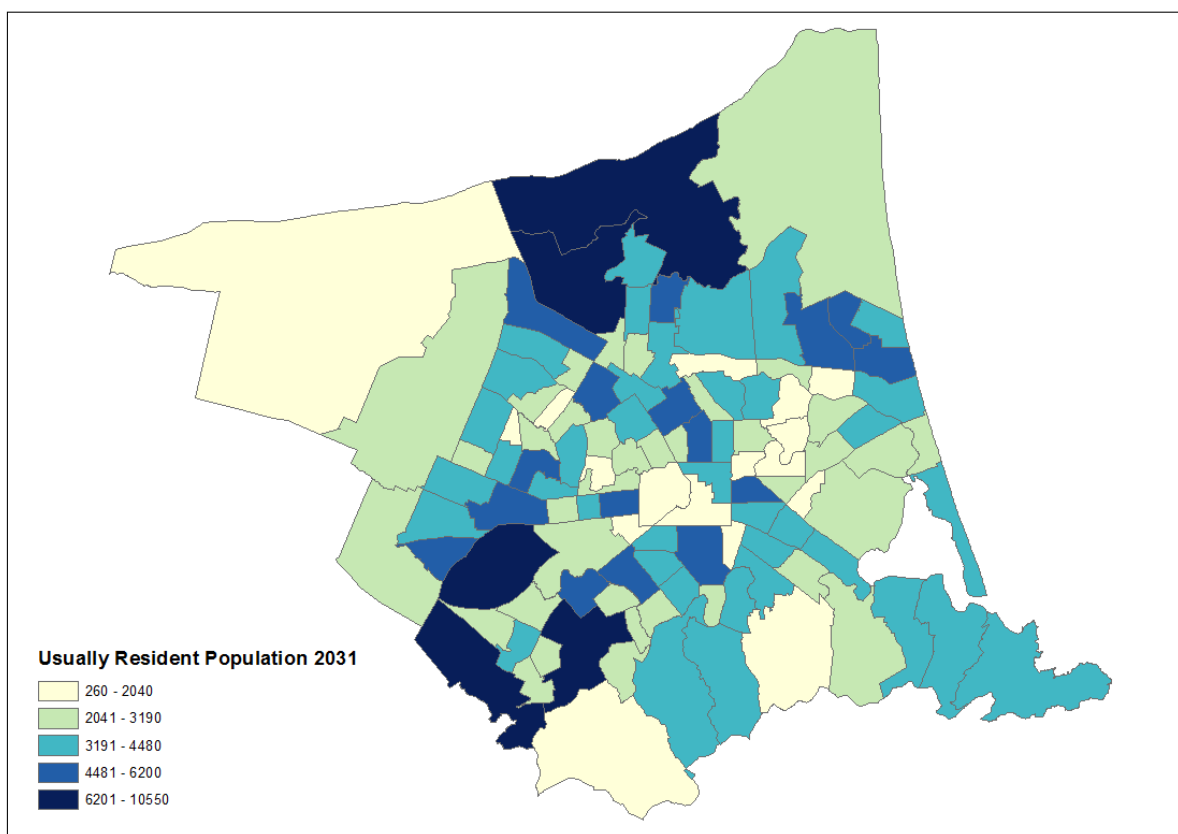

Figure 7.2.2 Projected usually resident population by area unit, 2031

Data Source: Statistics New Zealand

7.3 Household and Employment Distribution, 2041

There have been many predictions made as to how Christchurch will develop in the next 20 – 30 years. The results to follow are an outline of forecasts developed for use in transport modelling for Christchurch, looking forward to the year 2041. Whilst the 2031 data focuses on population growth, the forecasts below examine how households and employment locations will likely be dispersed throughout the city. Figure 7.3.1 illustrates that while Statistics New Zealand population projections for 2031 suggest there will be high levels of growth in areas such as Belfast and Halswell, the RAPID data expects the areas with the highest household density to include Sumner, Hendersons and Barrington, with lower levels of household density predicted in Belfast, along with other outlying northern suburbs. Although Halswell is not expected to be one of the most densely populated areas, it is expected that there will be significant growth in the number of households in the area. It is important to note however that the type of residential development expected in these areas is likely to impact expected household density.

Though there are some discrepancies between the household (RAPID 2041) and population (Statistics New Zealand 2031 projections) data, these can be explained, at least in part, by the nature of the households found in an area. Whilst Statistics New Zealand's population data examines the likely usually resident population, the household data is simply looking at the number of households expected in an area, as opposed to the number of people living in them. Consequently it is likely the household data has the potential to skew results in areas where there are a large number of single person households, as opposed to areas where there are a smaller number of households with more people living in them. It is also important to note that as the CAST zones are smaller than the area units, resulting in the projections being measured at different levels of aggregation.

As this research focuses on utility cycling, an understanding of how employment will be distributed throughout the city in the future is imperative. Identifying where key employment zones will likely be located following the completion of the central city rebuild will assist in the current planning of major infrastructure, ensuring that this infrastructure is still able to service high demand areas in 2041 and beyond. Figure 7.3.2 exemplifies areas that are likely to have high levels of employment activity in 2041. Areas that have emerged with strong business and employment rates throughout the rebuild period are expected to maintain their current high levels of activity; these include Middleton, Riccarton, Addington, Yaldhurst, Russley and Hornby. It is however expected that there will also once again be a significant business hub in the CBD. In order to encourage more of the

city's population to engage in utility cycling, it is important that these areas are well serviced by cycle infrastructure, and ensuring they are prioritised in planning being undertaken presently is essential.
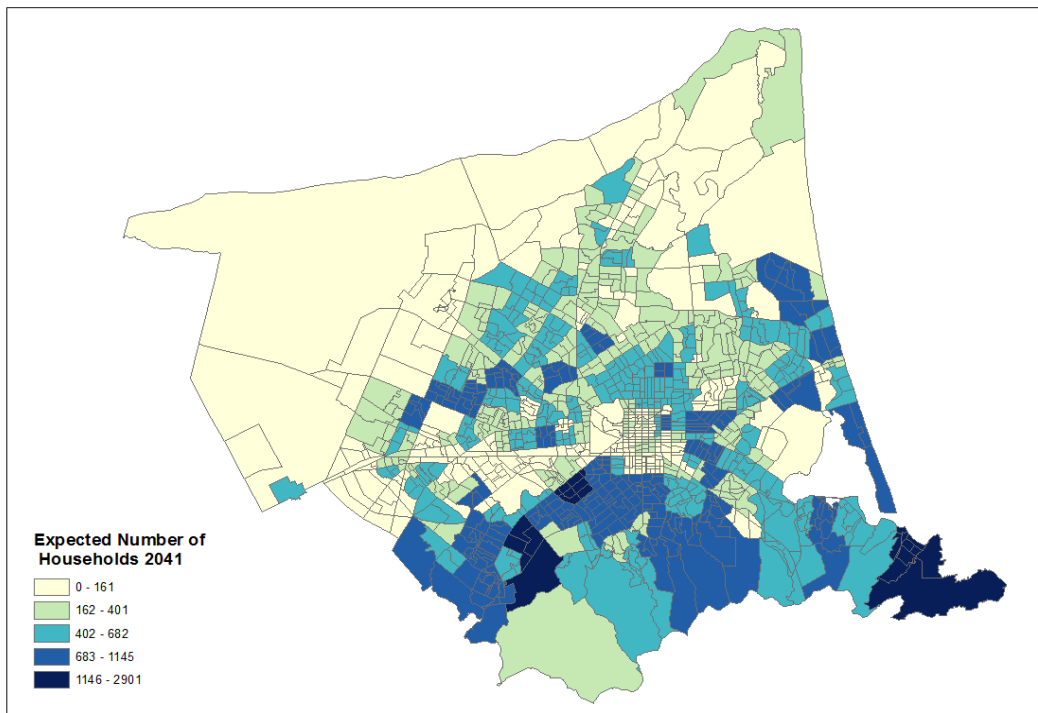

Figure 7.3.1: Expected number of households in each CAST zone, 2041
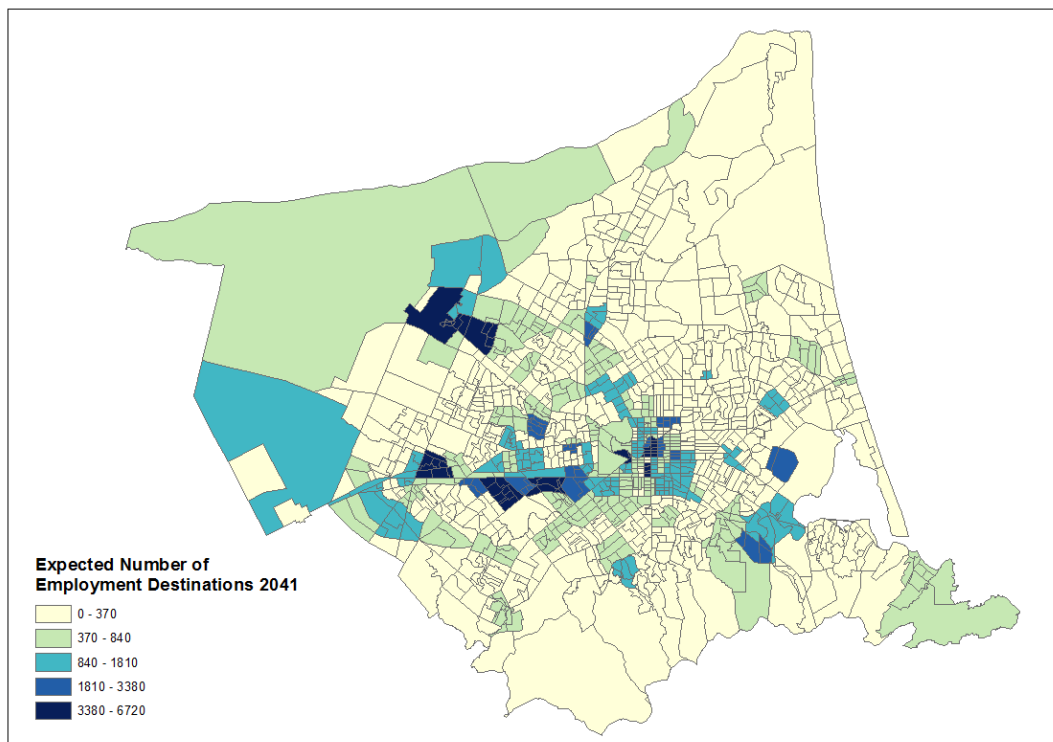
Data Source: CCC RAPID 2041 Data

Figure 7.3.2: Expected number of employment destinations in each CAST Zone, 2041

Data Source: CCC RAPID 2041 Data

7.4 Liveability and Sustainable Growth

As cities around the world continue to grow, the concepts of liveability and sustainability are becoming increasingly important. It has been acknowledged that cities around the globe are growing at an unprecedented rate; a trend that is not expected to subside in the years to come (Shamsuddin, Hassan, & Bilyamin, 2012). The continued growth expected in cities will undoubtedly put a substantial number of constraints on the way in which cities develop, particularly in terms of the infrastructure they provide. It also generates an enormous amount of pressure to ensure that development is sustainable, providing not only for the needs of the city at present, but also meeting the needs of the city in the future.

The concepts of sustainability and liveability are becoming more widely discussed in the context of urban growth and development, particularly in terms of transportation. As cities begin to struggle to accommodate their rising populations, growth begins to: 1) intensify in areas in the central city and 2) spread out into the city's peripheral. The results above indicate that Christchurch is a prime example of the latter, where growth is expected to be concentrated largely in the northern and western areas of the city. Whilst there are a number of definitions available for both sustainability and liveability, it has been suggested that liveability most commonly refers to a specific set of sustainability goals that have a direct effect on community members (Litman, 2015). These goals often include but are not limited to local economic development and environmental quality, equity, affordability, basic mobility for non-drivers, public safety and health, and community health (Litman, 2015). Amongst the key liveability principles defined by the US Interagency Partnership for Sustainable Communities is 'provide more transport choices', acknowledging that in order to develop sustainably and promote liveability, safe, reliable and economic transport choices must be established, which decrease household travel costs as well as dependence on oil, promote public health and improve air quality through decreasing greenhouse gas emissions (Interagency Partnership for Sustainable Communities, 2010).

With this in mind, in order to safeguard Christchurch as a liveable city, it is going to be essential that any development of the city's transport infrastructure and network ensures that the high demand growth areas, such as Belfast, Prestons, and Halswell, are well connected to the rest of the city. Whilst it is going to be vital that these areas are well connected, in order to ensure that the growth is managed in a sustainable manner, it is also going to be important that people living in these areas are provided with transport choice. Although progress is being made, Christchurch is a city that is currently still very car centric. Subsequently, it is relatively safe to assume that the areas where

there is expected to be high levels of growth will be provided with good arterial connections to the rest of the city. However in order to promote sustainable growth and improved liveability throughout the Christchurch, it is going to be indispensable that commuting by means such as active transport is encouraged, primarily through the appropriate infrastructure provisions.

7.5 Commuter Origins and Destinations

As this research has been primarily focused on utilitarian cycling, commuter origins and destinations have been limited to residential addresses (origins) and places of employment (destinations). Research has found that the first and last 100 metres of a trip are critically important in encouraging an increased uptake of utility cycling (van den Dool, 2013). If there is attractive, inviting infrastructure on which to start and end your trip, then a person who may not normally consider cycling is far more likely to reconsider their mode of transport. Similarly, as discussed in Chapter 2, accessibility, proximity and attractiveness are imperative when encouraging more of the population to reconsider their transport behaviour (CROW, 2007; Geller, 2006; Land Transport Safety Authority, 2005). Consequently, derived trips were generated between each origin and destination, in an attempt to gain further understanding as to how commuter travel patterns might look throughout the city in the years to come.

