The Influence of Sociodemographic and Land Use Patterns on Public Transport Use in Christchurch, New Zealand

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Abstract

This thesis investigated the links between public transport use and sociodemographic and land use factors. A dataset of address information about regular bus smartcard users was sourced. These addresses were geocoded using Geographical Information Systems, and the address points derived through this process were used to calculate the percentage of regular bus users in Census meshblock spatial areas. This percentage was then compared to a number of different factors, including deprivation levels (a measure of sociodemographic status), average distance to the nearest bus stop and bus route, and a number of variables from the New Zealand Census of Population and Dwellings, using a number of forms of analysis. The number of cardholders in different residential zonings was assessed, along with the average number of trips taken per day by cardholders. Results indicate that there was a relationship between the regular Metrocard users and deprivation, and regular Metrocard users and land use, however the statistical validity of these relationships was low. Principal component analysis and regression analysis were carried out to assess what variables best explained the proportion of bus use. It was found that the presence of International Students in an area accounted for the biggest variation in the levels of bus use, along with people who were Unemployed and of Maori or Pacific ethnicity, and people who have limited access to vehicles. However, the statistical validity of these results was again low.

1 | Introduction

Public transport services are an intrinsic part of almost all modern cities, providing an affordable alternative to private car transport. For some people it may be the only viable way of travelling, due to practical affordability or accessibility reasons. In a world where the supply of oil is forecast to become scarcer, the importance of public transport looks set to grow.

In New Zealand, public transport is often seen as an unattractive alternative rather than a vital form of transit. Private car use dominates, and the proportion of travel by public transport is low. The dispersed nature of the urban form of cities means that the provision of public transport services is sometimes difficult.

There has been little research investigating why people use public transport services in New Zealand. Is it primarily a social service used by people with no other option? Will people use it if it is convenient and suits their needs, for example if they live directly adjacent to a bus route which travels where they want to go? Is the use of it linked to population density and land use - in essence the way we plan, design and build our cities?

The answers to these questions are particularly important in Christchurch, the largest city in the South Island of New Zealand. Public transport use in this city is growing, but is still very low. To increase the proportion of public transport users in the future, the reasons why people do or do not use these services needs to be better understood, so that services can be designed to best meet the needs of the population.

1.1 | Background to Research

Two main influences guided the initial selection of the topic of this research. Firstly, the authority charged with planning public transport services in Christchurch, Environment Canterbury, has a strong interest in better understanding the demographic and land based influences that influence the choice of people to use (or not use) the bus and ferry services under its jurisdiction. This is consistent with the recommendations of a recent report commissioned by Environment Canterbury (Abley Transportation Engineers, 2009).

Secondly, there is a paucity of academic research in New Zealand into these influences. The way in which these influences operate in New Zealand is of particular interest, due to the dispersed urban form of cities and high levels of car ownership. Christchurch City is of even more interest because of the decentralised nature of workplaces.

This research will explore three major factors that influence public transport use. Sociodemographic influences will be assessed by comparing data about regular bus users with demographic data sourced from the New Zealand Census of Population and Dwellings. The influence of land use will be investigated through a comparison of the Christchurch City Council City Plan Zoning Information with data about regular bus users. Finally, the influence of the distance of regular bus users to both bus routes and bus stops will be measured.

1.2 | Aims and Objectives of Research

The overall aim of this research is to investigate the way in which sociodemographic and land use factors influence public transport use in Christchurch, New Zealand.

This aim will be achieved through fulfilling the following research objectives:

Objective One: Sociodemographic Factors

- to find out whether regular Metrocard users are evenly spread across the Christchurch urban area, or whether they are clustered in certain parts of the city
- to use Metrocard address and usage information to ascertain how sociodemographic factors influence public transport use, and to investigate how this varies spatially across the Christchurch urban area

Objective Two: Land Use Factors

- to use Metrocard address and usage information to investigate what impact (a) residential land use zoning and (b) residential housing density has on public transport use

Objective Three: Distance and Regularity of Use Factors

- to determine whether the distance from a bus core route (15 minute or less weekday service intervals) or non core bus route (less frequent weekday service intervals) correlates in any way with Metrocard usage, and if this varies spatially across the Christchurch urban area
- to investigate whether the distance from a bus stop correlates in any way with Metrocard usage, and if this varies spatially across the Christchurch urban area
- to find out whether the regularity of bus use is evenly spread throughout the city, or if some geographic areas have higher proportions of regularity of use than others

Objective Four: Factors Determining Regular Metrocard Use

- to find out if there are any particular variables that are directly linked with Metrocard use, and therefore can be used as a proxy to determine expected usage patterns

Objective Five: Policy Recommendations

- to make policy recommendations about how public transport services in Christchurch could be altered or improved in terms of sociodemographic and land use criteria, based on the outcomes of this research

1.3 | Location of Research – Christchurch, New Zealand

Christchurch is the largest city in the South Island of New Zealand, and the second biggest in the country, with a population of 348 435 in 2006 (Christchurch City Council, 2007). The population of the city is expected to reach 450 000 by 2041.

The urban area of the city is mainly flat, the only exception being the Port Hills which line the Southern Fringe of the city and separate it from Lyttelton Harbour. The city sprawls outwards in every direction from a central business district. In 2006 there were 19 100 hectares of land used for urban uses within the boundary of the Christchurch City Council, with an average population density of 19.4 people per hectare. Commuting towns in the adjacent Selwyn and Waimakariri Districts include Rolleston, Lincoln, Rangiora, Kaiapoi and Woodend.

In 2006, there were 133 746 households in the city, with an average household size of 2.5 people. This is projected to fall to 2.2 people by 2041. In the 2006 Census, 75.3% of the population of Christchurch identified their ethnicity as European. Although 12.9% selected 'other', the vast majority of these respondents listed their ethnicity as 'New Zealander'. 7.9% of the population selected Asian, and 7.6% Maori.

The majority of journeys in Christchurch are made using a car – public transport accounted for 4% of journeys to work in 2006 (Statistics New Zealand, 2009), and bus patronage equated to 43 trips per person per year. The 'Metro' branded public transport network is made up primarily of over 40 bus routes, complemented by a ferry service on Lyttelton harbour. The network is described in depth in Section 3.3.

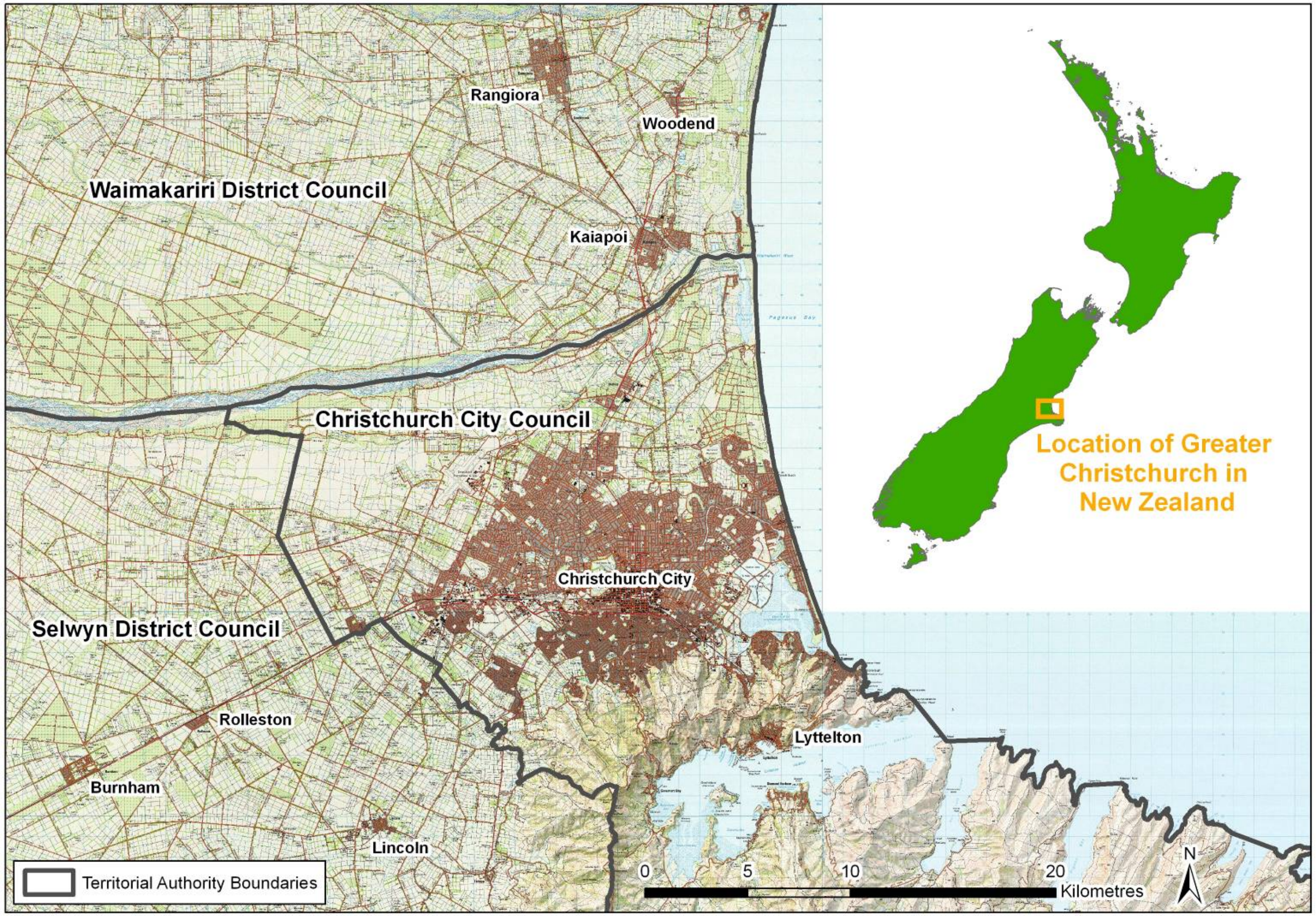

Figure 1.1: Shows the Greater Christchurch area (including the location of commuter towns), and the location of Greater Christchurch in New Zealand (Topographic Map Imagery sourced from Land Information New Zealand).

1.4 | Structure of this Thesis

The next chapter, the Literature Review, sets out the context for the research. Academic work investigating the links between public transport use and sociodemographic and land use factors from around the world is reviewed. Chapter Three discusses public transport in Christchurch, detailing both the history and the current situation. Details about the selection of the study area are also included in this chapter.

The methods used in the research are explained in Chapter Four, with the results being presented and discussed in Chapter Five.