In order to understand likely commuting patterns in the years to come, it is important to consider areas that are expected to have a large number of trips beginning and concluding in them. Figure 7.5.1 below provides an indication of areas that are expected to have a large number of trips originating in them; as aforementioned, in this case trip origins have been limited to residential addresses. Looking forward to 2041, it is clear that key residential development areas are located largely in the suburbs on the outskirts of the city centre, with more development expected to ensue on the city's Greenfields. The population distribution patterns that can be identified in Figure 7.5.1 are not too dissimilar to those that were observed in Chapter 7.3, where a substantial number of households can be seen in the city's southern areas, particularly in and around Halswell. Whilst the results presented in Chapter 7.3 examined the distribution of all households, in this case the households have been limited to include only those who are likely to be making utility trips to employment; consequently household categories such as single or multiple occupant retiree households have been excluded. The areas in blue in Figure 7.4.1 are expected to contain the largest proportion of the city's households in them in 2041. Consequently, providing effective transport links in these areas is going to be crucial in ensuring the city remains well connected, and people can move throughout the city with ease. It is important to once again acknowledge Van Den Dool's

(2013) findings that if attractive cycle infrastructure is found within the first or last 100 metres of a trip, then it is more likely someone will chose to make the trip by bicycle, as opposed to hopping in their car. Whilst it is important to provide transport provisions to connect the areas discussed above to the rest of the city, it is also important to consider the type of infrastructure provided, particularly in terms of encouraging more of the city's population to capitalise on the numerous benefits of utility cycling.
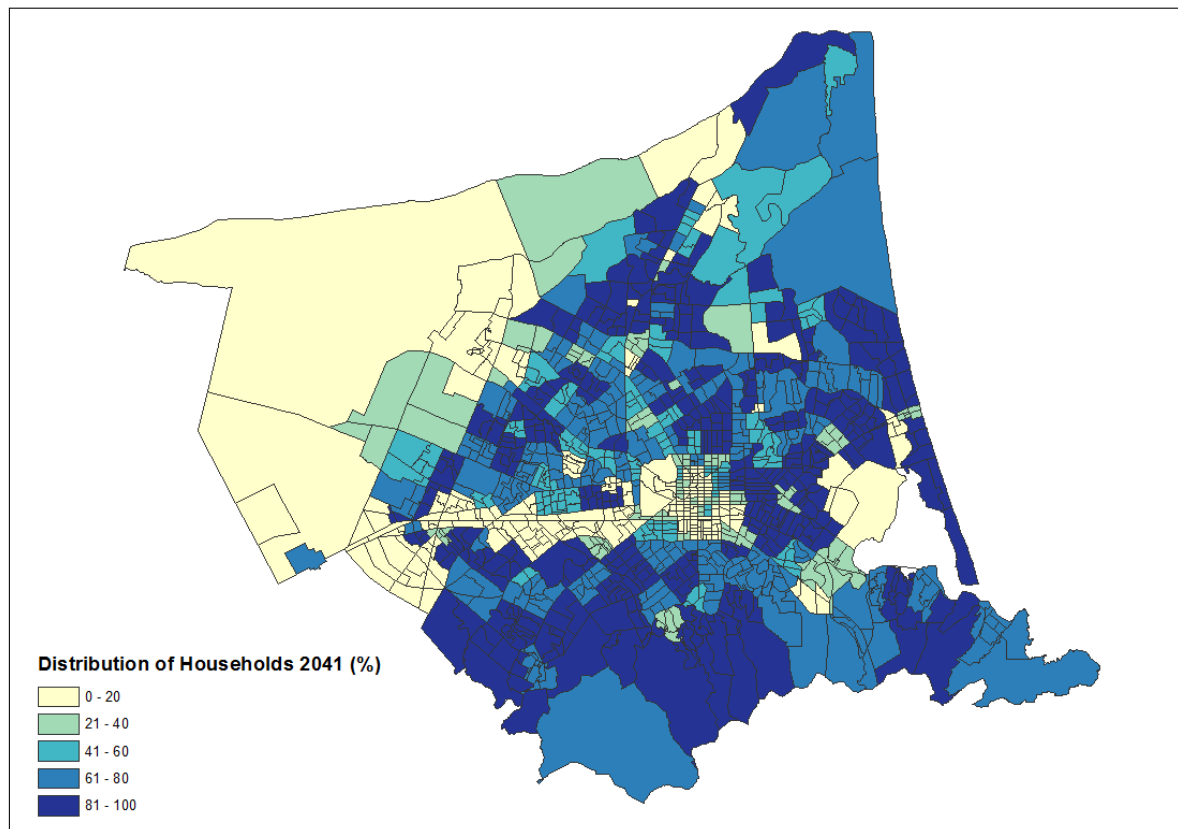
Figure 7.5.1: The expected distribution of residential households in 2041

Data Source: CCC RAPID 2041

Following the series of earthquakes, the business composition of the city has undergone significant change, with a substantial number of businesses moving out of the CBD into new key business hubs. Whilst the Rapid 2041 data does suggest that the CBD will recover and once again become a strong business hub, it also highlights that the new key business hubs are expected to remain significant business locations (dark blue in Figure 7.4.2). Although there are a number of smaller business hubs scattered throughout various parts of the city, areas such as Riccarton, Hornby, Yaldhurst, and Middleton are expected to have a large number of commuters travelling to and from them. Arguably these areas are already relatively well connected to the transport network; thus when assessing

future transport needs in these areas, the focus should be on providing more access for people using alternative modes of transport, including cyclists. As a substantial proportion of business activity is expected to return to the central city, it is going to be essential that there is an effective transport network connecting the wider city to CBD, with once again, some thought given to the type of infrastructure provided.
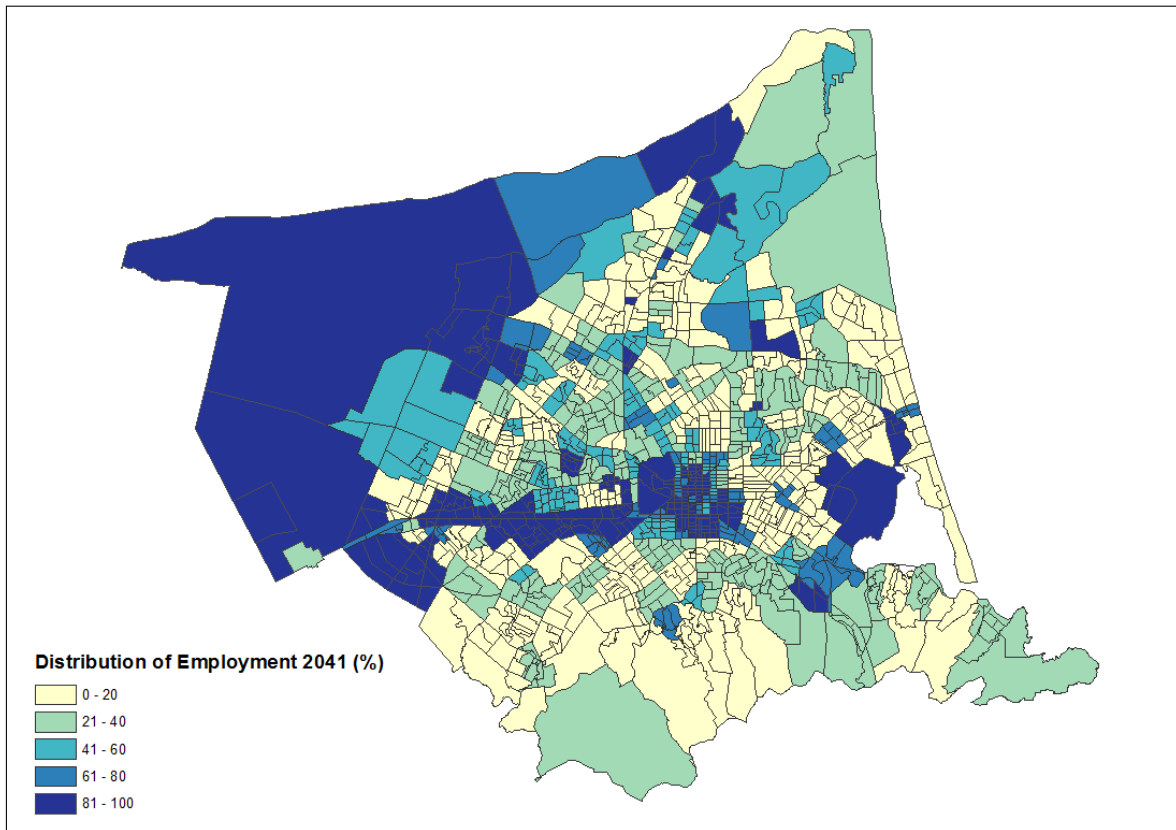
Figure 7.5.2: The expected distribution of key employment locations in 2041

Data Source: CCC RAPID 2041

7.6 High Demand Transit Zones

Chapter 2 discussed the importance of transport planning in improving a city's overall levels of liveability and sustainability, as well as reducing congestion. Whilst the results presented in section 7.4 addressed the significance of providing attractive infrastructure in the first and last 100 metres of a trip, the results to follow aim to deliver an indication of areas that can be expected to experience high travel demand in 2041 and beyond. Ensuring that the transport network is designed with the capacity to support high levels of demand in these areas will go a long way towards decreasing congestion and improving the city's overall level of liveability.

Following the network analysis process outlined in Chapter 6, a trip count was ascertained for each CAST zone, providing an indication of how many trips can be expected to pass through each zone, regardless of the mode of transport. Figure 7.5.1 illustrates that those areas with the highest number of potential trips passing through them are unsurprisingly mostly located in close proximity to significant arterial routes, as these often represent the most direct route between two points on a network. In saying this however, there are also a number of areas where there is expected to be a substantial number of trips passing through areas where there is minimal cycle infrastructure, a number of which are located on the western side of the city (Figure 7.5.2). There are also a number of areas with medium to high trip density and minimal cycle infrastructure (highlighted in red in Figure 7.6.1), arguably representing zones where accessibility could be easily improved through minor extensions to the current proposed major cycleways network. It is important to once again point out that a large number of the city's key growth areas are located on the western side of the city, as can be seen in rest of the results presented in this chapter. Improving access to cycle infrastructure between key residential growth and employment zones would not only help to expand the overall levels of accessibility throughout the city, but also contribute to the city centre and surrounding areas being more accessible to the key growth areas by alternative modes of transport; in consequence contributing to the overarching goal of making the city more liveable and sustainable.
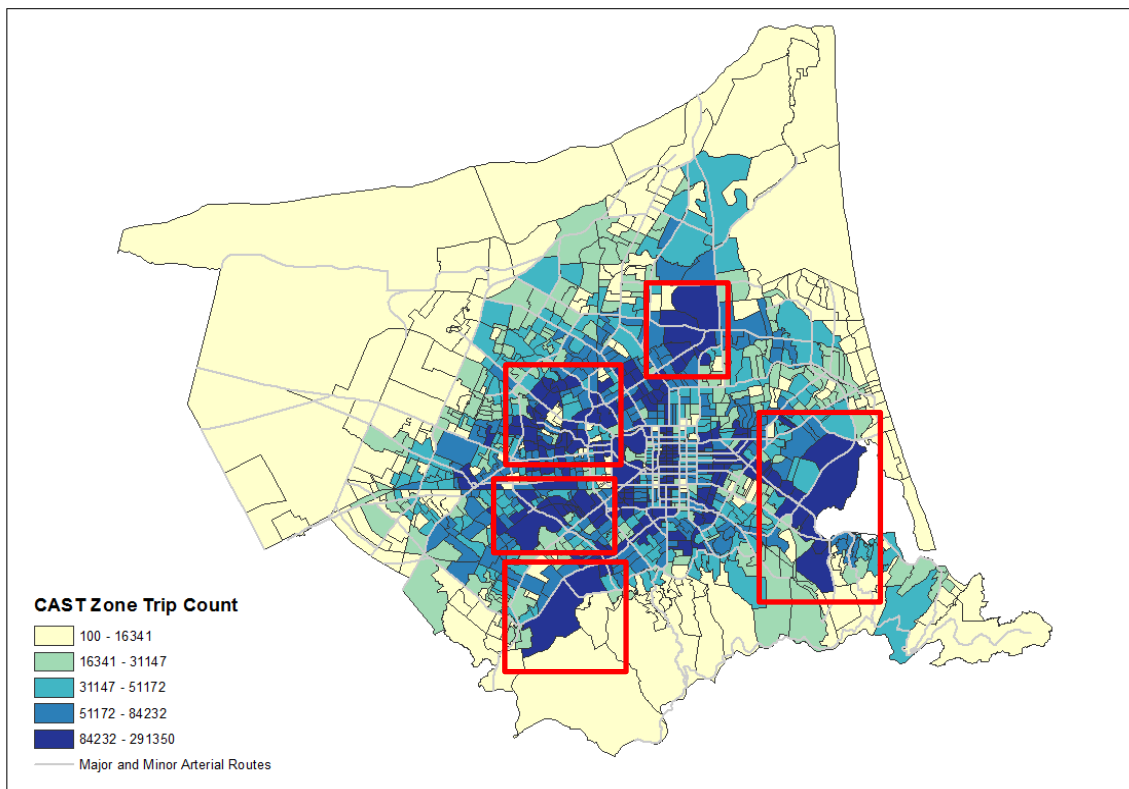

Figure 7.6.1: A summary of the number of trips expected to pass through each CAST zone with key high demand areas highlighted

8. The Major Cycleways Network

As research exploring key motivators and deterrents to utility cycling continues, it becomes increasingly obvious that two of the key factors associated with increased cycling uptake are accessibility of, and proximity to cycle infrastructure. The results presented examine just how well the proposed major cycleways network for Christchurch will fit the city in 2041. Over recent years, there have been suggestions that car use throughout New Zealand has started to decline. The average distance travelled per person in light passenger vehicles has decreased by approximately eight percent between 2008, when it reached its peak, and 2013 (Ministry of Transport, 2014b). Whilst in part this decline can likely be attributed to economic factors such as the cost of fuel, it is also indicative of a change in people's attitudes towards transport. If this shift away from the peak car culture is to continue, then it is essential that planning and network design being undertaken now accounts for both present and future transport needs.

It has been proposed that if people live or work within 500 metres of a cycleway or network then they have reasonable access to it, a distance that would take an average commuter cyclist approximately ninety seconds to two minutes to traverse with assumed cycle speeds of twenty and fifteen kilometres per hour respectively (Macbeth et al., 2007). Accordingly, cycle infrastructure has been regarded as accessible to all areas within 500 metres of it throughout this chapter.

8.1 How well will the proposed network service Christchurch City?

As noted above, if someone lives or works within 500 metres of cycle infrastructure, than it can be assumed that they have reasonable access to appropriate infrastructure. Given the importance of perceived safety as a key deterrent for many potential commuter cyclists, ensuring that a cyclist can both start and end their journey on attractive infrastructure is critical (van den Dool, 2013). Figure 8.1.1 highlights which areas throughout Christchurch will likely be well serviced by the proposed major cycleways network, along with those that is it reasonable to suggest will require some attention during the planning of any future infrastructure.

The zones in yellow represent the areas to which a good level of service is provided by the initial proposed network; encompassing forty percent of the cast zones. The zones that can be seen highlighted in green represent the areas which are partially serviced by the initial network; in most cases these are the CAST zones where part of the zone lies within 500 metres of the proposed cycle network. Due to the partial level of service already provided, it could be contended that focusing on

future infrastructure in these zones would be a positive step towards improving the level of service the cycle network provides to the city. However, taking into account that both the yellow and green areas are already provided with a reasonable level of service by the proposed network (Figure 8.1.1), when planning for new cycle infrastructure throughout the city delivering facilities to those areas in blue should be a priority. As discussed in Chapter 7, many of the city's key growth areas are located in areas on the outer fringe of the city limits; therefore improving access to appropriate transport infrastructure in these areas is going to be essential to not only connect these areas to the rest of the city, but also ensure development in Christchurch is sustainable and results in a highly liveable city. It is clear that the proposed network will effectively service both the central city and the central city fringe; however due to a substantial number of the key growth areas being located on the city peripheral, providing links from these areas would represent a significant step towards encouraging more of the city's population to utilise utilitarian cycling, both now and in the future. It is likely that the people living in peripheral areas will be required to travel further to get to workplace destinations; thus it is going to be important to provide access to safe, attractive alternatives if they are expected to reconsider the way in which they are travelling, and make the change from private motor vehicle to a more sustainable mode of transport. This will be discussed further in the chapters to follow.
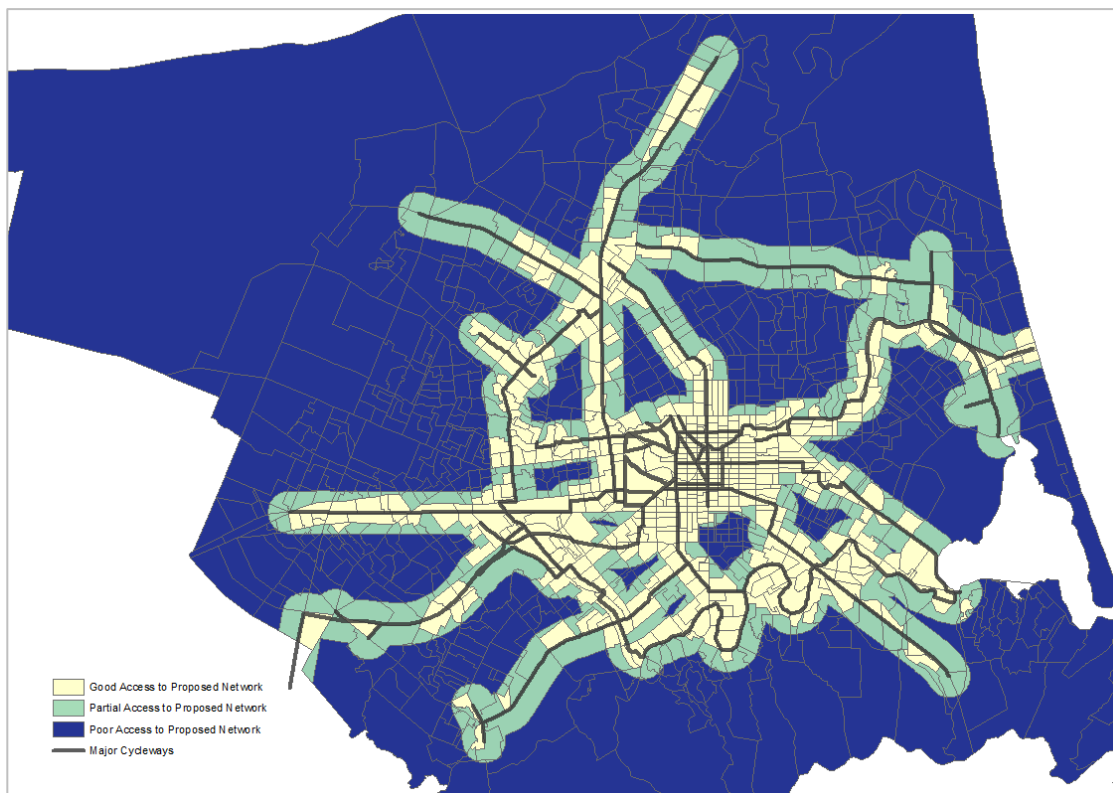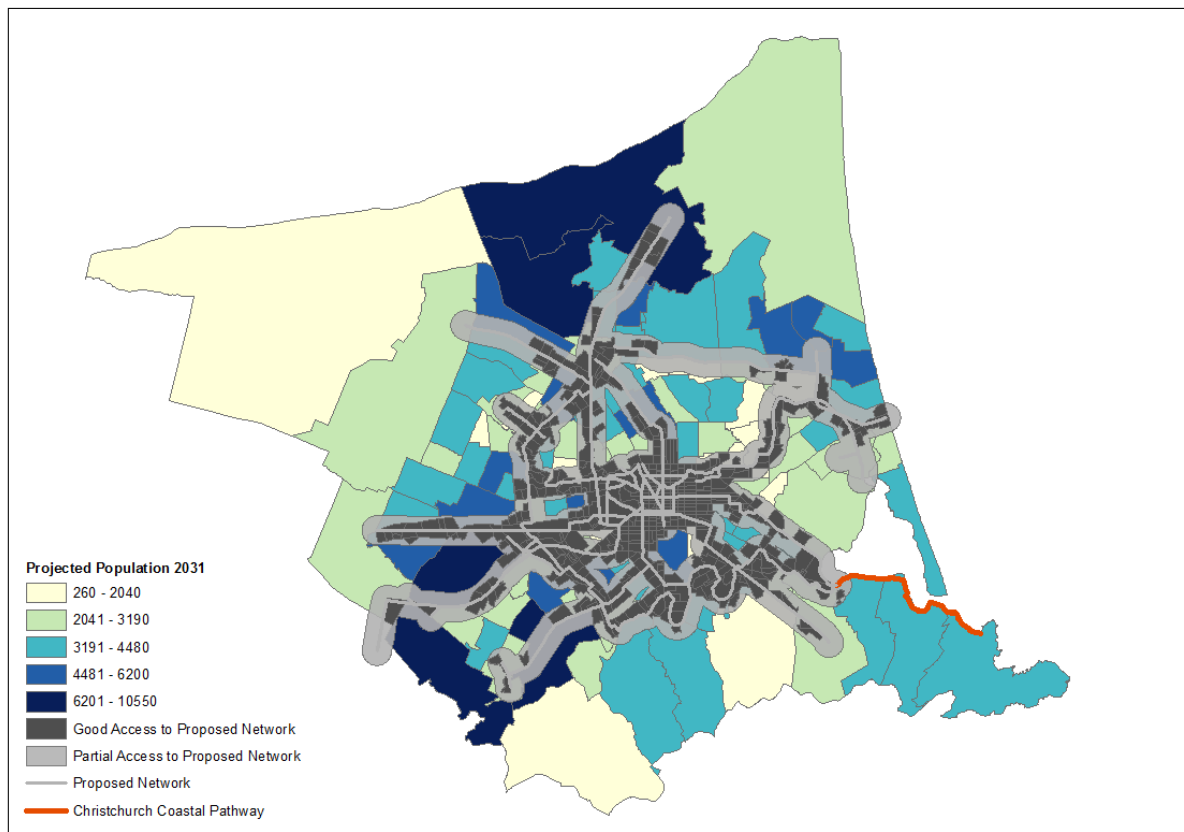

Figure 8.1.1: An indication of how well the proposed major cycleways network services Christchurch City based on the 500 metre reasonable access assumption

Accessibility has been discussed heavily in the results both is this chapter, and throughout the rest of this study as it plays a large role in how people choose to travel. Chapter 2 deliberated the importance of the relationship between land use and travel behaviour, acknowledging that whilst there has been some debate around the exact affiliation, there is undoubtedly an influential relationship between the two. Saelens, Sallis and Frank (2003) identify that researchers have long known that neighbourhood design and development play a role in how people chose to travel, with two major factors contributing to whether people choose to travel by motorized or non-motorized modes – proximity to infrastructure and directness. The impact density has on proximity and directness has long been an issue, with it recognised that density plays a large role in the distances between destinations (van Wee, 2011). The projections discussed in Chapter 7 highlight that whilst Christchurch's population is expected to grow over the years to come, significant population growth areas are expected to be areas on the city's peripheries. With this in mind, it is clear that ensuring the major cycleways meet proximity and directness requirements, along with providing a reasonable level of accessibility is going to be essential in encouraging a change in the way people in Christchurch are choosing to travel. Providing cycle infrastructure in the green and blue areas in Figure 8.1.1 would certainly improve the accessibility of the proposed cycle network, and as a result likely encourage people to reconsider their travel choices due to improved accessibility to alternative modes of transport.

8.2 Residential Service Areas

As discussed in Chapter 7, the city is expected to continue experiencing a high level of both change and growth between now and 2041. Consequently, it is critical that cycling infrastructure implemented now will still service key demand areas in 2041. Figure 8.2.1 emphasises that whilst the initial 13 cycle routes provide a reasonable level of service to most of the city's central areas, there are some key residential growth areas on the outskirts of the city that are either only partially serviced by the initial 13 routes, or not serviced at all. Though both Halswell and Belfast are expected to undergo a significant amount of growth, there currently is not enough cycle infrastructure planned to service these areas to an adequate level; this is particularly an issue in Belfast and Parklands. Although some minor extensions of the proposed network would be required to improve accessibility in Halswell, there is currently very little infrastructure planned to service the Belfast area.

Although Figure 8.2.1 seems to indicate that there is a large area to the south east of the city that does not have reasonable access to appropriate infrastructure, it is important to note that the Christchurch Coastal Pathway[5] is expected to extend into this area, providing suitable facilities for utility cycling.

Figure 8.2.1: An indication of how well the proposed major cycleways network is likely to service Christchurch in 2031, analysed using the Statistics New Zealand Population Projections

Similarly, Figure 8.2.2 also provides an indication of areas that are expected to be highly populated in 2041, but do not fall within the current proposed networks 500 metre buffer zone. As Figure 8.2.2 looks very different to Figure 8.2.1, it is important to once again point out that this is because the rapid data measures the number of households that will be in the areas, whereas the statistics New Zealand projections used in Figure 8.2.1 are based on the usually resident population. The missing connections to the Halswell area are again highlighted here; although there is expected to be a relatively large number of households located in Halswell, in most cases the 500 metre reasonable access requirement is not being met with a large proportion of the area having limited access to the major cycleways network.

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[5] The Christchurch Coastal Pathway will be a 6.5km pathway stretching along the coastline from the Ferrymead Bridge to Scarborough Bridge in Sumner, connecting with the major cycleways network at the Ferrymead Bridge.
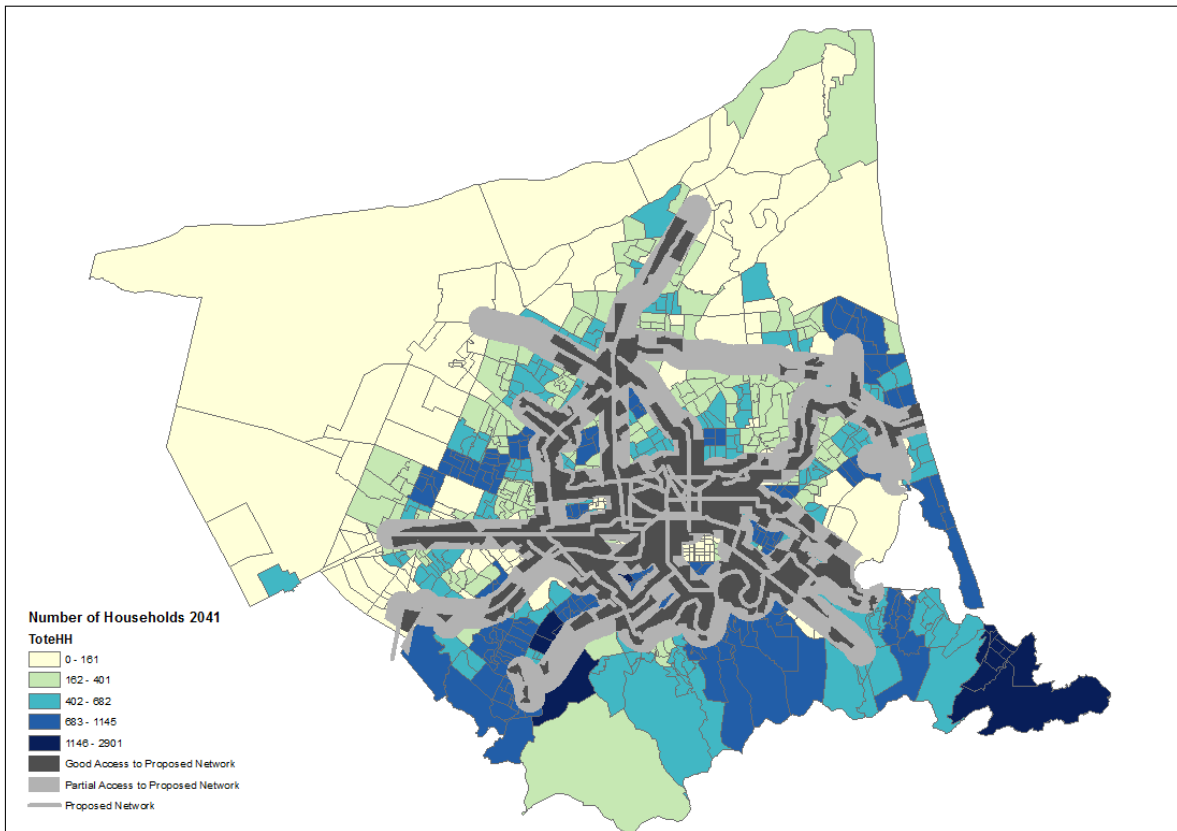
Figure 8.2.2: An indication of how well the proposed major cycleways network is likely to service Christchurch in 2041, analysed using the CCC RAPID 2041 projections

8.3 Proximity to Employment

When considering the best location for cycle infrastructure to further encourage utility cycling, it is important to not only consider the proximity of the network to likely origins, but also destinations. As noted previously it has been suggested that the first and last 100 metres of a trip are the most important; if there is attractive cycle infrastructure at the beginning or end of a trip, additional uptake of utility cycling can likely be expected (van den Dool, 2013). When exploring the level of service provided by the proposed major cycle network to employment zones in 2041, it appears that areas expected to have high levels of employment are relatively well serviced, with only a few clear exceptions. Perhaps the most predominant of these are the Yaldhurst and Russley zones in the city's North West, which can be seen in dark blue in Figure 10.2.1. As a result of the earthquakes, there was significant movement of business from the central city to the city's outer suburbs; whilst the CBD is expected to recover and once again become one of the city's main business and employment hubs, it is also likely that many employers will chose to remain in the many new business hubs (as discussed in Chapter 8), such as those in Yaldhurst and Russley. Figure 10.2.1 highlights how little

infrastructure is planned to service these areas of the city; in order to encourage the use of utility cycling in these areas, the implementation of some cycling infrastructure should be considered.
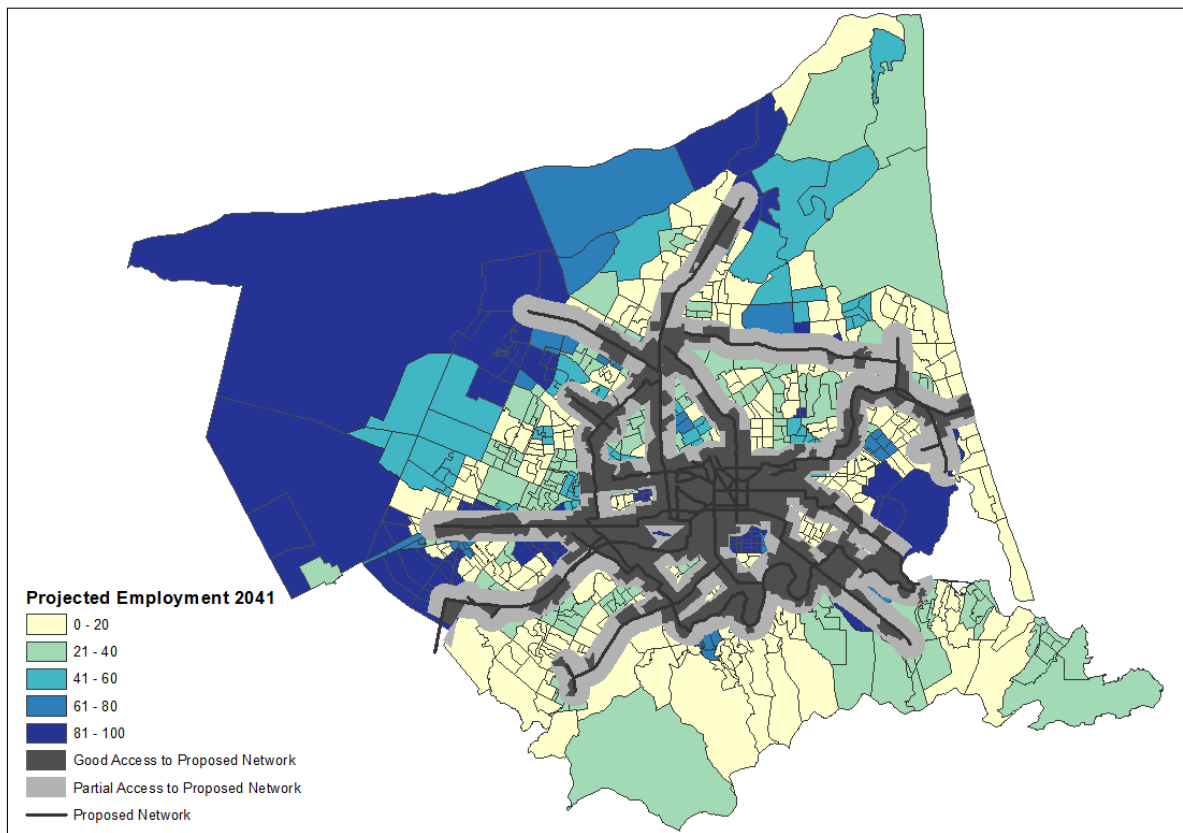
Figure 8.3.1: An indication of how well the proposed major cycleways network is likely to service key employment destinations in Christchurch in 2041, analysed using the CCC RAPID 2041 projections