Chapter Six ties the research together, presenting the conclusions of the work and providing recommendations for both future research work and the future development of the public transport network.

2 | Literature Review

2.1 | Sociodemographic Research on Public Transport Use

Early research investigating the travel behaviour of individuals tended to originate from an engineering perspective. This work did not focus specifically on public transport, but rather all modes of travel behaviour. Some of this research noted that travel-activity behaviour by adults who are employed outside the home is affected by whether or not there are children under the age of 12 in their household (Pas, 1984). Furthermore, those with a higher education level were more likely to undertake more trips than the daily work commute, due to higher car ownership levels, more disposable income, more flexible work schedules and higher levels of involvement in community activities. Such research noted the relationships between higher car ownership and higher income levels in low density residential areas, and that people who fall into these categories are more likely to take multiple daily journeys for all kinds of activity types.

Other research highlighted the complex nature of travel patterns, noting that simple measures such as trip frequency and travel distance do not always take into account all of this complexity (Hanson & Hanson, 1981). This research also found that using a single sociodemographic variable was insufficient for modelling travel behaviour. However, this research found the use of principal component analysis was effective in grouping individual variables together to give an indication of how wider sociodemographic factors were important in explaining travel behaviour. In this particular case, seven factors were found to explain 75.5% of the total variance; with the factor described as ‘frequency of travel’ explaining the single largest portion of this variance (23.5%), followed by the factor described as ‘dispersion of variables visited’ (17.3%).

2.1.1 | Social Exclusion and Transport

There is little research specifically investigating the sociodemographic determinants of public transport use. However, the exclusion of some groups in society, and the role of transport access and provision in this social exclusion, has been an area of sustained academic interest over the last decade.

Social exclusion is a complex term to define, as there is no consensus on what it means (Preston & Rajé, 2007). It has its beginnings in the desire to better understand the root causes of poverty. It has been driven by Government desires to integrate groups into mainstream society that have previously been ignored, and it is noted that as such the agenda of social exclusion has both practical and moral concerns (Lucas, 2004). In the UK this interest was initially sparked by Government interest in how to plan integrated transport that helps to reduce social inequalities (Church et al., 2000). It has now become an accepted and important tool in public transport research and planning. It is recognised that future research into social exclusion cannot simply focus on those that are excluded, but rather needs to consider the way in which it is affected by society as a whole (Lyons, 2003). The broadening of the field of transport-related social exclusion will allow for theory around it to be expanded and tested, something which has not happened until now (Stanley & Vella-Brodrick, 2009).

Research carried out in London found that around a quarter of the residents of the city are prevented from participating fully in society because of a lack of 'connection', which is in part due to travel difficulties (Church et al., 2000). However, these travel difficulties are multi-dimensional and complex, meaning that a similarly divergent approach is needed to implement policies to reduce them. It is also noted that in previous studies, geographic factors have rarely been considered, such as the relationships between the location of a person's residence and the location of their activities, and the barriers that may exist between these locations.

Most discussions conceptualize the idea of transport disadvantage as being a homogenous problem for people. However, research has pointed out that the complexity of peoples' varied daily lives and varied needs mean that this is not the case (Hine & Mitchell, 2001). To help to mitigate this, when planning policies to address transport disadvantage, there needs to be consideration given to the many and varied social impacts of these policies.

Furthermore, it is suggested that some research into transport-related social exclusion has used aggregated mapping techniques which incorrectly assume that it is a socially or spatially concentrated phenomenon (Preston & Rajé, 2007). It is suggested that the solution to social exclusion issues may not lie simply in the provision of more bus services, but that other measures such as the lowering of fares might be more effective.

While there has been much research about the links between social exclusion and public transport, there has been no research exploring what links exist between the concept of social capital and public transport (Currie & Stanley, 2008). Social capital is the process by which people receive benefit from participation in their community. Currie and Stanley suggest that links should exist in terms of the role public transport has in providing mobility; helping to create 'liveable' cities through reducing car dependence; and increasing social interaction, as public transport allows for a shared travel experience. However, Currie and Stanley suggest that while these links exist, they are unlikely to be substantial in size.

2.1.2 | Vehicle Access and Transport Disadvantage

Many studies have used the indicator of not owning or having access to a vehicle as a measure of disadvantage. Johnson et al. (In Press) note that this has been mainly because of evidence providing a link between car ownership and income, along with the argument that not owning a vehicle has an impact on travel participation. However, they argue that this is not necessarily always the case, as some people may choose to not own a car if they have good access to public transport or can walk to activities. Furthermore, the cost of running a car may discourage some people from doing so.

In Australia, it has been noted the vast majority of urban travel is done using a car, meaning that transport disadvantage has normally been associated with the lack of ownership of a car (Currie, 2009). A place of particular note for transport disadvantage is those who live on the urban fringe who do not have access to a car (often as they are younger than the legal driving age) where there is limited access to public transport.

Conversely, there are limitations to how much use public transport can be to those who are transport deprived. It has been recommended in the USA that while improving public transport services will help, providing assistance to gain a car would be more effective (Rogalsky, 2010). This research focused on poor working women, and found that using a car was sometimes the only way to achieve the many trips needing to be undertaken, particularly for moving children about.

A recent Melbourne study has found that self reported measures of transport problems are not necessarily a good measure of transport disadvantage (Delbosc & Currie, In Press). This is because the vast majority of those who identified with having high transport problems had access to a car, and successfully made average numbers of trips. Most of those who had high self-reported transport problems lived on either the fringe or remote parts of the city, which had poor or no public transport services and where it was not possible to walk to a local shop. Public transport services were identified by this group as a problem.

2.1.3 | Transport Disadvantage in Australia and New Zealand

Traditionally there has been a lack of research into transport disadvantage in both Australia and New Zealand. Cities in these countries are geographically and culturally different to Europe, where most existing research has been carried out, as they are generally less dense and more decentralised.

However, there is currently a major research project underway investigating the links between transport disadvantage and social exclusion in Melbourne, Australia (Currie et al., 2009; Currie, 2010). One aspect of this study has included the calculation of accessibility to public transport services in each of the 5839 Census Collector Districts in Melbourne City from bus, tram and train stop locations and service frequencies.

Initial results from this study have shown that there is a needs gap for just over 1% of the total population of the city, as they have a very high social and transport need, but live in areas without public transport services (Currie et al., 2009; Currie, 2010). These areas were generally found to be located in fringe areas on the edge of the city, although it is noted that not all of the areas on the city fringe fall into this category. It is suggested that these and other similar results show a mismatch between social needs for public transport services and the actual supply of these services in Australian cities.

This research has also explored the effects of forced car ownership, where people who have an income of less than $500 per week are forced to own a car because of lack of access to public transport services and lack of walkable access to activities in fringe areas on the edge of Melbourne (Currie et al., 2009). Households which fell into this category were found to make fewer trips and travel a lesser distance than comparable households in other parts of the city. They were also found to own smaller and older cars. In households where no car is owned, walking has been found to be the main means of transport, indicating a need to live within walking distance of key activities.

These results have indicated a need for better public transport access to people living in fringe areas of a city. Such areas provide an ongoing challenge for transport planners as they are generally of low residential density, and therefore harder and more costly to provide with frequent public transport services (Currie et al., 2009).

Separate research in Melbourne has investigated whether increased bus services and frequencies can increase bus patronage and in doing so help to reduce transport disadvantage (Loader & Stanley, 2009). Where completely new services were provided, it was found that it needed to be at a reasonable frequency, such as every 30 minutes, to attract new patronage. Where existing bus services had their service hours extended, it was found that patronage gains were as expected when compared with international evidence. However, these increased service levels were found to be effective in decreasing transport disadvantage, as the extended hours opened up more employment opportunities and access for users.

A research project carried out by the Human Rights Commission in New Zealand looked into barriers faced by disabled people to using public transport. It is suggested that the lack of provision of accessible facilities and services, including both infrastructure such as footpaths, shelters and bus stops as well as the accessibility issues with the actual services, prevents the use of public transport services by disabled people (Human Rights Commission, 2005). It is argued that this in turn marginalises this group of people, forcing them into poverty and dependence.

2.1.4 | Work Related Transport Behaviour in New Zealand

Recent research in Auckland, New Zealand has found that work-related transport behaviours are influenced by both car parking availability and public transport accessibility (Badland et al., 2010). This study utilised data collected from a wider project concerning physical activity and nutrition. Results were mainly drawn from a self reported survey; however, a GIS program was used to assess accessibility to the closest public transport stop from a residential address, and also the distance to a workplace from a residential address.

This study found that respondents were more likely to use public transport services to commute to their worksite if they:

- had no access to car parking at their place of work
- lived less than 200 metres away from a bus stop
- worked in the central business district area
- had limited access to an automobile
- travelled 11-15 kilometres to work
- perceived public transport as accessible
- did not have a valid driver licence
- did not have a company car or require a vehicle for work purposes

These results suggests that people are more likely to use something that is convenient – such as a public transport stop that is close to their residence, or car parking that is freely available at their workplace. It also suggests that travel behaviours seem to be closely linked to life choices, and that many of the respondents in this study may have chosen to live in a location that supports their desired travel choice – for example, close to bus stops if they wish to commute by bus (Badland et al., 2010). Furthermore, the study has found that people are more likely to use public transport services if they perceive them to be convenient.

It should be noted that most measures in this study were self-reported (apart from those measured using GIS), which places some limits on the validity of the study. Nonetheless, this research shows important and relevant links between public transport use and a range of distance, land use, accessibility and convenience factors.

2.2 | Land Use Research on Public Transport Use

2.2.1 | Historic Links between Land Use and Public Transport Use

The influence of the evolution of new forms of transport has been noted to be important in influencing the development of the urban areas in the United States of America. The development of electric tramway services lead to suburban development being clustered along the routes of this services, typically with commercial uses along the route itself, with residential areas several blocks either side of this (Muller, 1986). The advent of the private car changed this, with areas some distance from tramway services becoming more easily accessible, and consequently being developed for residential purposes. The development of better roads, including freeways, has meant that areas that were previously considered to be too far from a city centre are now within an easy commuting distance. Such forms of development, however, have had major ramifications for the provision and use of public transport services. Consequently, public transport services are found to be well used in some major cities such as New York, and in specific situations, such as for transporting high school and college students (Fielding, 1986). Overall, however, they account for a very small proportion of trips taken (2.8% of all person trips in 1980).

A similar sequence of development of different transport forms also occurred in New Zealand and Australia. The history of public transport in Christchurch is detailed in Section 3.2.