8.4 Proximity to where People are likely to be Travelling

As discussed widely throughout this chapter, in order to encourage more people to cycle, providing appropriate infrastructure along the routes in which they would normally travel is essential. If people deem cycling infrastructure as accessible and attractive, they are more likely to reconsider their transport habits. However, in order to encourage this behavioural change, it is critical that cycling infrastructure is accessible. It is important to note however that dedicated cycle infrastructure is certainly more important on major and minor arterial routes with significant VPD counts, as opposed to quiet streets with low traffic volumes. Figure 8.3.2 provides an indication of how well the initial major cycle network will service the city for expected travel demand in 2041. The derived trips results presented in Chapter 7 highlight a number of areas throughout the city that are expected to be key transit zones for utility trips in 2041. As can be seen in Figure 8.4.1, zones with

high trip counts are not at all dissimilar to zones that are expected to have high levels of residential and employment activity in 2031 and 2041 (Chapter 7). This trend is particularly obvious in and around the CBD, along with other key employment zones such as Riccarton, Middleton and Hornby in the western area of the city and just to the west and south west of the central city.
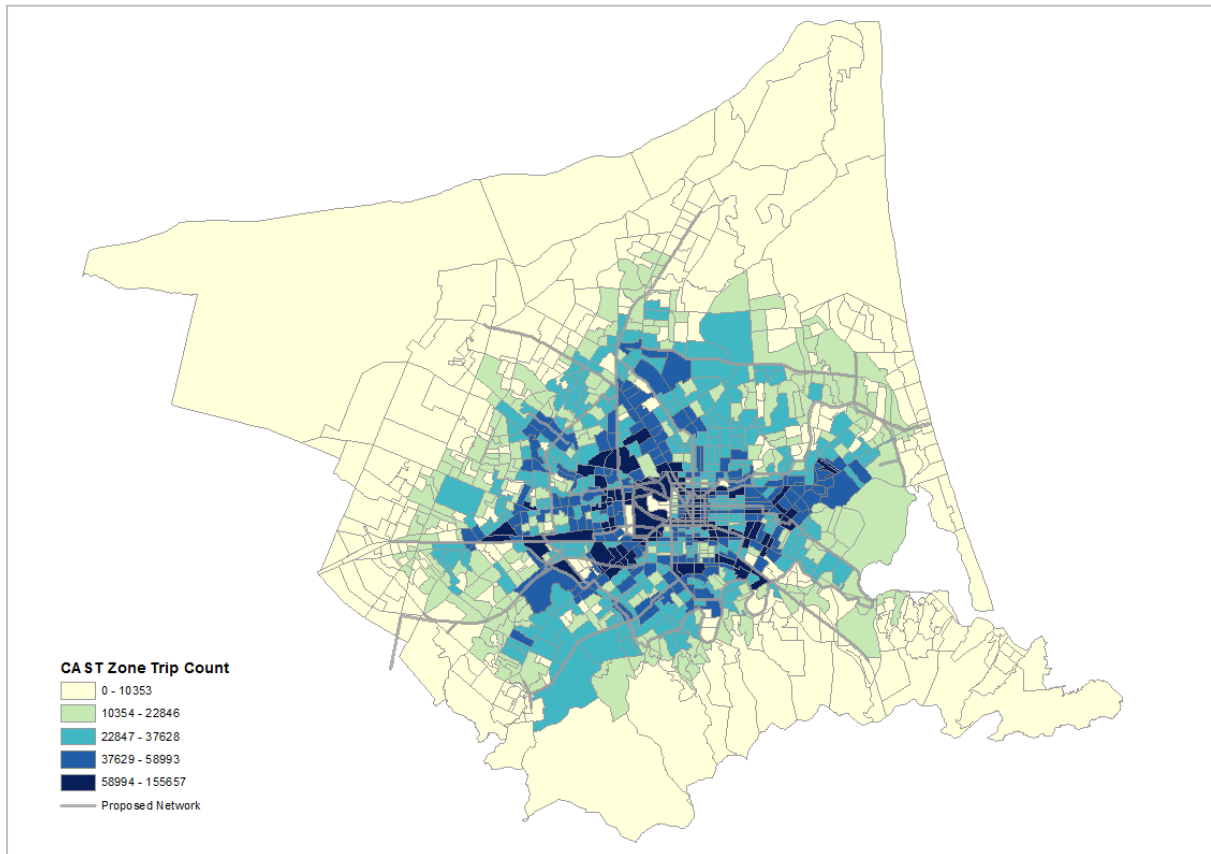
Figure 8.4.1: The number of trips expected to pass through each CAST zone. Trips were derived based on 2041 household and employment distribution

When the 500 metre reasonable service area was applied to the derived trips results, it was clear that a number of the transit key demand areas would already be provided with a reasonable level of service by the initial 13 route network. Key high demand areas that are not provided with an adequate level of service are highlighted in Figure 8.4.2. The most predominant of these can be seen on the north western side of the city, and includes areas such as Merivale, Bryndwr, Holmwood and Deans Bush. Although these areas in particular are not expected to be high demand origin and destination zones, it is clear that they are expected to experience a significant number of trips passing through them. Though not as substantial, a number of smaller gaps can also be seen around the southern and south western edges of the central city, including areas such as Sydenham, Riccarton, Waltham, and Phillipstown. Many of these are already busy transit areas, and the derived trip results suggest that this trend is not likely to change in the years to come. Consequently,

implementing infrastructure in these areas would be a good step towards encouraging those commuting through these areas to reconsider their travel decisions.
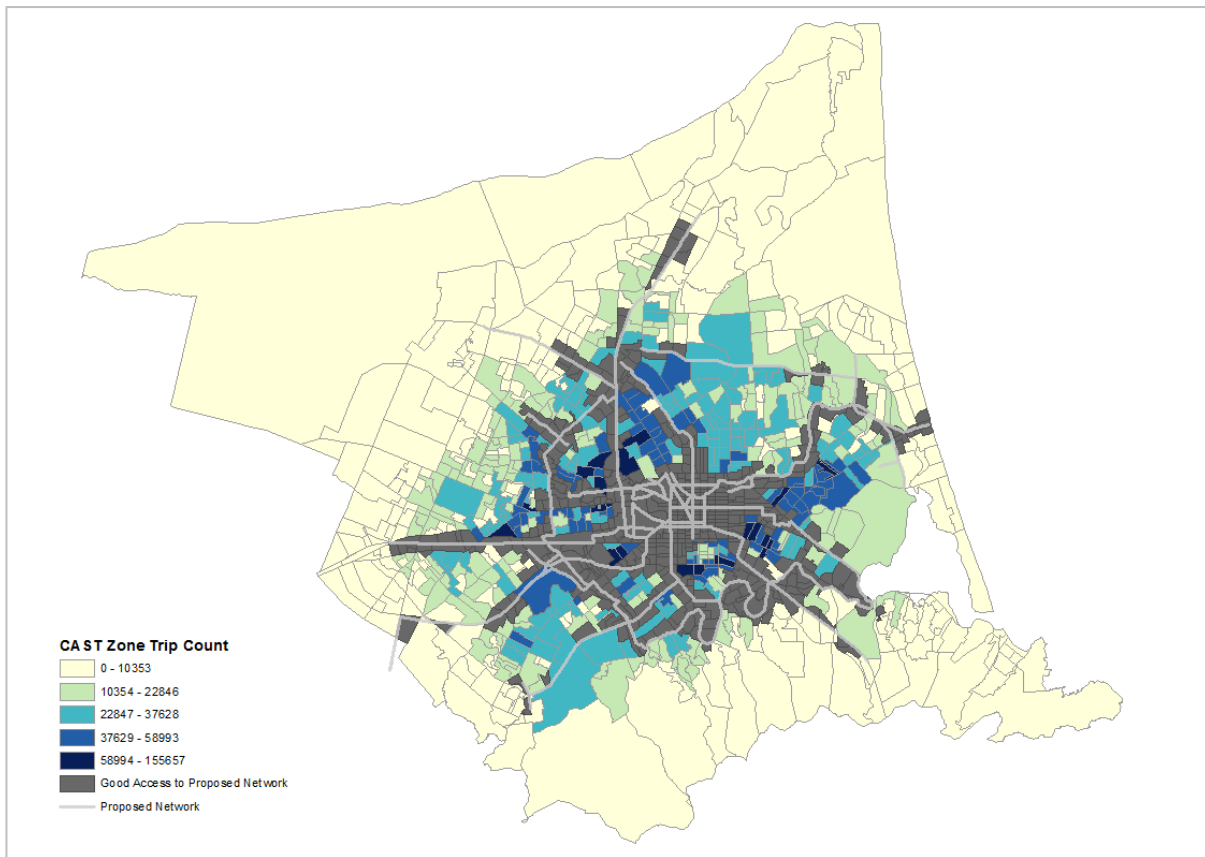

Figure 8.4.2: The number of trips expected to pass through each CAST zone, with an indication of zones already provided with a reasonable level of service. Trips were derived based on 2041 household and employment distribution

9. Cycling Safety

It has been highlighted throughout both the literature, as well as throughout this study, that cyclist perceived safety is one of the key deterrents for potential cyclists making the decision to take up utilitarian cycling. In order to encourage more everyday people to capitalise on the many benefits utilitarian cycling can provide, it is important to provide what is perceived as a safe and attractive cycling environment (Geller, 2006; Parkin & Koorey, 2012). As discussed in Chapter 2, the majority of all potential cyclists fall into the category of "interested but concerned" (Geller, 2006), thus in order for these potential cyclists to see cycling as being perceivably more attractive, the appropriate cycling infrastructure becomes critically important.

The results to follow provide a summary of further network analysis, again deriving trips, however this time with a key focus on cyclist safety. As discussed in Chapter 6, the Abley Route Choice Metric scaling factors were applied to the road network to deliver a weighted network that could be used for determining cyclist safety during analysis. Consequently, the following results highlight areas that are likely to have high levels of cyclist demand, whilst also identifying key areas that saw a large reduction of trips passing through them when safety was factored into analysis.

9.1 Expected High Demand Zones for Safe Cycling

Figure 9.1.1 provides an indication of the cast zones that saw the most trips pass through them when trips were derived with a focus on cyclist's perceived safety. As can be seen below, the areas with the largest number of trips passing through them are very different to those highlighted in Chapter 8.4.

 As the road network was weighted based on cyclist safety, not surprisingly the zones with the largest number of trips passing through them are largely located both in and around the central city and the city's inner suburbs where there is a large amount of cycle infrastructure planned. Areas such as Hagley Park, the central city, Riccarton, Middleton and Addington experienced high volumes of trips passing through them. It is particularly important to note that many of these trips are located in areas where there is already major cycleway infrastructure planned; consequently two significant conclusions can be drawn. Firstly, with a few exceptions, it is relatively safe to assume that the proposed major cycleways network services areas that are going to be key cyclist demand areas (Figure 9.1.1). This will make cycling a more attractive transport option, particularly for those

who fall into the interested but concerned category. And secondly, as discussed above, when planning for future cycling infrastructure and expansions of the key cycleways network, it is imperative that key growth areas that lie further from the city centre, such as Halswell and Belfast, are considered. Figure 9.1.1 again draws attention to these areas, this time providing an indication that unless a cyclist's perceived safety improves in these areas, there is unlikely to be a notable increase in the amount of people travelling to, from and through these areas by bicycle.
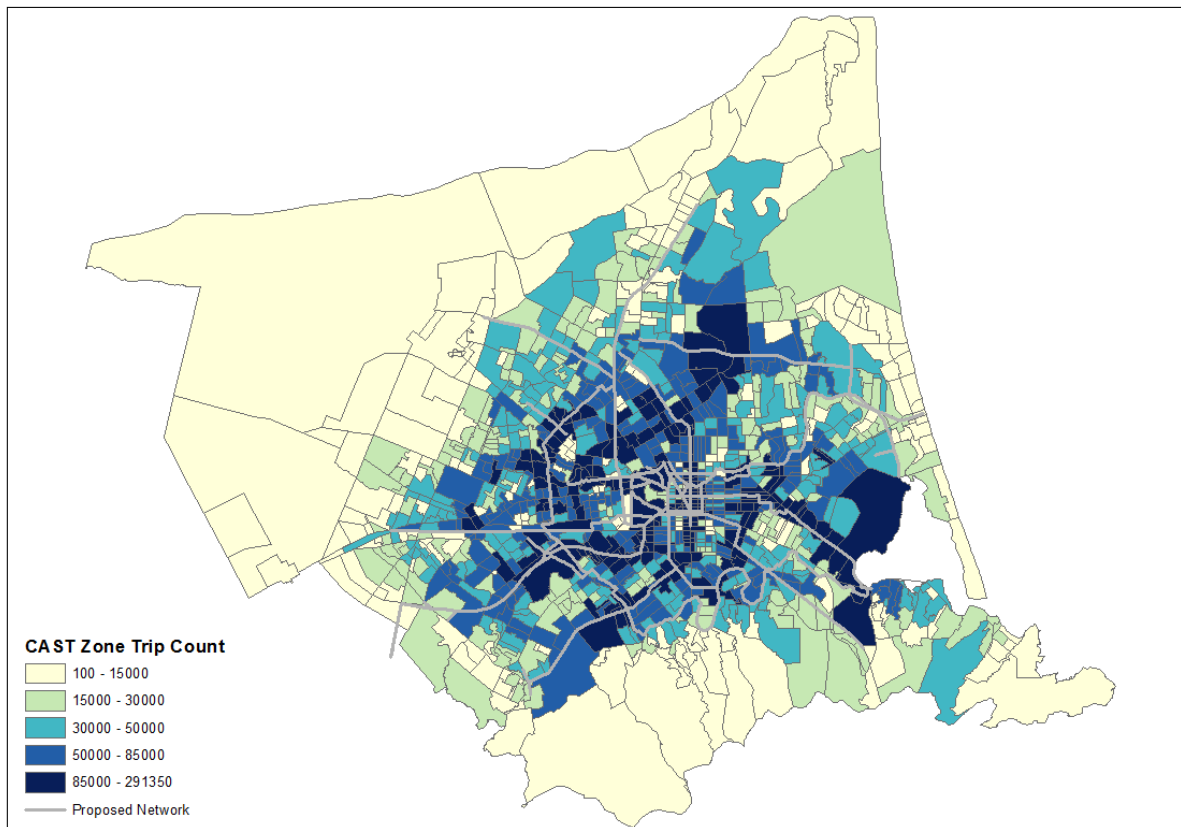
Figure 9.1.1: The number of trips expected to pass through each CAST zone when the road network was weighted to take into account cyclists' perceived safety. Trips were derived based on 2041 household and employment distribution

9.2 Key Zones for Improving Cyclist Safety

In order to identify areas in which cyclists are likely to feel safe throughout the city, and areas where they will not, Figure 9.2.1 below distinguishes zones which experienced a decrease in the number of trips passing through them when analysis was focused on cyclist safety using the ARCM scaling factors (as explained in Chapters 5.4 and 6.7). Of the 1265 CAST Zones, 200 (16%) of the zones experienced a decrease in the number of trips passing through them. As the focus was safety, it can be assumed that the zones that saw significant reductions in the number of trips passing through them likely contain infrastructure that is not safe or attractive for cyclists. Whilst a number of the

zones highlighted are bordered by planned cycle infrastructure, it is likely these areas also contain some of the city's major and minor arterial roads which often have vehicle volumes that make them an undesirable route for a cyclist.

As discussed above, for zones within 500 metres of cycle infrastructure, it can be expected that there is an alternative route for a cyclist that is both accessible, and would make the journey perceivably safer, thus making cycling a more viable option than it would otherwise be. However, for those zones not within 500 metres of any cycle infrastructure, it is important that they become focus areas during the planning of any future infrastructure, whether it is extensions of the current proposed routes, or new cycle routes throughout the city. Once again, it is also important that infrastructure services zones where a substantial number of trips will begin and end (van den Dool, 2013).
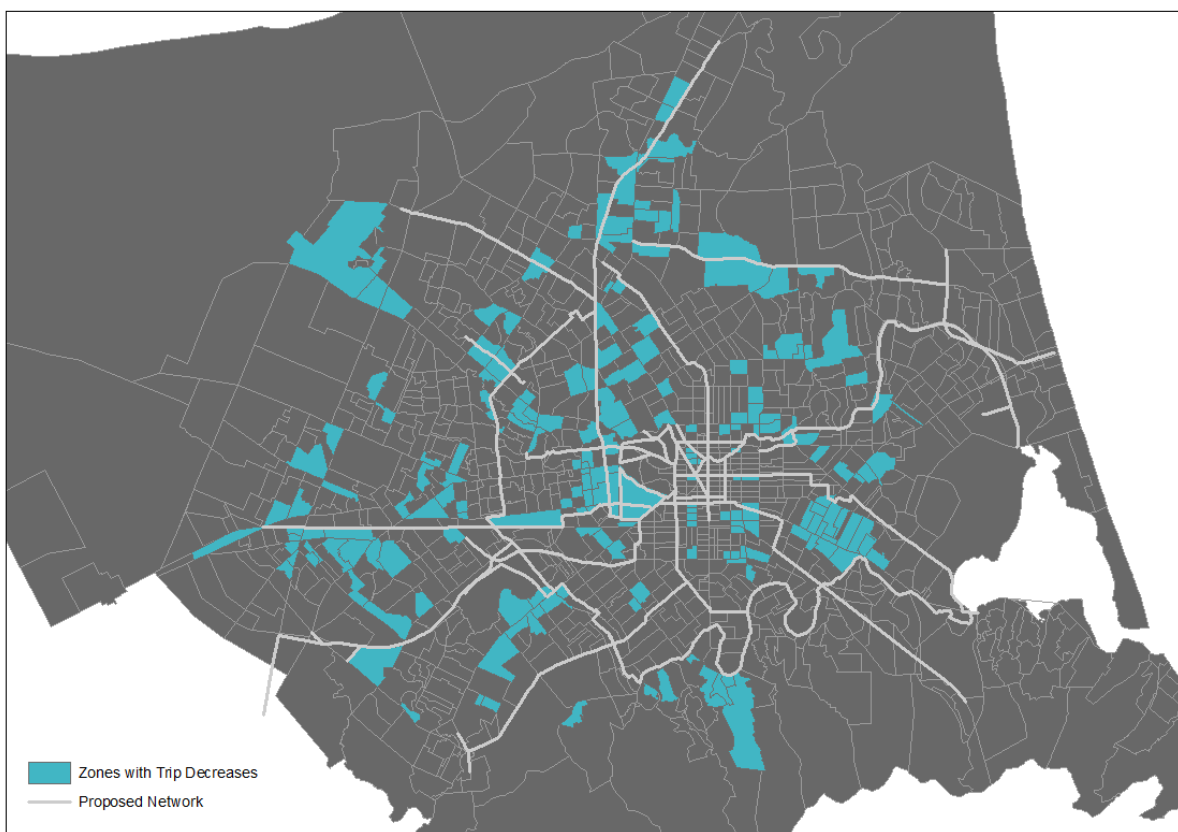
Figure 9.2.1: CAST zones where there was a trip decrease when analysis was weighted based on a cyclists perceived safety and cyclist preference

Figures 9.2.2 and 9.2.3 provide an indication of which zones experienced the largest decrease in the number of trips passing through them. When studying the raw numbers, it appears that Hagley Park experienced the largest decrease in trips; however it is import to note that due to the park having a

number of off road cycle tracks, it can be concluded that the park would provide facilities that are highly desirable to potential cyclist who are concerned about their safety and they are not exposed to other traffic as they would be on an on-road cycleway.

Consequently, when examining Figure 9.2.2, the key zones of concern are those highlighted in blue, excluding Hagley Park, but particularly those that are not within 500 metres of a proposed cycle facility. Figure 9.2.3 examines which areas experienced the largest decrease in cyclist numbers when analysis was completed with a focus on cyclist safety, however this time results are presented as a percentage decrease. As with Figure 9.2.2, those zones that can be seen highlighted in dark blue are particularly important, as they have seen the largest decreases in potential cyclist numbers. It is however important to point out that a number of these zones are located close to major or minor arterial routes with large VPD counts, making them an undesirable route for those cyclists who fall into the interested but concerned category.
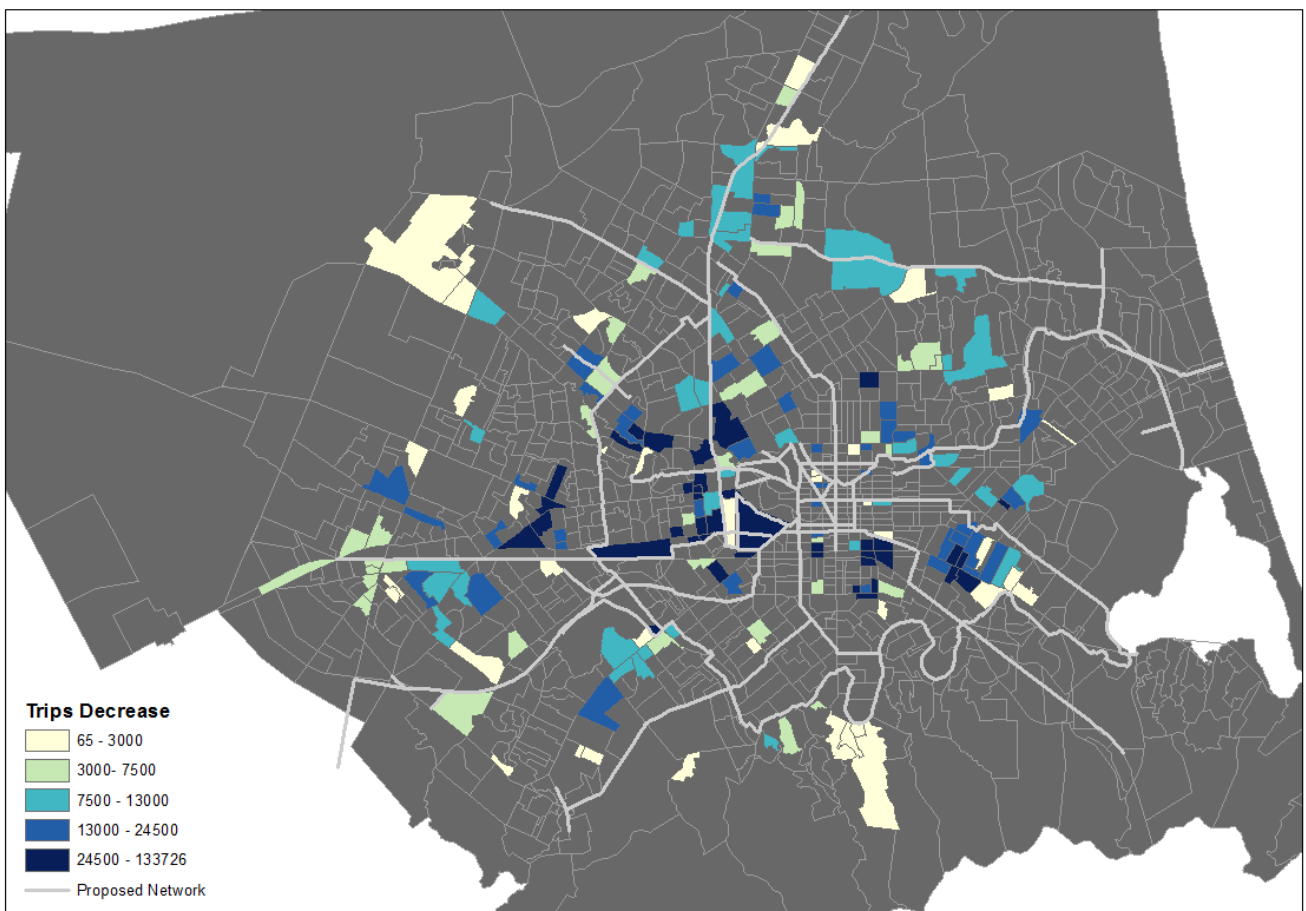

Figure 9.2.2: The number by which the trip count decreased in CAST zones that had less trips pass through them when cyclist safety was factored into analysis
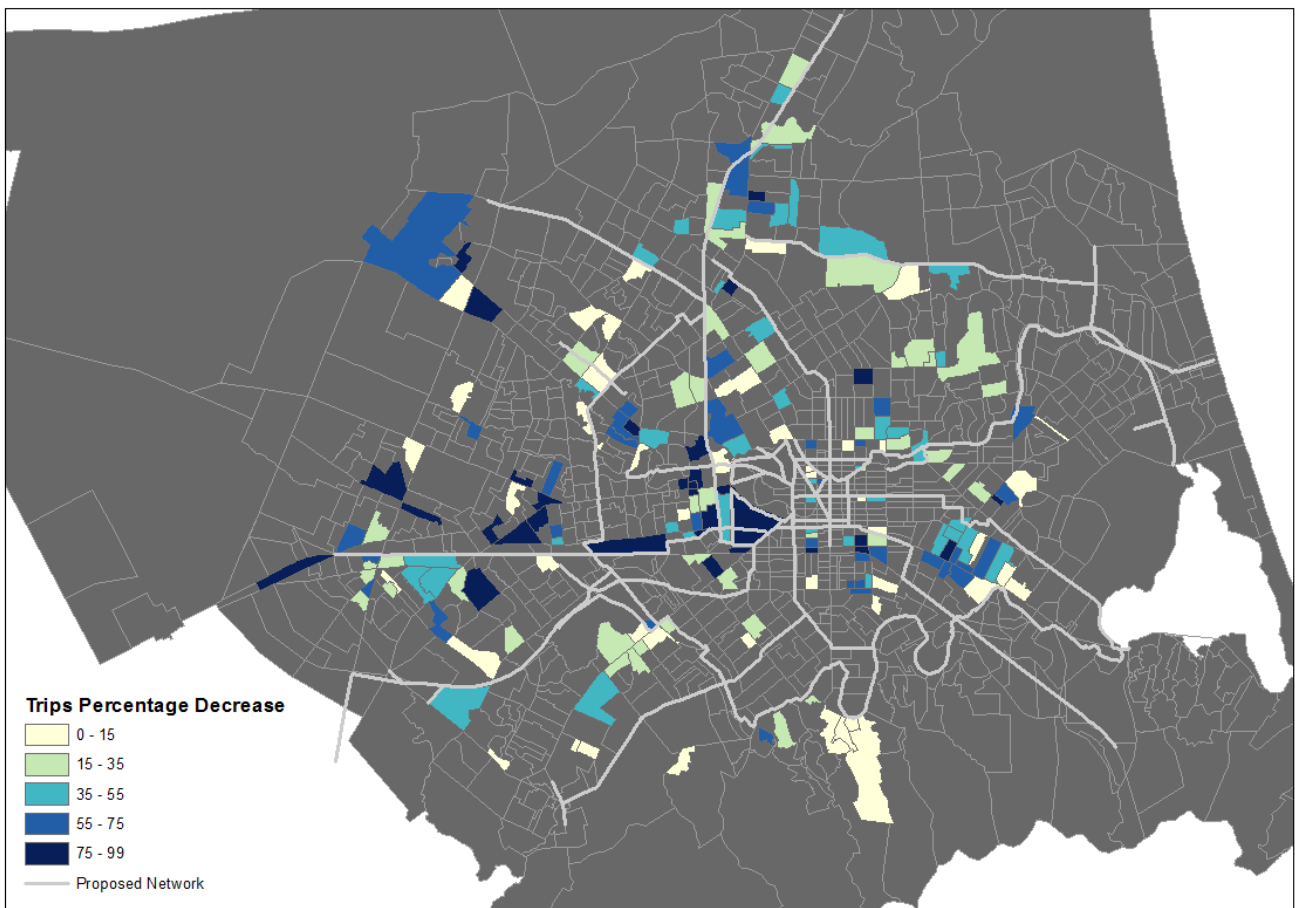
Figure 9.2.3: The percent by which the trip count decreased in CAST zones that had less trips pass through them when cyclist safety was factored into analysis.

In order to further ascertain areas throughout the city where improvements could be made to improve cyclist safety, the results presented in figures 9.2.2 and 9.2.3 can also be found in Table 9.2.1 below. Here a brief overview of the decrease in cyclist numbers in various areas of the city is provided. It can be assumed that if an area has experienced a large reduction in the number of potential cycle trips passing through it when cyclist safety has been prioritised, then improvements will be required to make the area both more cycle friendly, and more attractive to cyclists.

The table below identifies those areas that contain zones that experienced a decrease of eighty percent or more when cyclist safety was factored into analysis. Whilst realistically, the decreases may not be as substantial as in the results below, it is likely the results presented do give a relatively accurate depiction of the zones where a trip decrease would be expected if a cyclist was factoring safety into their route choice. Examining which areas had the most prevalent decreases in cyclist numbers, it is clear that improvements need to be made in Riccarton. Of the zone with decreases of eighty percent or more Riccarton features seven times, demonstrating that cyclist perceived safety is a significant issue in the area, particularly for those cyclists who are in the interested but concerned

category (Geller, 2006). It is likely that this can be attributed to a large number of busy major and minor arterial routes located within Riccarton (Figure 9.2.4). Riccarton Road represents a significant arterial route for the city, connecting not only private motor vehicles to the city's western suburbs, but is also the busiest bus route in Christchurch (Christchurch City Council, 2015). Consequently, due to large traffic volumes and substantial VPD counts, Riccarton Road does not characterise an attractive or safe cycling environment.