2.2.2 | Recent International Research

Recent research on the links between transport and land use has provided varied results, sometimes showing a clear link and other times not – meaning that there is no clear consensus what, if any, link exists (van Wee, 2002). Reasons for the variation in research results include differences in research methods; the geographic scale at which research is undertaken; and between countries. These discrepancies in evidence suggest that land use planning should cater for a wide range of modes of transport, rather than focusing on just one.

European research has shown that major cities in different countries have large differences in the levels of use of public transport and private vehicles for commuting (Schwanen, 2002). It is suggested that this may be linked to urban form, but there are many other background factors that also contribute. In Madrid, the increased urban sprawl of the city has led to an increase in car use for work-related journeys, even where good public transport services are available (García-Polamares, 2010). This is particularly interesting, as traditionally Madrid was a compact city, with jobs concentrated in the central city and a consequent high level of public transport use.

The link between land use and non-work travel has also been identified. Research has shown that people are more likely to use modes other than the private car for non-work travel if they live in a neighbourhood with mixed land use, and where infrastructure to support other transport choices (including walking and cycling infrastructure as well as public transport services) is available (Cao et al., 2009).

Different land use patterns have been found to explain some of the differences in travel behaviour between people in the United States of America and Great Britain (Giuliano & Dargay, 2006). In Great Britain the number of daily trips undertaken and car ownership levels are both lower, and public transport use is higher. Greater population densities in Great Britain have often been used to explain why these rates differ, but it is suggested that wider land use issues are at play. In particular, the greater prevalence of mixed land uses in Great Britain reduce the needs of individuals to travel to source what they need, meaning that they can take shorter trips and use alternative modes to their car-focused US counterparts. Higher densities that are in close proximity to public transport services in Great Britain are also suggested as a key reason why car ownership in that country is lower than in the US. Furthermore, the costs of running a vehicle are higher in Great Britain, meaning that this option is less attractive to people. Importantly, it is noted that levels of accessibility are much more consistent across social groups in Great Britain, meaning that density is a much less useful proxy for transport disadvantage than it is in the US.

2.2.3 | Land Use and Public Transport in New Zealand and Australia

New Zealand cities have some of the lowest rates of public transport use in the world, along with cities in Australian and the United States of America (Newman et al., 2001). New Zealand cities have a greater population density, however, than those in Australia and the US (18 people per hectare, compared to 12 in both other countries). Research has also suggested that while some Australian cities can be classed as having an extreme automobile dependence, no New Zealand cities are in this category. Christchurch and Auckland have a high automobile dependence, while Wellington has a moderate automobile dependence.

Various reasons have been given for the low proportion of trips taken by public transport in New Zealand cities, including the dispersed nature of cities, low residential area densities, and the prevalence of suburban workplaces. However, it has also been contended that the situation in Auckland is solely due to the automobile-orientated policies which have became prevalent from the 1950s (Mees & Dodson, 2007). It is suggested that evidence for this is provided by the rapid fall in use of public transport services (from 290 unlinked trips per capita in 1955 to 41 trips per capita in 2005). The

1955 figure was very similar to other cities which still have a very high number of trips per capita, such as Toronto in Canada.

The argument that urban density is the main reason why public transport services are not successful in some cities is also questioned (Mees, 2009). It is suggested that evidence from Australia, Canada and the United States of America shows that population density has only a weak link to the proportion of trips to work made by public transport. Finally, it is noted that while land use planning is accepted as being important to increase public transport use, it is also important that the public transport services themselves are improved, and that new and innovative solutions are sought in the provision of such services (Mees, 2000).

2.3 | Commuting Patterns in New Zealand

The effects of urban growth on commuting patterns have been observed in research carried out in Christchurch. Over the period between 1991 and 2001, the proportion of journeys to work undertaken by car increased compared to other modes, while journeys by bus decreased (Buchanan et al., 2006). The majority of journeys to work were between two outer suburbs, rather than to a workplace in the inner city. However, bus journeys were predominantly between the outer suburbs and the inner city, suggesting that these services did not provide an adequate level of service for the majority of commuters. Furthermore, the average distance of journeys to work increased, particularly for people in lower density suburbs. These results are consistent with the greater levels of residential development on the urban fringe of Christchurch in recent years.

Further recent research has also explored the commuting patterns of workers in Christchurch, based on data sourced from the 2006 Census (Statistics New Zealand, 2009). Although other research has suggested that the majority of employment places in Christchurch are spread around the suburbs, these data indicated that the biggest commuting hub was the Cathedral Square Census Area Unit, which covers the majority of the Central Business District. Almost 26 000 people listed a workplace in this area unit.

The median distance commuters travelled to work in Christchurch was 5km in 2006, which was lower than Auckland (6 km) but higher than Wellington (4.8km). Public transport users across New Zealand tended to live relatively close to their workplace, 31% between 2 to 5km, and 28% between 6 to 10km. Public transport users were more likely to be women (58%), and over half of the total users were under 35 years of age.

Interestingly, the study noted that Wellington commuters were most likely to walk, jog or use public transport to travel to work. Christchurch commuters shared similar patterns with their Auckland counterparts, using these modes less. It is suggested that this can be attributed to the geography of the Wellington region, and public transport service provision. Other research has also highlighted the difference in commuting patterns in Wellington, noting the impact of the high population density and easily walkable areas surrounding the central business district (Dodson & Mees, 2003).

3 | The Study Area

3.1 | Selection of the Study Area

It was decided that the study area selected for the research should fall entirely within the boundaries of the Christchurch City Council (CCC), the territorial authority which governs all of the Christchurch urban area. Some of the Christchurch 'Metro' public transport network services extend beyond the CCC boundaries and into part of the areas of the Selwyn District Council and Waimakariri District Council, serving the towns of Lincoln, Rolleston, Burnham, Kaiapoi, Rangiora and Woodend. However, it was decided to exclude these areas from the study, as it is primarily focused on the main urban area of Christchurch City.

To allow for the use of sociodemographic information from the New Zealand Census of Population and Dwellings in the analysis stage of this research, it was decided that the study area should be made up of Census meshblocks. Meshblocks are the smallest spatial resolution at which information collected in the New Zealand Census is aggregated. In the 2006 Census, there were 3009 meshblock areas that fell within the Christchurch City Council boundaries. Of these, 122 fell within the area formerly governed by the Banks Peninsula District Council (BPDC). The BPDC merged with the CCC in March 2006, and the BPDC is now entirely encompassed by the Banks Peninsula ward of the CCC. It was also decided to exclude all areas that fall within the Banks Peninsula Ward from this study, as they are predominantly rural. Although not rural, the township of Lyttelton, which is separated from Christchurch by the Port Hills, was also excluded. This is because of its unique location and character – a small port town – together with its segregation from the main urban area of Christchurch.

The remaining part of the CCC area also includes a number of rural areas on the periphery of the city. The meshblocks in these areas are generally much larger in area than those in the urbanised areas, and including them in the research could lead to skewed statistics. To eliminate the larger rural meshblocks, a criterion excluding all meshblocks larger than 0.3 square kilometres in size was applied. This also removed some meshblocks from industrial areas in the city, which was a desirable outcome as the study is focused on urban residential areas.

However, a few slightly larger meshblocks within the urban area were also excluded through this criterion. To allow for this, it was decided to add a second criterion which took into account population density. All meshblocks with a population density of 500 people per square kilometre or greater were included regardless of the size of the meshblock area. This meant that the only meshblocks excluded in the city area were either those that covered open space, such as Hagley Park, or meshblocks that were predominantly industrial, with a low residential population.

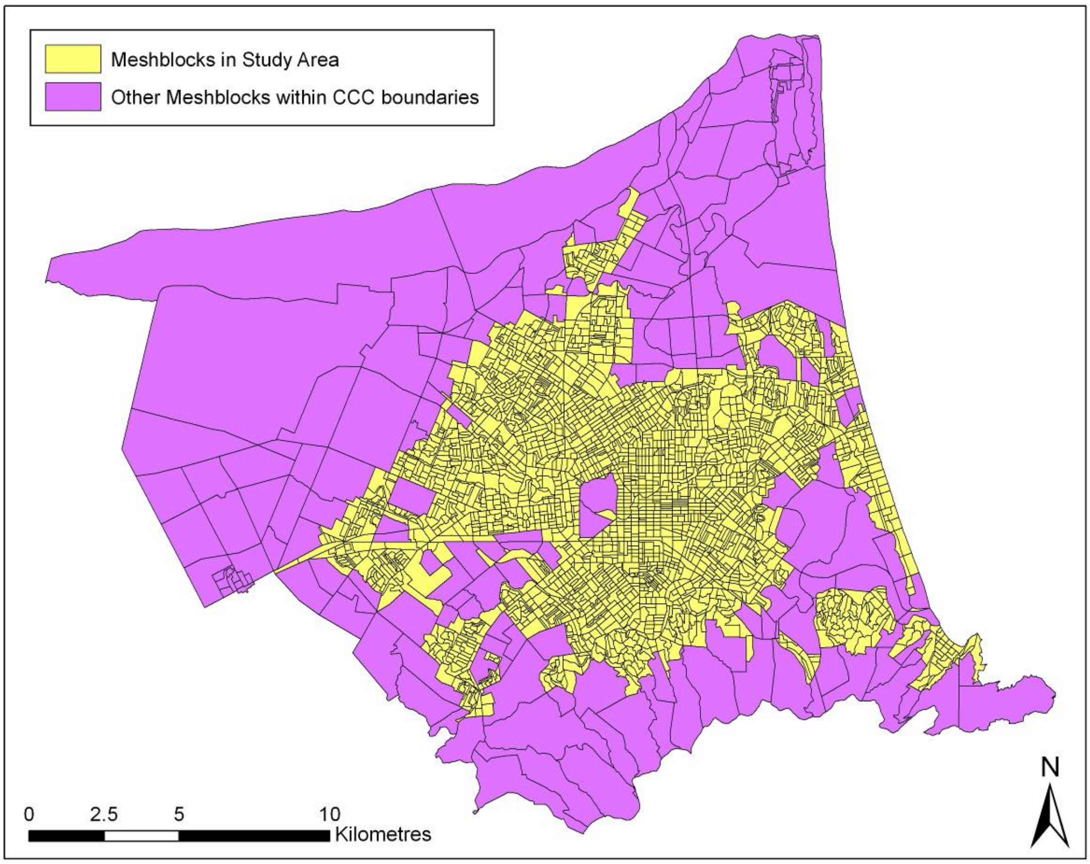

Figure 3.1: The final study area, shown against the wider area governed by the Christchurch City Council (excluding the Banks Peninsula Ward).

Finally, a number of meshblocks that met one of these criteria but were separated from the main urban area by a rural boundary were removed, as it was decided that these areas have significantly different characteristics to the main, contiguous urban area. These areas included Templeton and Brooklands.

These restrictions left a study area of 2700 meshblocks, covering a land area of 149.3 square kilometres. The final study area is shown in Figure 3.1. Figure 3.2 shows the location of the study area in the Greater Christchurch area, while Figure 3.3 shows the locality of suburbs which are mentioned later in the research within the study area.

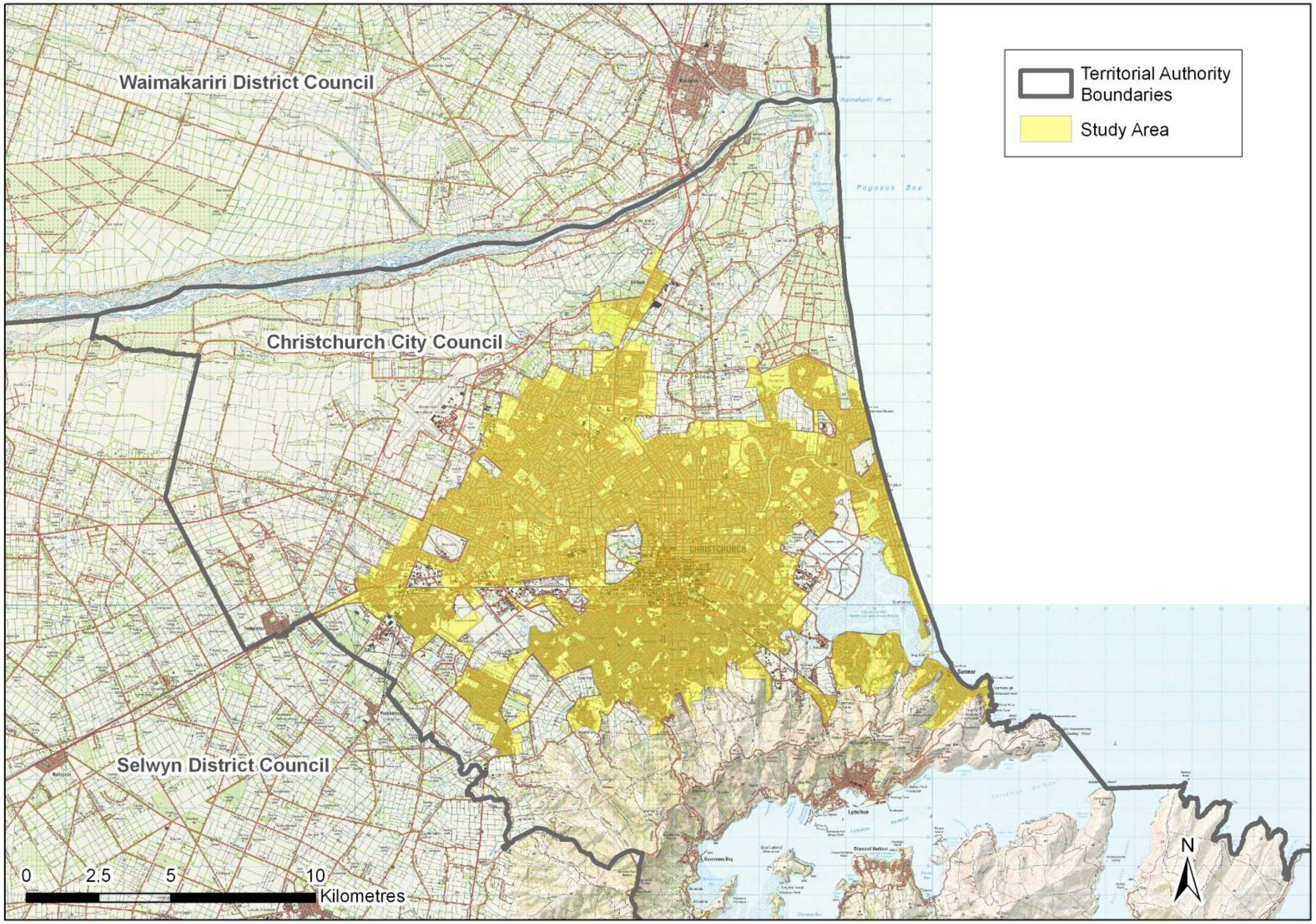

Figure 3.2: Shows the study area within the Greater Christchurch area (Topographic Map Imagery sourced from Land Information New Zealand).

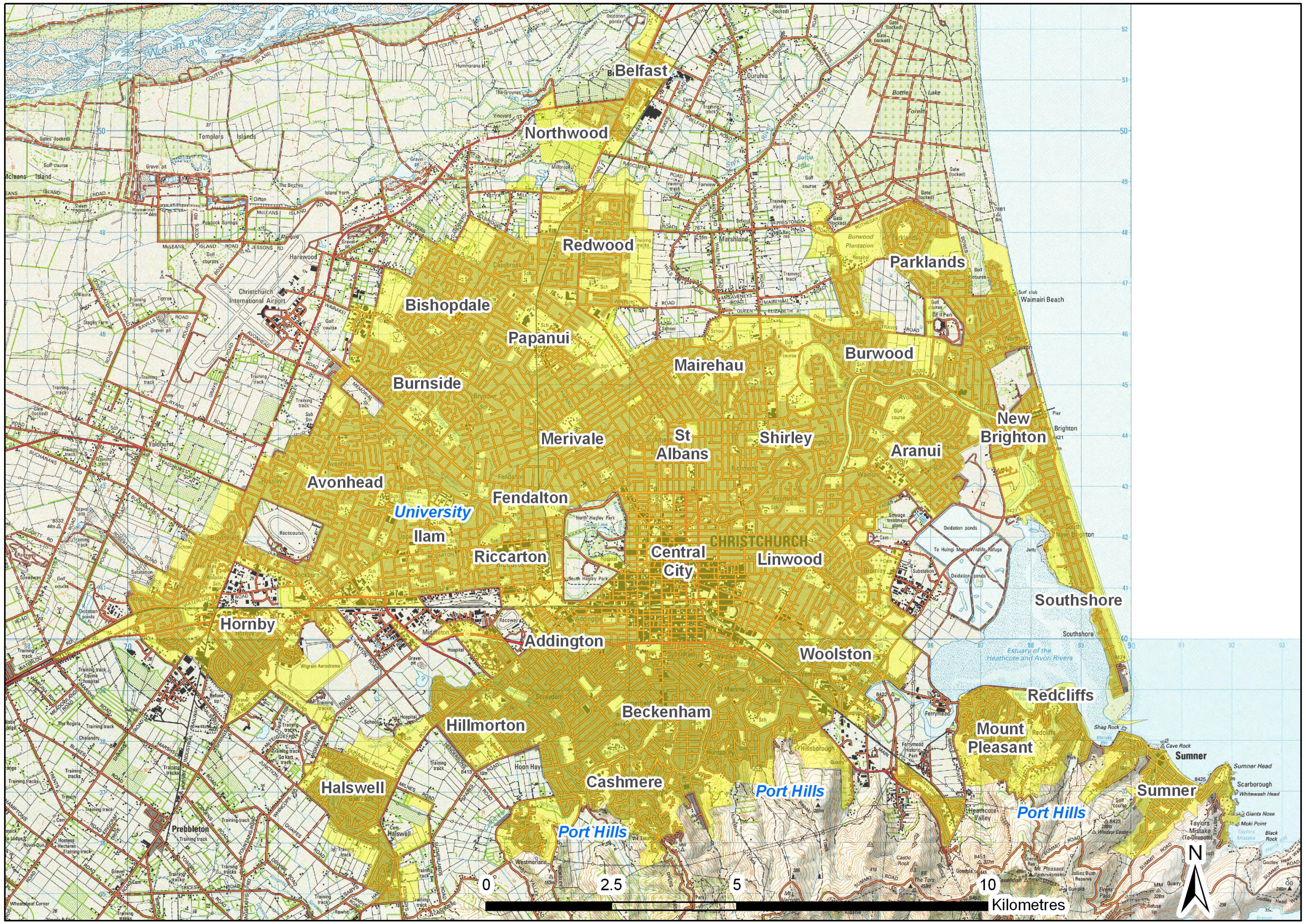

Figure 3.3: Shows the location of suburbs within the study area (Topographic Map Imagery sourced from Land Information New Zealand).

3.2 | History of the Christchurch Public Transport Network

Public transport services have been provided in Christchurch in one form or another for since the city since soon after the city was settled in 1850. Earliest omnibus services where horse drawn services, which ran as early as 1852, and became commonplace by the mid 1860s (Alexander, 1985 a). Rail services were quick to commence as well, with the first railway in New Zealand opening between Christchurch and Ferrymead wharf in 1863, followed closely by services to the Port of Lyttelton through a newly completed rail tunnel in 1867 (Dew, 1988).

A tramway service was under discussion as early as 1855, but the first services did not eventuate until 1880, when a steam hauled tram line opened between Cathedral Square and the Christchurch Railway Station (Alexander, 1985 b). These steam tram services evenutually extended as far as Papanui, Addington, the foot of the Cashmere Hills and Sumner, and were supplemented with horse drawn tram services to New Brighton.

An electric tram service began in 1905, replacing the Horse and Steam drawn routes, and extending services to a number of other suburbs (Alexander, 1986). These routes radiated out in all directions from a hub in Cathedral Square. In a similar way to the American experience detailed in Section 2.2.1, the tram network was to have a major influence on the layout and growth of Christchurch city until after the Second World War. New housing developments quickly sprung up alongside new tram routes. This pattern of development is generally similar to what has been described in the United States (Muller, 1986). New opportunities were opened up, such as development on the Port Hills, which were served by the Cashmere Hills route. Sumner and New Brighton beaches were popular for weekend excursions, as well as being viable places to commute to the city daily from.

The first motor bus appeared on the streets of Christchurch in 1904 (Dew, 1996). Initially, services were sparse, and were generally feeder or supplementary services to the tram network. In 1931, an electric Trolley bus service began to the North Beach area.

From the 1930s onwards, petrol and diesel buses also began to be introduced. Initially, the services operated to areas not served by trams, but in 1936 they replaced tram services to Linwood and Dallington. However, the outbreak of World War Two halted further route conversions, due to fuel and tyre shortages. At the same time, fuel restrictions also caused the public to have a greater reliance on public transport services for the duration of the War. New bus routes were opened to new housing developments from 1946, and tram routes began to be closed in earnest from 1950. The final trams were withdrawn in 1954. Bus services were much more flexible than the tram services which they replaced, and consequently urban development was no longer constrained by layout of the public transport network. In fact, the pendulum swung from new housing being built around public transport services, to public transport services being created or extended to travel to new housing developments.