Table 9.2.1: A summary of which CAST zones saw the most substantial decreases in the number of trips passing through them when network analysis was weighted based on cyclists perceived safety

Area Unit	Trip Count: Shortest Route	Trip Count: Safest Route	Trip Count Decrease	Percentage Decrease
Russley	8722	100	8622	99
Riccarton	64983	1315	63668	98
Riccarton South	84648	2451	82197	97
Yaldhurst	3037	100	2937	97
Riccarton South	84158	2469	81689	97
Islington	6898	176	6722	97
Redwood North	20406	820	19586	96
Hornby North	17048	1317	15731	92
Riccarton	69072	6047	63025	91
Ilam	25591	2469	23122	90
Mona Vale	64396	7905	56491	88
Middleton	70445	8913	61532	87
Mona Vale	65088	8775	56313	87
Broomfield	18103	2600	15503	86
Hagley Park	155657	21931	133726	86
Wigram	18079	2580	15499	86
Linwood East	38403	5892	32511	85
Holmwood	54180	8242	45938	85
Fendalton	36812	5684	31128	85
Waltham	61404	10121	51283	84
Sockburn	60612	9529	51083	84
Sockburn	52127	8088	44039	84
Riccarton	38539	6138	32401	84
Riccarton South	70493	11460	59033	84
Cathedral Square	61797	10463	51334	83
Mona Vale	82300	13871	68429	83
Sockburn	29161	5385	23776	82
Northcote	17409	3051	14358	82
Sydenham	34288	6764	27524	80
Phillipstown	67462	13232	54230	80

Areas such as Sockburn, Sydenham, Hornby and Mona Vale also suffered large decreases in the number of derived trips passing through zones within them. Again, it is not unreasonable to conclude that this can largely be attributed to the presence of significant arterial routes (Figure 9.2.4), particularly in Sockburn and Hornby where there is also likely to be a substantial number of heavy vehicles on the roads due to a large volume of industrial activity. It is however important to note that often major arterial routes represent the most direct route between an origin and destination due to their locality to key activity centres. Whilst potential cyclists, particularly those who fit into Geller's interested but concerned category are going to be looking for the safest route, in most cases, it is likely they will also be looking for the most direct route. Subsequently, providing infrastructure that will meet both safety and directness requirements is going to be invaluable in encouraging further uptake of utility cycling.
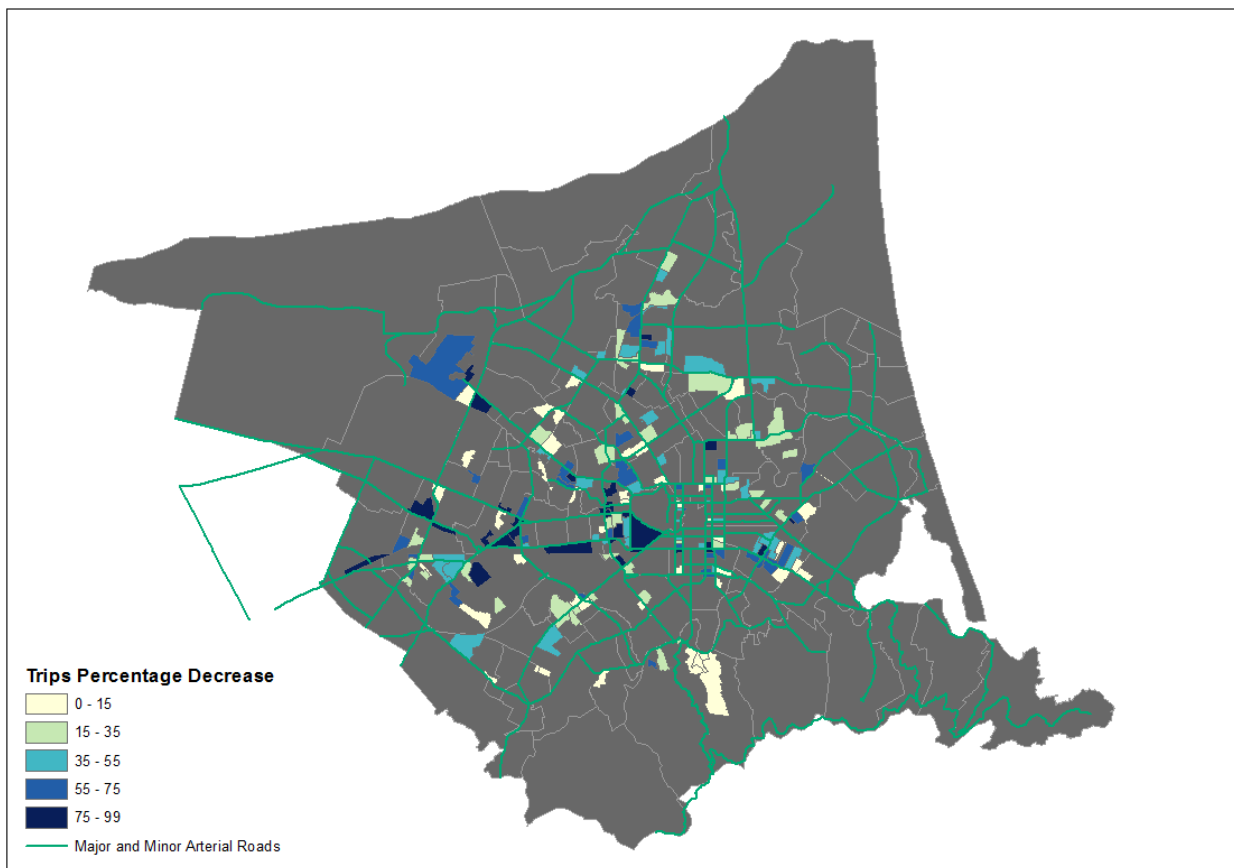

Figure 9.2.4: Proximity of major and minor arterial routes to CAST zones that experienced a decrease in the number of trips passing through them when analysis was weighted based on cyclists perceived safety

Whilst providing infrastructure to areas that are not deemed perceivably safe is going to be critical in further encouraging utility cycling, it is also important that infrastructure will service areas where there is a substantial amount of transit demand. The importance of proximity has been widely discussed throughout this research, as it plays a major role in the decisions people make about their chosen mode of transport. Cycling in New Zealand is undoubtedly a minority form of transport, with a mere 2.5 percent of trips made by bicycle (Smith, Wilson, & Armstrong, 2011).

9.3 Areas for Improvement

Taking into account the results presented in Chapters 7 and 8, a number of places where infrastructure could be added to the proposed network or areas where the network could be improved were identified. As network cohesion has been identified as a major player in encouraging more people to take up utilitarian cycling, the suggestions below are largely focused on areas where it would be relatively easy to add extensions to the current proposed network that would make the network not only more cohesive, but also more accessible and direct.

It has been identified that often addressing small gaps, or adding small amounts of infrastructure to an existing, or planned network can make a significant difference in improving network accessibility (Lehman, 2013). As discussed extensively throughout this research network accessibility, directness and cohesion are essential in providing an attractive cycling environment that is likely to encourage new cyclists to take up utility cycling (CROW, 2007; Land Transport Safety Authority, 2005; Parkin & Koorey, 2012). A study undertaken by Lehman (2013) found that providing infrastructure in what may seem like the most inconsequential gap can have positive repercussions for the wider network in terms of greatly improving network accessibility, directness and cohesion. Figure 9.3.1 highlights that through filling a small 150 metre gap, as marked in yellow, Lehman found that an extra 3 kilometres of road access was unlocked, consequently making the network accessible to a further 184 properties (Lehman, 2013). It is likely that providing infrastructure in small gaps such as these in the major cycleways network could have similar results, particularly in terms of improving accessibility to the network. As highlighted numerous times already, if a potential cyclist has reasonable access to cycle infrastructure (within 500 metres of where they live, work, or travel (Macbeth et al., 2007)) then they are much more likely to perceive utility cycling as a viable mode of travel.

Figure 9.3.1: An example of the difference filling a minor gap can have on network connectivity and accessibility

Source: Lehman, 2013

Despite a global shift towards the increased use of more active modes of transport, there is still much resistance towards to concept of utility cycling in New Zealand. The most recent quality of life survey[6] found that of those surveyed (n = 5290), only five percent considered cycling as their main form of transport (Figure 9.3.2), while only eight percent of respondents considered cycling to be a safe form of transport (Figure 9.3.3) (The Big Cities Project, 2014). There are many relationships between the built and social environments that have been attributed to this resistance; however the most predominant of these remains that between the built environment and cyclist perceived safety.

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[6] The quality of life project is a joint initiative between Auckland, Wellington, Christchurch and Dunedin City Councils initiated in 1999 in response to growing pressure on urban communities, concern about the impacts of urbanisations and the effects of it's wellbeing on city's residents.
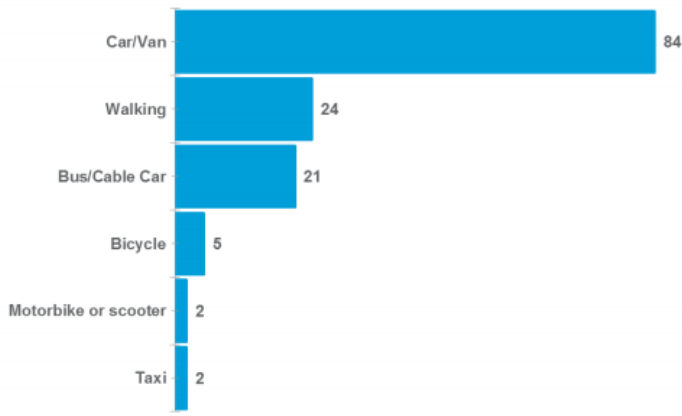
Figure 9.3.2: Respondents reported main mode of transport
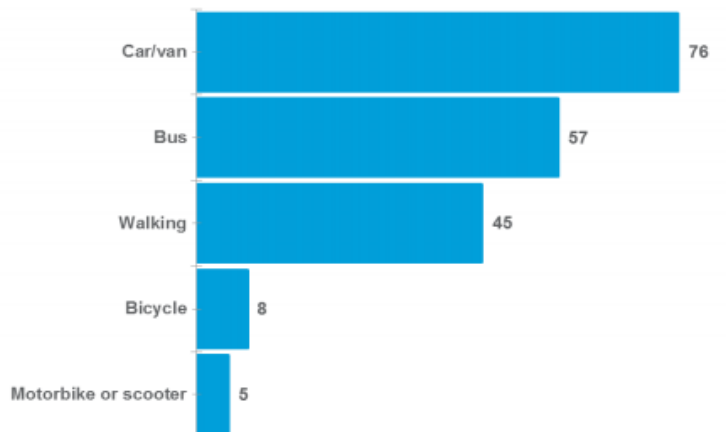
Source: Quality of Life, 2014

Figure 9.3.3: Respondents perception of the safety of different modes

Source: Quality of Life, 2014

Following a substantial number of cycling fatalities in Christchurch over recent years, the need for safe and attractive cycling infrastructure has become more predominant than ever before. From the results presented in Chapters 7 – 9, it is clear that the proposed major cycleways network is a large step in the right direction towards rehabilitating the reputation cycling safety currently has in Christchurch. Copenhagen's cycle strategy places a significant amount of importance on cycle travel time (The City of Copenhagen, 2011); it is acknowledged heavily throughout the strategy that in order to encourage more people to commute via bicycle, travel time must be competitive with other modes of transport. However, the strategy suggests that travel time is not simply about speeding through the streets and getting to your destination as quickly as possible, but also about being able to choose your own travel tempo and most direct route. Not surprisingly, the strategy points out that fewer missing links in a network leads to more direct routes that require less stops and greatly improve travel times. Consequently, minimising gaps in Copenhagen's cycle network has become one of the city's key goals throughout the life of the strategy. Taking into consideration the success that Copenhagen has had in implementing an effective and widely utilised cycling system, it is not unreasonable to suggest that Christchurch follow their lead when planning for cycling infrastructure. Taking the time now to ensure that the city's cycle network is cohesive and well connected will go a long way towards reaching the goal of Christchurch becoming a cycle city, encouraging more of the population to make use of utility cycling and its many benefits.

9.4 Policies and Initiatives to Improve Cyclist Safety

As highlighted extensively throughout this research, it is widely recognised that in order to encourage more people to utilise utility cycling, it must be a safe and convenient option. Pucher and Buehler (2008) discuss that in order to make cycling a safe and feasible mode of transport, a number of policies and programmes are required. After gathering information from a number of Dutch, Danish and German cycling coordinators, Pucher and Buehler were able to draw some conclusions on exactly which innovative measures and policies are required to promote safe and convenient cycling in cities, further detail about which can be found in Figure 9.4.1.

Predictably, effective cycling systems tops of the list of key policies and measures used to promote safe and convenient cycling in Dutch, Danish and German cities; again reinforcing the importance of effective and attractive cycling infrastructure. Pucher and Buehler acknowledged that the success of cycling and cycling infrastructure in Dutch, Danish and German cities can largely be attributed to the decades of planning that has gone into the implementation of successful cycle networks. The importance of planning for future cyclist behaviour and demand has been discussed greatly throughout this research, as it is going to play a significant role in improving Christchurch's standing as a cycle city; the fact that the Dutch, Danish and Germans attribute a large amount of their cycling success to quality planning (Pucher & Buehler, 2008) once again attests to the importance of planning for cycling.

Chapters 3 and 4 discussed extensively the planning frameworks and legislation that is being put in place throughout both New Zealand and Christchurch to further enhance cycling culture in New Zealand. As the importance of reducing motor vehicle dependence and encouraging the use of alternative modes of transport comes to the forefront of people's attention, planning for this change in transport behaviour is going to be indispensable. Whilst having frameworks in place to support the development of cycling and cycle infrastructure throughout the country is a significant step towards becoming more cycle friendly, it is important that these frameworks are designed to not only support cycle development now, but to also ensure that future cycle demand being planned for.

Extensive systems of separate cycling facilities
- Well-maintained, fully integrated paths, lanes and special bicycle streets in cities and surrounding regions
- Fully coordinated system of colour-coded directional signs for bicyclists
- Off-street short-cuts, such as mid-block connections and passages through dead-ends for cars

Intersection modifications and priority traffic signals
- Advance green lights for cyclists at most intersections
- Advanced cyclist waiting positions (ahead of cars) fed by special bike lanes facilitate safer and quicker crossings and turns
- Cyclist short-cuts to make right-hand turns before intersections and exemption from red traffic signals at T-intersections, thus increasing cyclist speed and safety
- Bike paths turn into brightly coloured bike lanes when crossing intersections
- Traffic signals are synchronized at cyclist speeds assuring consecutive green lights for cyclists (green wave)
- Bollards with flashing lights along bike routes signal cyclists the right speed to reach the next intersection at a green light

Traffic calming
- Traffic calming of all residential neighbourhoods via speed limit (30 km/hr) and physical infrastructure deterrents for cars
- Bicycle streets, narrow roads where bikes have absolute priority over cars
- 'Home Zones' with 7 km/hr speed limit, where cars must yield to pedestrians and cyclists using the road

Bike parking
- Large supply of good bike parking throughout the city
- Improved lighting and security of bike parking facilities often featuring guards, video-surveillance and priority parking for women

Coordination with public transport
- Extensive bike parking at all metro, suburban and regional train stations
- 'Call a Bike' programmes: bikes can be rented by cell phone at transit stops, paid for by the minute and left at any busy intersection in the city
- Bike rentals at most train stations
- Deluxe bike parking garages at some train stations, with video-surveillance, special lighting, music, repair services and bike rentals

Traffic education and training
- Comprehensive cycling training courses for virtually all school children with test by traffic police
- Special cycling training test tracks for children
- Stringent training of motorists to respect pedestrians and cyclists and avoid hitting them

Traffic laws
- Special legal protection for children and elderly cyclists
- Motorists assumed by law to be responsible for almost all crashes with cyclists
- Strict enforcement of cyclist rights by police and courts

Figure 9.4.1: Key policies and innovative measures used in Dutch, Danish and German cities to promote convenient and safe cycling.

Source: Pucher & Buehler, 2008

10. Planning for Future Infrastructure

The results have drawn attention to the fact that although the current proposed major cycleways network provides acceptable coverage across some areas throughout the city, there is also substantial room for improvement when considering how the network could be developed in the future. As the earthquake recovery phase continues, it is clear that the transport patterns and needs of the city will also continue to change. At this point, it is important to once again highlight that the main function of the city's transport network is to enable the movement of people and goods throughout the city, through the use of a variety of transport modes. With this in mind, the results to follow provide an indication of areas where future cycle infrastructure could be implemented to make the city more accessible by active modes of transport.

10.1 The Demand for Future Infrastructure

As Christchurch continues through the earthquake recovery phase, the city's usually resident population is expected to not only recover, but grow (Statistics New Zealand, 2014b). With growth in population, comes greater pressure on the transport network to perform effectively and efficiently. Whilst there is certainly a global shift occurring towards the increased use of more sustainable modes of transport, Christchurch remains, on the whole, a very car-centric city. In order to ease the significant demand the road network is likely to be put under in the years to come, it is important that the city begins to implement measures that will encourage people to reconsider their travel behaviour.

Chapter 2 drew attention to the fact that one of the CCC's main goals for the rebuild period, is to see Christchurch develop into a more cycle-friendly city, where utility cycling is not uncommon. It was also discussed that the Greater Christchurch development strategy acknowledges that the decisions people make about where they are going to live have much wider flow on effects, particularly in terms of the city's transport requirements (Greater Christchurch UDS Partners, 2010). It has been recognised that as the city and the greater Christchurch area continue to grow, the areas where residential growth is focused are generally moving further towards the city fringe, and further away from key employment zones; as a result there is expected to be a 320 percent increase in traffic volumes by 2041 (Greater Christchurch UDS Partners, 2010). These amplified traffic volumes further reinforce the need to encourage the city's population to reconsider the way in which they are travelling through providing attractive alternatives to private motor vehicles. Whilst the strategy

acknowledges that where people choose to live will play a large role in the mode of transport they use for utility trips, it is also important that they are provided with transport choice and attractive alternatives to encourage a decrease in the use of private motor vehicles throughout the city.