Although there have been a number of route extensions and new routes added to the network since the 1950s, the general shape of the network remains remarkably similar. The majority of routes still radiate out from the central city (with the exception of two cross-suburban routes). The greater availability and reducing cost of private vehicles has meant that bus patronage continually reduced for the second half of the twentieth century. Deregulation of bus services in 1991 caused further upheaval. Bus patronage levels started increasing again in the mid-1990s, as service improvements began to take effect.

3.3 | The current Christchurch Public Transport Network

Today, the Christchurch public transport network is formed primarily of bus routes, although there is one ferry route which travels across Lyttelton Harbour. For this research, the bus routes were divided into two service level groupings:

- 'core' routes – those which run every 15 minutes or more frequently on weekdays
- 'non-core' routes – those which run less frequently, usually every 30 or 60 minutes on weekdays.

These service level groupings are also used by Environment Canterbury for network planning purposes.

In some parts of the city, such as Papanui Road and Colombo Street, two or more non-core routes combine (for part of their route) to provide a service equivalent to that of a core service. Such sections of these routes have been included as core routes in the research.

The Bus Routes used are correct as at the time which the Metrocard data pertains to (May – August 2009), and consist of nine 'core' routes and 24 'non-core' routes. There are a further three corridors where non-core routes combine to provide a core route frequency. The bus routes included in this research are listed in Appendix One. A number of bus routes changed significantly from November 2009. These changes took place after the study period and are not represented in this research.

There are a number of smaller services on the periphery of the city which offer a shuttle service from an outlying town. These shuttle services do not travel into the city centre, but rather connect at an interchange point to more frequent routes. These shuttle routes have been excluded from this research, as they have a distinctly different nature to other bus routes in the city. These routes are:

- 480 The Palms Mall - Kainga
- 518 Hornby – Lincoln
- 520 Hornby – Rolleston and Burnham
- 521 Hornby – Templeton
- 912 Kaiapoi – Rangiora via Woodend
- 913 Kaiapoi – Rangiora via Woodend and Waikuku Beach
- Lyttelton – Diamond Harbour Ferry

Furthermore, four peak-only services have also been excluded, as they have a very low and irregular frequency. These are:

- 5X Southshore Express

- 28 Rapaki (only the section of route between Lyttelton and Rapaki, which has an irregular and infrequent service)
- 77 Kennedys Bush
- 92 Rangiora – Christchurch via Waikuku Beach, Woodend and Kaiapoi
- B Burnham – Christchurch via Rolleston

School Bus Services, After Midnight Services and the Free Inner City Shuttle are also excluded from this study.

The Christchurch bus network (as at the time of the study period and excluding the shuttle and irregular routes not included in the research) is shown in Figure 3.4.

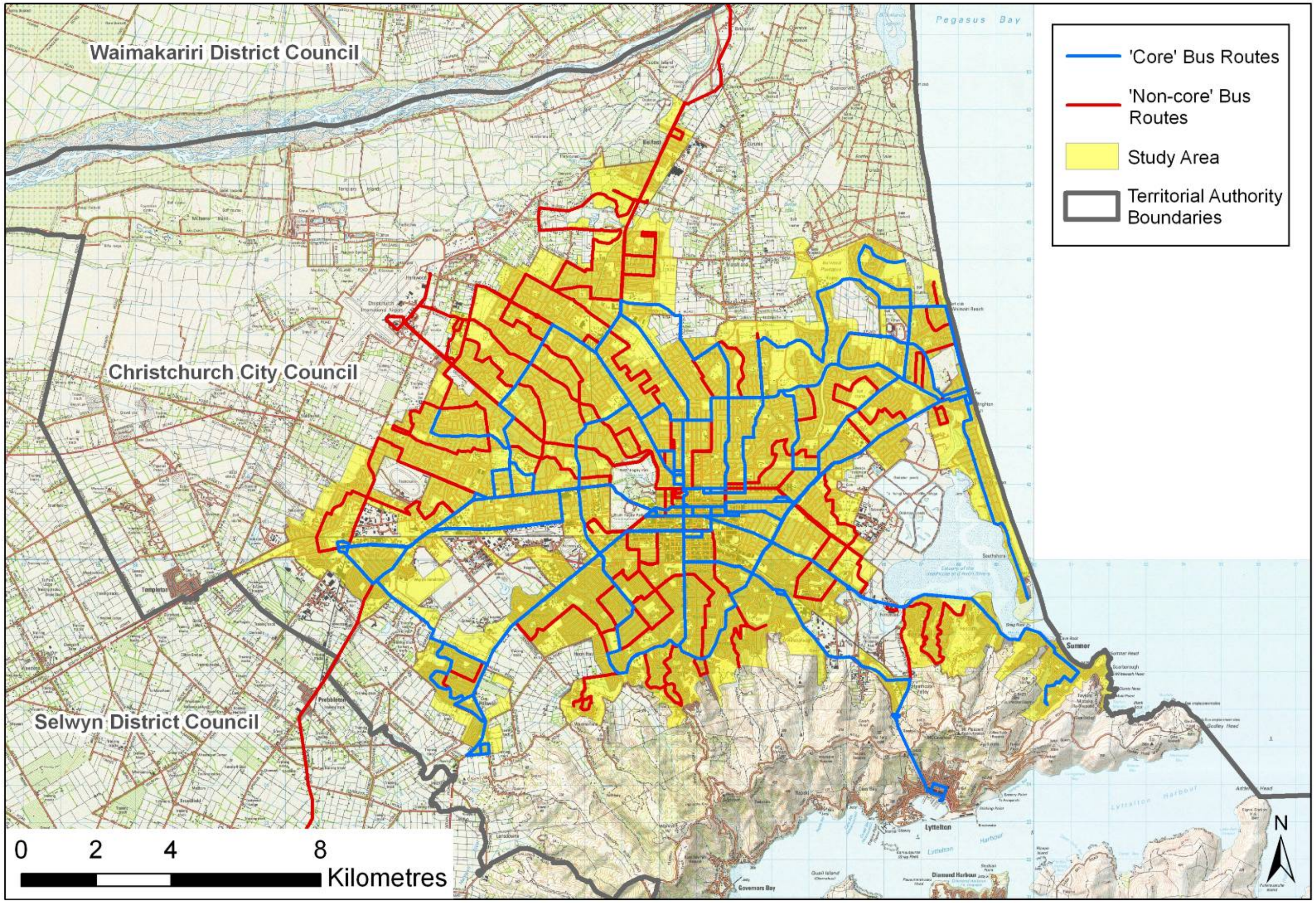

Figure 3.4: The Christchurch Bus Network during the study period (Topographic Map Imagery sourced from Land Information New Zealand). Note: Bus routes excluded from this research are not shown on this map.

4 | Research Methods

4.1 | Data Sources

4.1.1 | The Metrocard Dataset

The primary source of data for this study was the Metrocard dataset obtained from Environment Canterbury. The dataset consisted of address and transaction information, primarily relating to a three month period from 24 May to 23 August 2009.

Metrocards are smart cards used by bus and ferry passengers to pay for travel on the Christchurch public transport network. The cards hold a monetary value, which the user can 'top up' at any time. Passengers using Metrocards receive a discount on the normal cash fare; this discount is usually around one quarter of the normal fare. For example, during the period of this research the normal cash fare for an Adult zone one trip was $2.80, while a Metrocard fare for the same zone was $2.10 (zone one includes the majority of the Christchurch urban area, and encompasses the entire study area for this research).

As a further incentive, Metrocard users also have a daily and weekly limit on how much their travel can cost. In zone one, adult passengers using a Metrocard have a daily limit of $4.20 (the cost of two trips) and a weekly limit of $21.00 (the cost of ten trips). These benefits are designed to encourage regular bus users to use a Metrocard to pay for their fares. The use of Metrocards speeds up passenger boarding times on buses, and reduces the amount of cash drivers are required to handle. In August 2009, 72.83% of public transport trips in Christchurch were made using a Metrocard.

When applying for a Metrocard, applicants must state their name, address, phone number and date of birth. These are all held in a database by Environment Canterbury. Other information held in the same database and associated with the same cardholder record include:

- the serial number of the card

- the date on which the card was issued
- the total number of transactions (trips) made using the card
- the most recent time and date the card was 'topped up' with money
- the total value of money held on the card at the time

All values held in the database are current at the end of the previous working day; they are updated overnight rather than in real time.

Metrocards have been used in Christchurch since November 2003. At the time the dataset was sourced (August 2009) over 294 500 cards had been issued. However, many of these cards are replacements for previously lost, damaged or faulty cards; or belong to people who no longer live in Christchurch or who no longer regularly use public transport. In order to select cards that were still active and regularly used from this large database, two key criteria were applied:

First, only Metrocards that had been used for travel within the three month period from 24 May 2009 to 23 August 2009 were selected (the dataset was sourced from Environment Canterbury on 24 August, and technical restrictions meant that the data sourced was required to be for a set period of months immediately preceding this date). A total of 74 360 cards met this criterion, which was used to identify active card holders. It is dutifully acknowledged that this criterion excludes cards which are still active but which are not regularly used. However, this research is primarily focused on current and frequent public transport users.

Second, Metrocards were only selected if they had been used over 50 times since being issued. This criterion was chosen to exclude cards which may have been active during the three month period, but were only used by occasional or irregular passengers. Once this criterion was applied, the dataset which met both criteria totalled 60 762.

It is recognised that the selection methods chosen would exclude very regular travellers who had recently had their cards issued but had not yet reached the 50 trip threshold. It is also noted that the criteria used would mean that cardholders who had misplaced their cards and had new ones issued within the study period could be represented twice in the dataset. This duplication would, however, be dependent on both cards being over the 50 trip threshold.

There are some issues with the Metrocard dataset which should be noted at this point. First, the information contained in the dataset was not collected for research purposes, and hence some fields contain extraneous information not related to the research (as well as the actual information sought). For example, information on whether the card has been lost or stolen is often contained in the same field as the residential street address.

Furthermore, the residential address held in the dataset was only correct at the time when the card was issued. There is no requirement for Metrocard holders to provide a new address to Environment Canterbury if they move house. Furthermore, there is no way of monitoring whether cards have been passed between people, meaning that a card could be no longer used by the person to whom it was initially issued. However, it is assumed that such issues should be relatively evenly spread, both across the dataset and across the study area, meaning that it is less likely that the validity of the research is affected.

Finally, the use of the Metrocard database in this research presented a number of confidentiality issues, as the privacy of cardholders could be impinged on. Environment Canterbury required that a confidentiality clause was signed (a copy of this is attached in Appendix Two). This clause prohibited the disclosure of the identity of any cardholder, or any other form of confidential, private or identifying information. Furthermore, the dataset provided by Environment Canterbury excluded the name, phone number and date of birth of all cardholders.

Consideration of the ethical implications of using the Metrocard database was also required to be made. This research was able to qualify as a 'low risk' application due to the measures taken to protect the confidentiality of Metrocard holders. The application was reviewed and approved by the Department of Geography and by the Chair of the

University of Canterbury Human Ethics Committee. A copy of the ethics approval is attached in Appendix Three.

4.1.2 | Bus Route and Bus Stop Dataset

The bus route data used in this research was sourced directly from Environment Canterbury. The data came in the form of at least two polyline shape files for each route (one separate shape file for each direction of the route, with further files if there were any variations or extensions to the route on certain services). The routes used were those current as at August 2009.

These shape files were merged using the ArcCatalog program to form two more comprehensive shapefiles. The first incorporated all 'core' bus routes (those with a 15 minute or greater weekday daytime service), and the other all 'non-core' bus routes (those with less frequent service provision – usually with frequencies of every 30 or 60 minutes on weekdays). Care was taken when forming these merged route shapefiles to make sure that route variations on the inwards and outwards services were also included. As noted previously, a number of shuttle or infrequent bus and ferry services were excluded from this study.

The bus stop dataset (a point shape file) was also sourced from Environment Canterbury. The most recent dataset available was from 2006, meaning that a small number of recent bus stop additions, deletions and changes were not represented.

4.1.3 | Census Meshblock Dataset

This dataset contains a wide range of variables at the meshblock level of aggregation obtained from the 2006 New Zealand Census of Population and Dwellings. Information in this dataset covers variables about people, families, households and dwellings. As previously noted, meshblocks are the smallest spatial resolution at which Census data is aggregated. There are strict confidentiality measures in this dataset, meaning that values are withheld in some cases to protect the confidentiality of individuals and families.

Variables covering the following areas were sourced from this dataset:

- Age
- Ethnic group
- Property ownership
- Employment status
- Transport mode used for travel to work
- Vehicle ownership
- Years lived at current residence
- Country of origin
- Number of years lived in New Zealand
- Current study participation (the number of people aged 15 years or older studying at a school or any other education institution)

4.1.4 | New Zealand Deprivation Index Dataset

An Index of Deprivation calculated at the meshblock level was also used in the study. This index was calculated by the Department of Public Health at the University of Otago, Wellington using a number of census variables (Salmond et al., 2007). The index, termed the NZDep06, is used extensively in health and social science research, as well as for funding allocation purposes for healthcare and social services. Importantly, the index relates to areas, rather than the people who live within these areas. Census variables used in the calculation of this index include measures of income, home ownership, family composition (in particular, single parent families), unemployment, qualifications, living space (a measure of the number of people living in a dwelling), access to telecommunications, and access to vehicles.

In this research, the NZDep06 ordinal scale values have been used. This scale ranges from 1 (least deprived) to 10 (most deprived), with each number representing 10 percent of the areas of the country. For example, a score of ten indicates that the meshblock in question falls within the 10% of most deprived meshblocks in New Zealand. It is important to note that as the Index of Deprivation covers the whole of New Zealand, the number of meshblocks which fall into each category on the scale are not equal within the study area (see Table 4.1). Of particular importance is the fact that the number of meshblocks in the most deprived tenth is significantly underrepresented within the study area (only 176 of the 2700 meshblocks, or 6.52%).

Table 4.1: Shows the number of meshblocks which fall into each ordinal scale value within the Study Area.

NZDep06 Ordinal Scale	Number of Meshblocks	Percent of Meshblocks
Least deprived - 1	299	11.07
2	222	8.22
3	242	8.96
4	272	10.07
5	277	10.26
6	305	11.30
7	262	9.70
8	332	12.30
9	313	11.59
Most deprived - 10	176	6.52

4.2 | Geocoding Process

The 60 762 Metrocard records that fitted the selection criteria were converted to a point data file through a geocoding process. The ArcGIS 9.3 software package was used for geocoding the addresses, and was also used in subsequent analysis. The address locator tool used for geocoding was developed for use with the Arc 9.x package by Eagle Technology, and was released in June 2006. It incorporates cadastral information supplied by Land Information New Zealand (LINZ).

The software requires two fields of information to be provided – ADDRESS and ZONE. The ADDRESS field needs to contain the number and street name of the residence, while the ZONE field needs to state the suburb name. These two fields match with the first two address fields of the Metrocard dataset. The third field in the Metrocard dataset, which contains the city name, was not used in the geocoding process.

Initially, the geocoding software standardises the address information provided. This removes any extra information contained in the address field, so that the address conforms to the following format:

PROPERTY NUMBER | STREET NAME | STREET TYPE

Any extra detail, such as a letter associated with the property number, is removed. The software then searches the address locator database, attempting to match the standardised address with one which has been provided by LINZ. If matched, a percentage score of accuracy is given – a 100% score indicates that the standardised address exactly matches one in the database. Where there is a minor error in the spelling of a street or suburb name, the software will generally still match the address but with a lower accuracy score. Where there are two addresses in the database that exactly match the standardised address, the software will award a 'Tied' result, and will match the address to the first entry in the database.

Initially, several small test runs were conducted using a portion of the dataset. These tests allowed the process to be checked to ensure that address points were being geocoded correctly, and also that the software could handle a large dataset without any glitches.

After these tests proved to be successful, the first run was made where all 60 762 addresses were included for geocoding. The number of addresses in this dataset meant that this process took over 20 hours to complete using the computing resources available. The results of this first run were:

Addresses Matched	35 882	(59.1%)
Addresses Tied	6 235	(10.3%)
Addresses Unmatched	18 645	(30.7%)

Where results are tied the geocoding software is unable to decide between two or more records of equal value which the address could match. Upon further investigation into the high number of tied results in this first run, it was found that the software could not differentiate between cases where there is more than one property associated with the same street number – such as cases where addresses include letters as well as numbers.

For example, the hypothetical addresses 105a Smith Street and 105b Smith Street would both be recorded in the address locator database as 105 Smith Street. This means that if an address was matched to this location it would be recorded as a tie, as the system has no way of differentiating between the two entries. While it is likely that two addresses like 105a Smith Street and 105b Smith Street would be in slightly different physical locations, this difference is likely to be minimal (in most cases, only a few metres). Therefore addresses which fall into this situation are still geocoded to the correct geographic location, or a location very close to this. For this reason, tied addresses in this study are treated the same as matched addresses. This means that in the first run, a total of 42 117 of the 60 762 addresses entered (or 69.3%) were matched to a geographic location.

Attention was next turned to why 18 645 addresses were unable to be matched to an address in this first run. Reasons for this were found to include:

- either the address or zone being blank (the system could generally only recognise an address if both of these fields contained information)
- the suburb listed not being recognised by the software
- a postcode being present in the address or zone field, which the software could not recognise
- spelling errors in either of the address or zone fields
- other information which had been stored in either the address or zone fields, such as details about whether a card had been lost, listed as stolen or replaced
- a Post Office Box number being supplied instead of a street address
- a Rural Delivery number being present in the address or zone field
- records being incorrectly entered into the wrong fields of the database (such as address information being entered into the suburb field, and vice versa)
- address formats that were not recognised by the software:
    - C/- of (or variations thereof)
    - Flat X/XX (or variations thereof)
    - Unit X/XX (or variations thereof)

- addresses at institutions, such as University Halls of Residences, not being recognised

Furthermore, it was also noted that in a small number of cases where no suburb information was present, addresses were incorrectly being matched to a location with the correct road address in a city other than Christchurch. Given that no suburb information was present, this match could well have been incorrect. Many of these problems were not able to be remedied, particularly those where no residential address was provided. Others could not be fixed without making unjustifiable assumptions about the address, such as altering address formats that were not recognised.

However, several changes were possible to increase the number of addresses that could be matched from the dataset. Firstly, all records which contained either blank address or zone fields or where both fields blank were blank were removed. This reduced the dataset by 5 020 records in size to a new total of 55 742 addresses.

Next, attention was turned to the cases where the suburb entered in the zone field was not recognised by the software. These suburbs were identified by close analysis of the first run results, and by testing suburb names in the geocoding software to see whether or not they were recognised. Where suburb names were not recognised by the software, they were replaced with the name of an adjacent suburb that was recognised. For instance, the suburb name 'Barrington' was not recognised, so all records which had this suburb name listed were changed to the name of the adjacent suburb, 'Spreydon'.

Postcodes listed in either the address or zone fields were also manually removed. At the same time, minor spelling mistakes in the data were corrected, and other extraneous information was also removed. Finally, records where a University Hall of Residence was listed as the cardholder's residential address were corrected to an accurate street address, so that these were recognised by the software.

Following these changes, the modified dataset was run through the geocoding software again (the results of the original geocoding run were discarded). The results of this second run were:

Addresses Matched	42 390	(76.0%)
Addresses Tied	6 965	(12.5%)
Addresses Unmatched	6 387	(11.5%)

In total 49 355 of the 55 742 address records (88.5%) were successfully matched to a geographic location.

4.3 | Mapping the Location of Cardholders

After the cardholder addresses had been successfully geocoded, it was possible to assess how many of them fell within the study area.

As any public transport user is able to obtain a Metrocard, cardholders do not necessarily come from Christchurch or surrounding districts. The address locator used in this research geocoded addresses from all over New Zealand, and the geographic spread of cardholders across the country is shown in Figure 4.1. While many of the cardholders from outside Christchurch may be short-stay visitors to the city, the criteria previously detailed, which was used to select only regular Metrocard users, suggests that most are staying in Christchurch for an extended period of time but are people who still give their residential address as somewhere else in New Zealand – such as students studying in the city. It should be noted that any cardholders who gave an international address would have fallen into the ‘unmatched’ category, as the address locator used only covered New Zealand addresses.

Of the 49 355 addresses which were able to be matched to a geographic location in the second and final run:

- 46 570 (94.4%) were from within the Christchurch City Council Boundaries

- 1 262 (2.6%) were from within the Waimakariri District Council Boundaries
- 1 109 (2.2%) were from within the Selwyn District Council Boundaries
- 245 (0.5%) were from elsewhere in the South Island
- 169 (0.3%) were from the North Island

44 591 addresses (90.3% of the overall records geocoded) fell within the Study Area defined for this research. Figure 4.2 shows the general location of cardholders within the Greater Christchurch area.