In 2006 research was undertaken assessing New Zealanders readiness to change when it came to increasing the number of utility trips made by walking or cycling. Whilst it was found that thirty seven percent of people would be prepared to replace trips made by motor vehicle with trips made by walking or cycling on two or more days each week, only eleven percent of respondents reported cycling regularly (once a week or more), while sixty nine percent of respondents had not cycled at all in the last three months (Sullivan & O'Fallon, 2006). Similarly, research undertaken for the Christchurch City Council in 2005 found that twenty seven percent of the city's non cyclists were interested in taking up cycling (Opinions Market Research Ltd, 2005). Although these figures provide a very clear indication that people are interested in reconsidering the way in which they travel, the discrepancies between the figures above and the number of people actually utilising cycling as a mode of transport indicate that there is certainly some barriers preventing people from making the transition to more active modes of transport. The importance of the role perceived safety plays in utility cycling uptake has been discussed widely throughout this research, and when taking Sullivan and O'Fallon's (2006) findings into consideration, it is certainly not unreasonable to argue that there is still a significant amount of demand in Christchurch for robust cycling infrastructure.

As aforementioned, the results to this point have drawn attention to the fact that there is a significant amount of room for improvement when considering how the major cycleways network could be further developed in the future; both in terms of improving the current proposed network, as well as the implementation of additional infrastructure to further extend the network. The population projections discussed in Chapter 8 made it very clear that a large amount of development is expected to occur throughout the city in the years to come, particularly in fringe areas on the western side of the city (Figures 7.2.2 and 7.2.3). As a result, when additional infrastructure is being considered or planned, these areas should be prioritised to ensure that the network is servicing areas throughout the city where a large number of people will be beginning their daily trip to work. It is important to note that as these areas are on the city fringe, an increase in the uptake of utility cycling is going to depend on how far a person will have to travel to reach their place of employment. Whilst cycling is certainly a viable alternative for trips between two and five kilometres (Smith et al., 2011), in the case of lengthier trips it is unlikely cycling will be the preferred option. Although the current demand for infrastructure in these areas may be limited, considering future

transport needs throughout the city at present will contribute to a transport network that effective and robust in the years to come.

It has been noted a number of times already, when planning for future transport demand, it is critical that future transport patterns are considered. The derived trips results in Chapter 7.6 provided a summary of areas where there is expected to be a large number of trips passing through. Whilst it is important to provide infrastructure to areas where a large number of trips start and end, ensuring that there is infrastructure in areas people would normally travel is critical. As discussed previously, when choosing how to travel between an origin and destination, a mental trip cost calculation is made. Though safety certainly features heavily in the decision a person makes about how they will travel, so too does travel time and distance. As a result, if cycle infrastructure is provided to improve safety, but proximity, network cohesion and network directness requirements are not met, it is possible that the choice may still be made not to cycle. While it is always possible that in some cases these factors may not influence a person's decisions to cycle, generally providing both safe and attractive infrastructure is likely to have positive effects on utility cycling uptake.

10.2 Extensions to the Proposed Network and Future Infrastructure

As discussed in Chapter 4, a number of the key planning frameworks developed to govern the rebuild period highlighted the importance of the enhancement of the cycling facilities and culture in both Christchurch City and the wider Christchurch and Canterbury areas. Throughout the process of analysing the results in Chapters 8 and 9, a number of areas where improvements could be made to the initial proposed network were identified and discussed. Taking into account the 500 metre reasonable access assumption (Macbeth et al., 2007), it was possible to identify high demand transit zones that are not currently provided with an adequate level of service by the major cycleways network. These include areas such as Merivale, Bryndwr, Holmwood and Deans Bush and some smaller gaps in areas such as Sydenham, Riccarton, Waltham, and Phillipstown (Figures 8.4.1 and 8.4.2). Chapter 9.3 highlighted the significant impact that addressing seemingly inconsequential gaps in the network can have. With Lehman's (2013) findings, along with the results in Chapters 8 and 9 in mind, the following areas (Figure 10.2.1) were identified as prime candidates for exploring the impacts that future infrastructure could have on the network and where people are travelling.
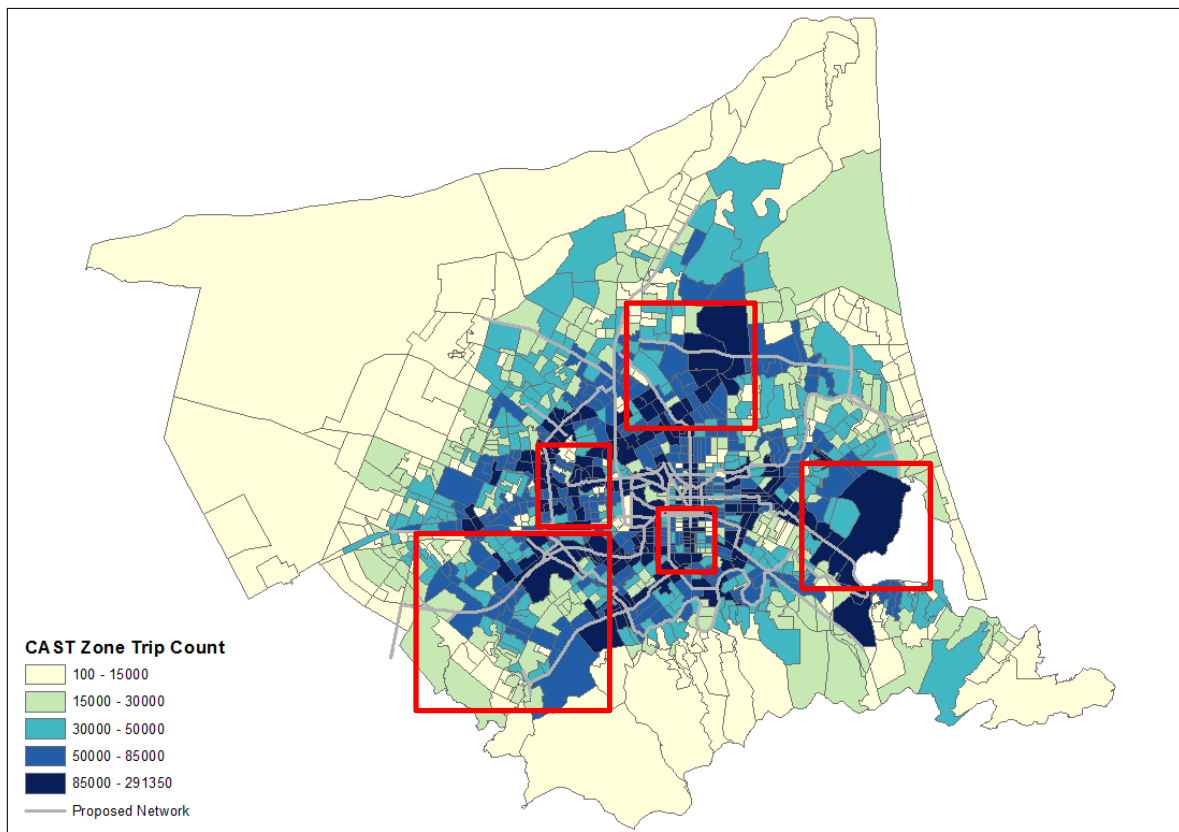
Figure 10.2.1: Suggested areas for network development and extensions based on the analysis results presented in Chapter 9

Notably, whilst some of the chosen areas do represent relatively small gaps in the network, they are also largely in areas that are expected to have high levels of cyclist demand. Following the identification of key areas for network improvement (Figure 10.2.1), some extensions were suggested (Figure 10.2.2). Ranging in length from 3.9 kilometres to only 212 metres, the suggested extensions have been selected as it is expected that whilst they will undoubtedly provide further access to the proposed network, particularly those in areas where substantial growth is projected, they will also make a significant contribution to improving network directness and cohesion. Although there are a number of areas where new infrastructure or more substantial extensions of the proposed network were explored, a number of the smaller gaps were also focused on due to the large impacts that they can have on many facets of a network.
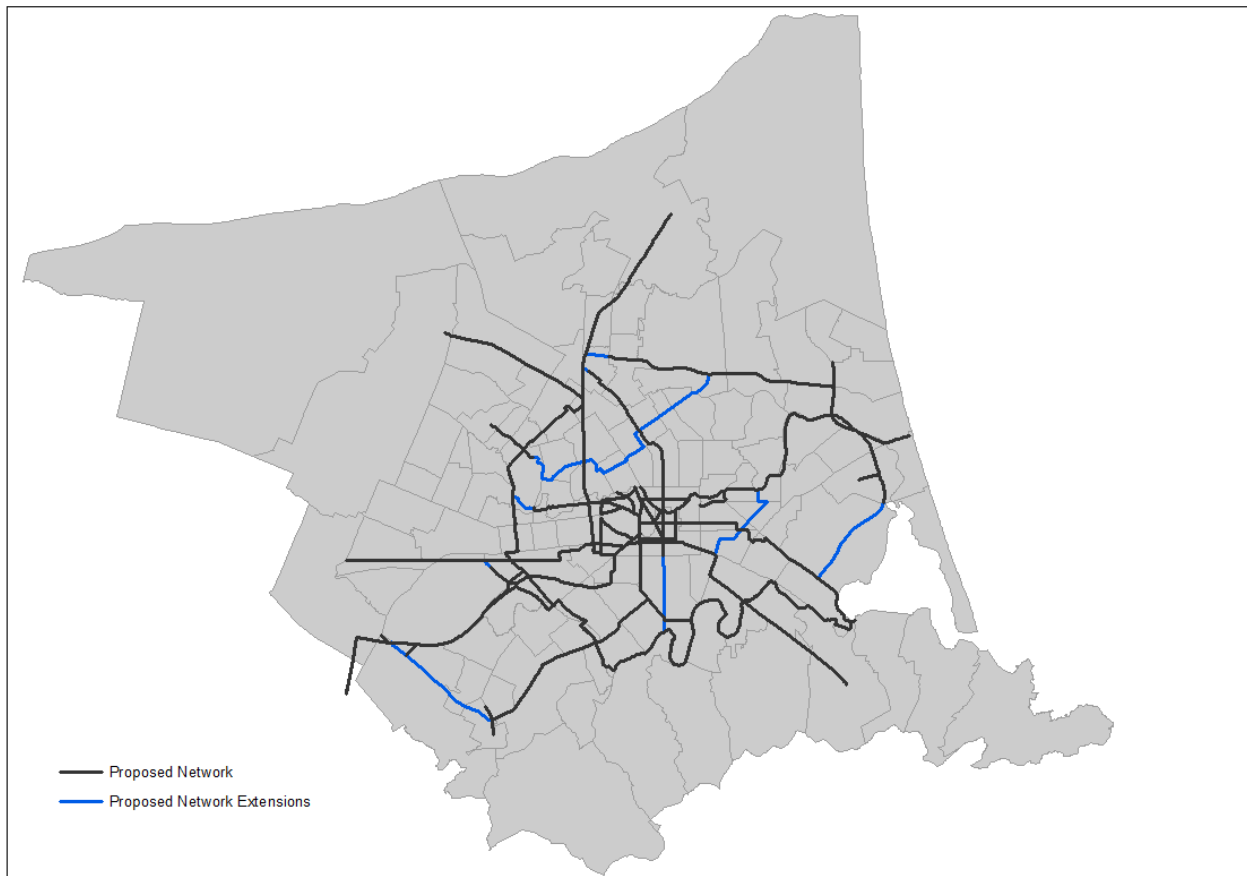
Figure 10.2.2: Potential network extensions, suggested based on cyclist demand

From the results presented thus far, it is clear that although there is room for some improvements, the proposed major cycleways network is a noteworthy step towards rehabilitating the reputation that cycling and cyclist safety currently has in Christchurch. Copenhagen's cycle strategy places a significant amount of importance on cycle travel time (The City of Copenhagen, 2011). It is acknowledged heavily throughout the strategy that in order to encourage more people to commute via bicycle, travel time must be competitive with other modes of transport, and suggested that travel time is not simply about speeding through the streets getting to your destination as quickly as possible, but also about being able to choose your own travel tempo and most direct route. Not surprisingly, the strategy points out that fewer missing links in a network leads to more direct routes that require less stops and greatly improve travel times; consequently, minimising gaps in Copenhagen's cycle network has become one of the city's key goals throughout the life of the strategy. Taking into consideration the success that Copenhagen has had in becoming a cycle city, it is not unreasonable to suggest that Christchurch follow their lead when planning for cycling infrastructure. Taking the time now to ensure that the city's cycle network is cohesive and well connected will go a long way towards reaching the goal of Christchurch becoming a cycle city, along with encouraging more of the population to make use of utility cycling and its many benefits.

10.3 The Implications of Extending the Proposed Network

Following the identification of potential network extensions, further network analysis was undertaken to examine whether the proposed extensions would improve accessibility, along with network directness and cohesion. In order to understand what implications the proposed extensions would have on the areas cyclists are likely to travel, closest facility analysis was run one final time. The proposed extensions were built into the road network used for analysis just as the proposed network was in previous analysis (Chapter 6.7). They were then applied the same weightings as the rest of the proposed major cycleways network based on the scaling factors provided by the ARCM (Rendall et al., 2012). The results from the final round of network analysis are presented in Figure 10.3.1.
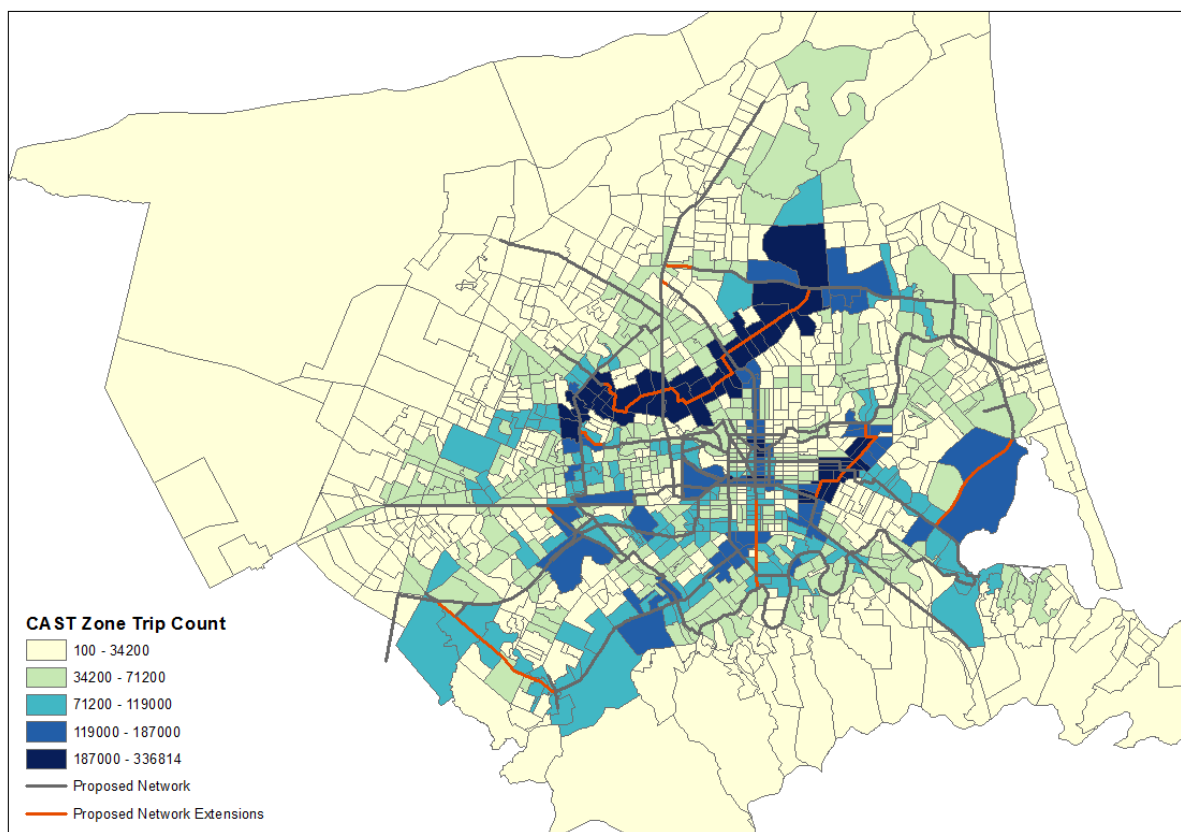
Figure 10.3.1: The number of trips expected to pass through each CAST zone when the proposed network extensions were built into the road network used for analysis

Results show that whilst trips still pass through similar areas to the results presented in Figure 9.1.1, the zones with the most substantial demand are far more concentrated around the cycle network and proposed extensions. Chapter 7 provided an indication of both residential growth areas, as well as areas that are likely to have a significant amount of employment activity in them. Belfast,

amongst other areas in the city's north is earmarked to be one of the most significant residential growth areas (Chapters 7.2 and 7.3), and it can be clearly seen in Figure 10.3.1 that there is significant cyclist demand for cycle infrastructure provisions that link the growth areas in the north to employment zones, particularly the CBD and Yaldhurst/Russley. Although the demand is not as substantial as that in the city's north, there are still a relatively extensive number of trips passing through zones where infrastructure has been implemented to link residential growth areas in the south (Halswell) to the rest of the city. As well as highlighting the need to provide cycle infrastructure from key residential growth areas, the results in Figure 10.3.1 also emphasises the need to deliver a cycle network that provides effective connections to the CBD. A substantial number of trips can be seen in areas where there are links between the proposed major cycleways network and the central business district (Figure 10.3.1).