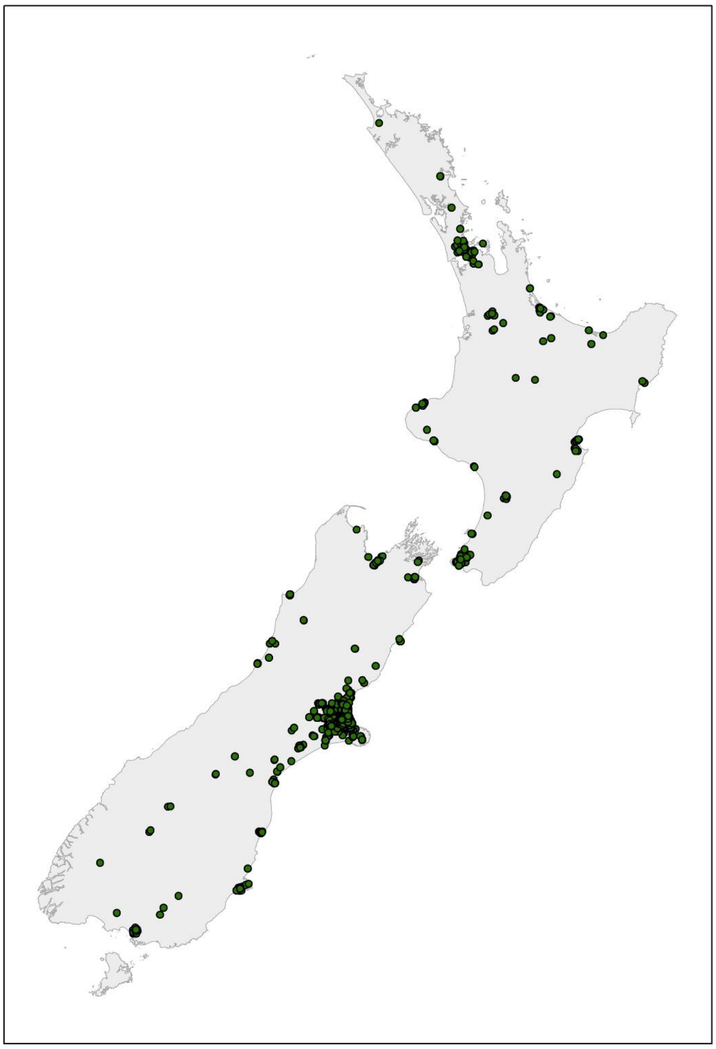

Figure 4.1: Shows the Geographic spread of cardholders across New Zealand. Note that while the majority of cardholders come from the Canterbury region, there are cardholders from most parts of New Zealand.

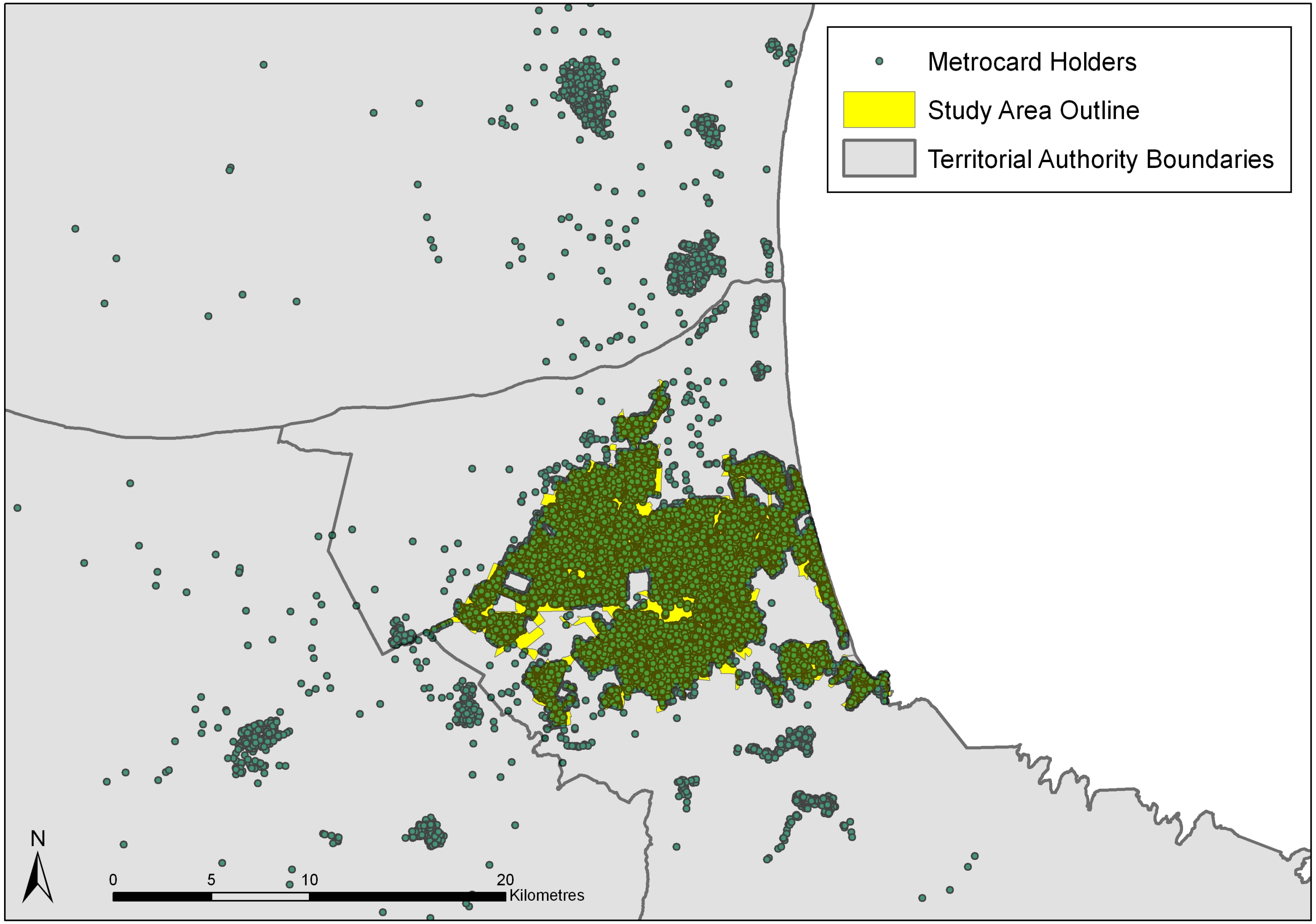

Figure 4.2: Shows the location of Metrocard holders within the Greater Christchurch area. The study area is highlighted.

To allow for statistical analysis to be undertaken, the cardholder address points needed to be converted into a total number of cards per meshblock. As shown in Figure 4.3, the address points are distributed throughout each meshblock area. These points are a separate layer to the polygon meshblock layer beneath them, so needed to be spatially joined to allow analysis to be undertaken. The ArcGIS *Join by Location* tool was used, all points within each meshblock being counted to produce a total as shown in the Figure 4.4. Note that in Figure 4.3 not all points are visible, as in some cases there may be more than one cardholder at a specific address (and hence points are hidden underneath each other); and also that not all of the total area of the meshblocks around the edge of the map is visible – explaining why the total number of points in each meshblock shown in Figure 4.4 may be higher than the number of points visible in Figure 4.3.

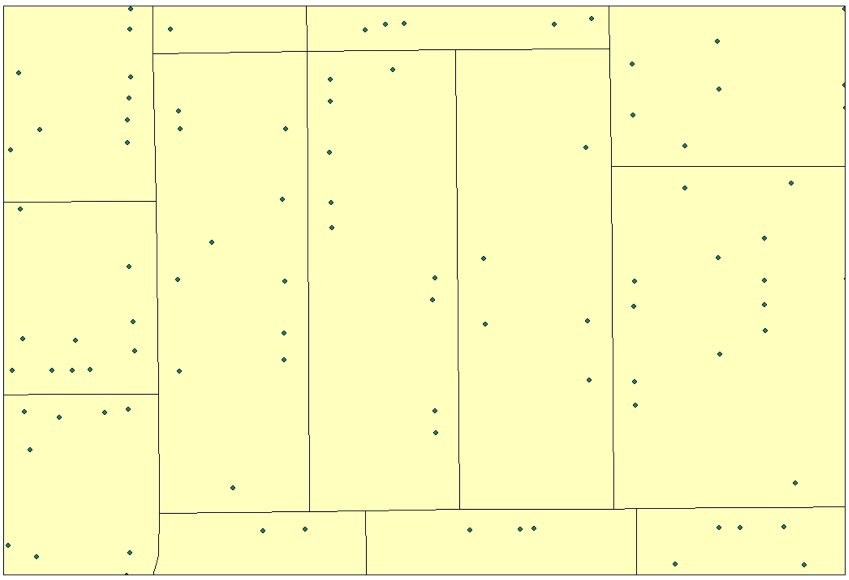

Figure 4.3: Shows how the address points are distributed around some example meshblocks.

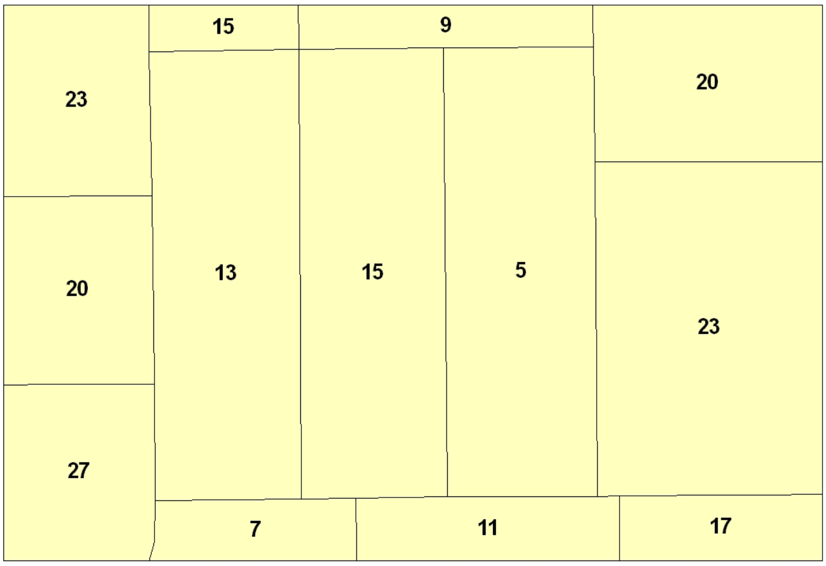

Figure 4.4: shows the same meshblocks as in Figure 4.3, with the total number of address points in each meshblock counted.