Chapter 7.4 discussed the concepts of liveability and sustainability and the implications that the transport network can have on them. The importance of providing transport choice was discussed in the context of ensuring that growth within major urban areas is sustainable. The results presented above highlight the impact transport choice can have. Implementing cycle infrastructure in areas where it is expected there will be demand has the potential to have significant impacts on the way in which people choose to travel. Network proximity, cohesion, and directness can have significant impacts on whether a person will consider making a trip by an alternative mode of transport (Parkin & Koorey, 2012); thus providing a cycle network that is both cohesive and direct can have significant positive repercussions on transport choice within a city.

It is also clear that when implementing network extensions, such as those suggested above, is likely to have significant impacts on how liveable Christchurch is. It is important to once again highlight that the main purpose of the city's transport network is to facilitate the movement of people and goods to various areas of the city, by a number of different modes. Extending the network is likely to provide people in various parts of the city with more transport choice, consequently improving the liveability of the city as a whole. Chapter 7.4 discussed the importance of developing links from the key growth areas, such as Belfast and Hornby, in safeguarding Christchurch's future as a liveable city. The results in Figure 10.3.1 indicate that the suggested network extensions would not only provide connections from the key growth areas, but also improve access to cycle infrastructure throughout other areas of the city, consequently contributing to Christchurch becoming not only more liveable, but more accessible by a number of modes of transport.

10.4 How should new infrastructure be prioritised?

As described in Chapter 6.9, following analysis, steps were undertaken to suggest how new infrastructure could be prioritised. In order to keep the prioritisation simple, this was done through calculating the number of additional trips that would likely pass through CAST zones within 500 metres of the proposed extensions, for every extra kilometre of infrastructure provided. In order to gain an understanding of the wider impacts the extra infrastructure would have, all zones that intersected to 500 metre buffer used during analysis were selected, not just those that are entirely within the buffer zone. The results from the prioritisation analysis can be found in Table 10.4.1, along with a context map to provide an indication of where each potential extension is located (Figure 10.4.1).
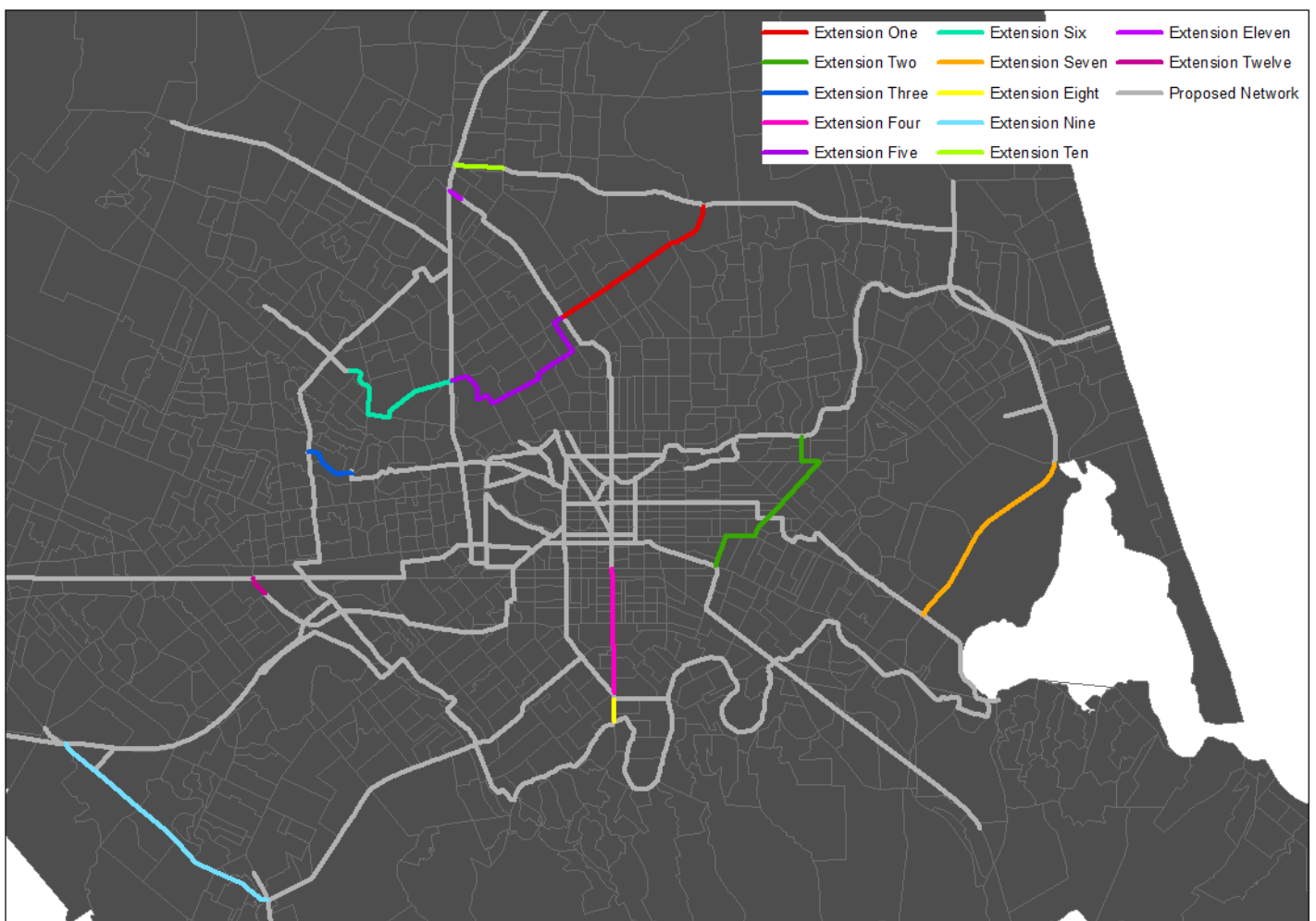

Figure 10.4.1: A summary of the suggested extensions for Christchurch's proposed major cycleways network

Extension	Extension Length (Km)	Trip Count Difference	Extra Trips per Km	Priority
One	2.82	2,541,951	901,401	2
Two	3.11	1,830,486	588,581	4
Three	0.84	158,020	188,119	6
Four	1.91	167,710	87,806	7
Five	3.20	3,409,496	1,065,468	1
Six	2.43	1,964,023	808,240	3
Seven	3.13	74,025	23,650	9
Eight	0.34	17,863	52,538	8
Nine	3.99	1,060,204	265,715	5
Ten	0.73	-158,629	0	0
Eleven	0.21	-182,340	0	0
Twelve	0.29	-149,783	0	0

The results presented in Table 10.4.1 suggest that though filling in smaller gaps in the network can lead to substantial increases in network cohesiveness and accessibility (Lehman, 2013), the demand in Christchurch is initially likely to be for more substantial extensions to the proposed major cycleways network. Prioritisation results showed that extensions five, one, six and two constitute the top four suggested extensions in terms of the order in which future infrastructure should be developed. Interestingly, there is a strong relationship between the locations of the extensions that led to the most significant increase in trip counts, and the zones that returned with the highest trip counts following closest facility analysis. As discussed in Chapter 10.3 whilst admittedly there was already a large number of trips passing through the northern part of the city, likely due to the large growth area that is expected to develop around Belfast and Prestons, the introduction of the new infrastructure led to the trips becoming much more concentrated around the areas where there was infrastructure provided (Figures 10.2.1 and 9.1.1). This once again highlights the positive impacts that implementing attractive infrastructure can have, along with the importance of network cohesion and directness; Chapter 2.4 discussed the importance of a well-designed, functional cycle network in encouraging more people to take advantage of the many benefits of utility cycling. Whilst providing infrastructure is important is an important step towards improving cyclist safety, providing a network that is cohesive and direct ensures that cycling provides an attractive alternative to travel by private motor vehicle (CROW, 2007).

Although there were a number of suggested extensions that resulted in increased trips in the zones around them, Table 10.4.1 indicates that 3 of the 12 extensions actually lead to a decrease in the number of trips passing through the zones around them. Looking closely at Figure 10.4.1, it becomes clear that all of the extensions where there were decreases in the number of trips passing through the zones around them were small extensions that had been suggested to fill the slight gaps in the network, with the aim of making the network more cohesive (Lehman, 2013). From this it can again be determined that whilst it is likely that filling small gaps in the network will undoubtedly play a key role in making the network more accessible eventually, initially longer, more substantial extensions to the network will be more beneficial.

Whilst the results presented above provide a good initial understanding of where extensions could be added and how they could be prioritised, it is important to suggest that the exact locations for the improvements and extensions could certainly undergo further analysis. Testing each one of the extensions individually within the network would be beneficial in understanding the impact each of them would have on route choice and travel patterns independently. Although key areas for development have been identified, further investigation into the best exact location would also be beneficial in ensuring that any new infrastructure is as effective within the wider network as possible.

11. Recommendations for Future Research

While this research has provided sound foundations for research surrounding the future of cycling infrastructure in Christchurch and potential improvements to the major cycleways network, as with any research there were some limitations that could be addressed in the future. Accordingly, a number of recommendations for future research are to follow.

As discussed in Chapter 6, there were a number of software and data challenges encountered throughout the research process. Though the software restrictions could largely be addressed and resolved during the analysis process, unfortunately there were not easy solutions to the data limitations. Owing to the environment in which the research was undertaken, there were a number of data availability issues. Although 2041 projections were used to determine where residential and employment activity would likely be located, no projected information was available as to where within the zones activity would be situated. Subsequently, the New Zealand property titles dataset was used to derive origin and destination points for each of the zones. Though the property titles dataset was up to date at the time it was downloaded, it is likely there will be significant changes to this data throughout Christchurch as the rebuild and recovery continues. Consequently, it is recommended that further iterations of the analysis process are undertaken as more detailed projections become available.

As cyclists' perceived safety played a large role in this research, detailed vehicle volume data was required; whilst every effort was made to obtain the most recent and accurate VPD data, this proved to be difficult. In order to undertake the necessary analysis, VPD data was required for every road in the Christchurch road network. Upon approaching the CCC, it became apparent that this data simply was not available. As a consequence, it was decided to instead use the counts provided in the CCC traffic management matrix; although the matrix does provide data for a significant proportion of the roads in the city, it is important to note that there is no data available about when the counts were collected – though given the availability of VPD counts it is relatively safe to assume that a number of them predate the 2010 and 2011 earthquakes. It is also important to acknowledge that as roads with VPD counts of less than 500 are not included in the matrix a number of roads were simply assigned a vehicle count of 500.

As with any research that relies on projected data, as time goes by projections are likely to be developed further; as projections develop it can be expected that they will provide a more accurate depiction of how the city is expected to look in the future. As a result, as further projections become

available, repeating the analysis would aid in the ability to make well informed suggestion as to where future cycle infrastructure should be located and how it should be prioritised.

Whilst the results presented in Chapter 10 provided a sound base for suggesting how future infrastructure should be prioritised, there is certainly scope to further develop the methods used for this. Although the results certainly validated the broad areas where the extensions were placed, further work could be done in terms of identifying the best location within these broader areas for future infrastructure development.

Along with developing more accurately informed infrastructure recommendations, there is also the ability to expand the scope of the research. In particular, including potential trips to schools and educational institutions would be advantageous. Trips to schools and other education institutions constitute a substantial proportion of all utility trips made. Consequently, providing infrastructure in areas where these trips are likely to occur would likely have positive impacts on the levels of utility cycling in Christchurch.

12. Conclusions

Following the earthquakes, the importance of improving Christchurch city's cycling environment to further develop the city's cycling culture was identified, and consequently featured in a number of the city's key redevelopment frameworks. From here the proposed major cycleways network was developed.

Using future population and employment projections likely travel patterns throughout the city were modelled. As a result, this study identified that although the initial network represents a good step towards improving the city's cycling environment, there are a number of areas where access will need to be improved throughout the years to come. A substantial amount of the city's growth is expected to occur on the fringe areas of the city, including Belfast, Prestons and Halswell, thus ensuring that these areas are well connected to the inner city is going to be indispensable. The importance of the relationship between land use and travel choice has been discussed widely throughout this study; as people move further away from where they work, their propensity to simply travel by private motor vehicle is certainly going to heighten if travel choice is not provided.

As safety is so often a deterrent to potential cyclists making the decision to instead travel by private motor vehicle, refining the network to improve cyclist safety became a focus throughout this research. Several areas where cyclist safety could be improved were identified, and potential extensions or improvements to the proposed major cycleways network were explored throughout these areas. Although it has been proven that addressing small gaps within a cycle network can have significant repercussions on access to the network, it was found that initially in Christchurch, more substantial extensions to the cycle network will represent better value for money, particularly in terms of the number of extra trips that will pass through a zone when safe and attractive infrastructure is provided.

Although potential extensions were tested in a number of areas across the city, it was those in the city's north that attracted the most additional trips per kilometre of infrastructure supplied. Accordingly it was suggested that development in these areas be prioritised when planning for future cycle infrastructure. Not only did extensions in this area lead to a much higher level of trip concentration in the zones surrounding the extensions, but also provided a key missing connection between the northern growth areas and a number of the city's most predominant business zones, including the airport business park and the CBD. Whilst investigating the impact potential extensions would have on travel patterns across the city led to prioritisation recommendations being made, it also highlighted the need to provide sound connections into the central city, as it is expected that

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the CBD will grow to once again be a key employment zone. The patterns uncovered during the prioritisation analysis once again highlight the need for effective and forward thinking planning when transport infrastructure is being implemented.

Whilst this research has provided a sound understanding of key transport development areas throughout Christchurch city in 2041, it has also developed a methodology that it is could be utilised in the future to further improve access to cycle infrastructure. Although the best conclusions have been drawn with the data and projections available presently, as with any research that relies on projected data, it is likely that these will change over time. Christchurch is expected to remain a very dynamic city over the years to come, changing often with the potential for growth to occur in areas where we may not expect it. With this in mind, it is hoped that the methods developed throughout this study can be utilised over the years to come, to provide Christchurch with a robust and effective transport network that offers attractive alternatives to travel by private motor vehicle.

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Major Cycleways Network

May 2014

Key

Completed

Major Cycle Routes/ Recreational Routes

Coastal Pathway - funded separately

Central City - CERA led

Key Activity Areas