Finally, the number of Metrocard users per meshblock was calculated. This was done using the 'Usually Resident Population' variable from the 2006 New Zealand Census of Population and Dwellings. The number of Metrocard holders was divided by the Usually Resident Population, and then multiplied by 100 – giving a proportion (and percentage value) of Metrocard holders per 100 residents for each meshblock within the study area.

4.4 | Analysis of Data

4.4.1 | Proportion of Metrocard Users in each Meshblock

For the first stage of analysing the results, the proportion of Metrocard users in each meshblock was mapped, and clusters of meshblocks of high and low Metrocard users were visually identified.

The ordinal scale values of the NZDep06 index were also mapped. Visual comparisons were made between areas of high and low deprivation and areas with a high and low proportion of Metrocard holders, and similarities in the distribution of these areas were noted. These observations were supplemented with calculations into the proportion of cardholders in each deprivation level, and the resulting trend was graphed.

4.4.2 | Distance of Metrocard Holders to Bus Routes and Bus Stops

The influence of the distance to the nearest bus stop and bus route is investigated in a number of ways. Firstly, the distance to bus routes is visually compared with the proportion of cardholders in meshblocks, and the deprivation of meshblocks. The number of cardholders within a certain distance increments of bus routes and bus stops (for example, within 50m or within 100m) is calculated using the ArcMap *Select by Attribute* tool. These totals are then used to calculate the percentage of cardholders in each distance increment. In a similar way, the percentage of cardholders within 200m of a bus route in each deprivation level is also calculated. To aid with the interpretation of these results, maps showing the land areas within 200 metres of bus routes and bus stops have also been produced.

Next, the distance from each cardholder address point to the closest bus stop, core bus route and non-core bus route was calculated using the ArcInfo *Near* tool. These results were then aggregated, so that the average distance of the address points in each meshblock to their nearest bus stop and core and non-core bus routes was found.

4.4.3 | Regularity of Metrocard Use

The regularity with which Metrocard holders use bus services was calculated using two of the variables from the dataset supplied by Environment Canterbury – the date which the card was issued, and transaction count (which is a record of how many times the card has been used to pay for travel). The number of days between the date which a card was issued and the date the data was sourced was calculated in a spreadsheet. The transaction count was then divided by the number of days since the card was issued to calculate the number of trips taken by the cardholder per day. The average number of trips per day for each meshblock was calculated by using ArcGIS *Join by Location* tool in the same way as previously detailed in Section 4.4. This was then mapped and visually compared with the level of deprivation in a parts of the study area.

The trips per day values of individual cardholder points were also used in analysis. The relationship between the distance to a bus route and the regularity of bus use was tested by calculating the average number of trips per day in 50m distance increments from the nearest bus route using the same method as in Section 4.4.2. These two results were then combined with the distance to the nearest bus stop, as well as the NZDep06 index value and density of the meshblock in which the address point was located, in a correlation analysis to test the relationship between these variables at the individual cardholder level. A similar correlation analysis was also carried out for a number of variables at the meshblock level. These included the proportion of cardholders per meshblock, the deprivation and density of the meshblock, the average number of trips taken per day in the meshblock, and the average distance of the meshblock to the nearest bus route and bus stop. These two correlations allowed for a comparison of results at the individual cardholder level with results at the meshblock level, which was useful as most of the results thus far have only been able to be calculated at the meshblock level.

4.4.4 | Land Use and Density

To assess the influence that different land use types exert on public transport use, a city plan zone layer file was sourced from the Christchurch City Council. This layer covered the entire Christchurch City Council area, and was subsequently modified using the ArcGIS Clip tool so that all areas outside of the study area were excluded. The address location point file was then joined to the zone layer file, allowing for the number of cardholders within each CCC zoning category to be assessed.

Every land parcel in Christchurch is zoned according to the purpose it is allowed to be used for. For example, commercial business and industrial areas are zoned 'Business', Schools 'Cultural', recreation areas 'Open space' and residential areas 'Living'. These wider categories are split down into more specific zones according to the exact use for which the land can be used. For example, within the 'Cultural' zoning, Schools are zoned as 'Cultural 3'and Tertiary Education facilities as 'Cultural 4'. The proportion of cardholders within each of these wider categories, and within each of the zoning types in the 'Living' category, has been calculated. Unfortunately the population density of each Living zoning was not able to be calculated, as no population information for the Living zone areas within the study area was available. However, the population density of each meshblock within the study area has been calculated, and this is mapped to allow a comparison with the location of Living zone areas.

4.4.5 | Correlation Analysis

In order to assess the relationships between a number of possible factors which influence public transport use, correlation analysis was undertaken involving the proportion of cardholders, and a number of variables included in the 2006 Census of Population and Dwellings. The data sourced from the census included 55 variables from the following areas:

- Age
- Ethnic group
- Property Ownership
- Employment status
- Transport mode used for travel to work
- Vehicle ownership
- Years lived at current residence
- Country of Origin and years lived in New Zealand
- Current Study Participation

All 55 variables are listed in Appendix Four. The ordinal scale of the NZDep06 Index, and the population, area and population density for each meshblock were also included in this analysis, giving a total of 60 independent variables. These variables were selected to represent a wide range of factors which are theorised to impact on the choice of individuals to utilise public transport services.

The correlations between the proportion of Metrocard holders and the 60 independent variables were calculated using the SPSS statistical analysis programme. A significant positive relationship was identified between the proportion of Metrocard holders and 26 of the census variables (at the 0.01 level). Of these 26 census variables, 7 were excluded from further analysis to prevent the duplication of data in more than one variable. The 19 variables that were included in further analysis are shown in Table 4.2. Those excluded from further analysis are shown in Table 4.3, and the reasons for this exclusion are given.

Table 4.2: The 19 variables found to have a significant positive correlation with the proportion of Metrocards per meshblock.

Variable	Correlation coefficient with proportion of Metrocards per meshblock
NZDep Index Deprivation Scale 2006	.166**
Proportion of the working population who travelled to work by Bus on the day of the Census	.236**
Proportion of the working population who travelled to work by Bicycle on the day of the Census	.059**
Proportion of the working population who travelled to work by walking on the day of the Census	.079**
Proportion of population who are unemployed	.152**
Proportion of population who are not in the Labour force (e.g. Retired)	.065**
Proportion of households with access to no vehicles	.191**
Proportion of households with access to one vehicle	.126**
Proportion of population aged between 15 and 24	.132**
Proportion of population aged between 25 and 49	.055**
Proportion of the population who have lived at their current residence for less than one year	.092**
Proportion of population born outside New Zealand	.164**
Proportion of population born outside New Zealand that have lived in the country for less than 10 years	.094**
Proportion of the population of Maori ethnicity	.067**
Proportion of the population of Pacific ethnicity	.063**
Proportion of the population of Asian ethnicity	.128**
Proportion of the population who do not own their own home	.168**
Proportion of the population participating in full time study	.150**
Proportion of the population participating in part time study	.061**

A correlation matrix was then calculated for these 19 remaining census variables. The correlation matrix expectedly revealed a high degree of cocorrelation between the selected census variables, introducing the threat of data redundancy and multicollinearity. In order to deal with the problem of multicollinearity, a number of factors were constructed using principal components analysis.

Table 4.3: The variables that were found to have a significant positive correlation with the proportion of Metrocards per meshblock and reasons for their exclusion.

Variable	Correlation coefficient with proportion of Metrocards per meshblock	Reason for exclusion from further analysis
Proportion of the working population who travelled to work either by walking or cycling on the day of the Census	.099**	To avoid doubling up - proportion of travel to work covered by individual walking and cycling variables
Proportion of population whose employment status is unknown	.072**	Attributes of variable unclear
Proportion of population aged between 20 and 29	.135**	Overlaps with other age variables
Proportion of population aged between 20 and 64	.089**	Overlaps with other age variables
Proportion of population born outside New Zealand that have lived in the country for less than 20 years	.082**	Overlaps with proportion who have lived in NZ for less than 10 years
Proportion of the population of Middle Eastern, Latin American or African ethnicity	.083**	Attributes of variable unclear - too many ethnicities included
Proportion of the population participating in any kind of study	.169**	To avoid doubling up - variable covered by individual full time and part time study variables

4.4.6 | Principal Component Analysis

The 19 independent variables were put through a factor reduction process using SPSS. The specific process used was principal axis factor analysis with varimax rotation. This determined the number of underlying constructs which account for the majority of the variance in the percentage of public transport use. A total of four factors were retained in the analysis. Maps indicating the geographic distribution of the four factors across the study area are included in Section 5.6 together with a table indicating the variables loadings per factor.

4.4.7 | Residual Regression Analysis

In order to analyse the significance of these four factors in explaining public transport use, these factors were put into a multivariate regression. The proportion of Metrocard holders per meshblock was the dependent variable, and the four factors retained in the principal component analysis were the independent variables. The results across the study area are presented spatially.

5 | Results and Discussion

5.1 | Number of Cardholders per Meshblock

The proportion of active Metrocard holders per meshblock is shown in Figure 5.1. While at first glance it may appear that Metrocard use is relatively evenly distributed around the city, there are some trends visible. Areas with no population (grey) are mainly found in the southern part of the central business district, and in industrial areas in western Christchurch. Meshblocks where the proportion of cardholders is greater than 30% (dark green) are common in the Central City area, as well as on the periphery of the study area and around the University of Canterbury (locations shown in Figure 3.3). Meshblocks with a value between 20.1% and 30% (light green) and 10.1% and 20% (yellow) are much more evenly spread throughout the study area, although there are few meshblocks in the Central City from these categories. Those meshblocks with a value between 0.1% and 10% are also found throughout Christchurch, but are particularly dominant in some areas to the northwest of the central city.

Table 5.1: Number and percentage of meshblocks in each category of proportion of active cardholders per meshblock.

Proportion of Active Cardholders per Meshblock	Number of Meshblocks	Percentage of Meshblocks
0	73	2.70
0.1 - 10 %	720	26.67
10.1 - 20%	1490	55.19
20.1 - 30%	249	9.22
Greater than 30%	77	2.85
No population	91	3.37
TOTAL	2700	100

Table 5.1 shows the percentage of meshblocks that fall within each category. This indicates that over half of all meshblocks (55.19%) have an active Metrocard holder rate of between 10 and 20 percent. There is also a notable proportion of meshblocks that have a lower usage (less than 10 percent). Conversely, the number of meshblocks with a proportion greater than 30% is very low – only 77 of the 2700 in the study area, or

2.85%. The median proportion of cardholders per meshblock is 12.70, and the average number is 13.91 – both falling within the most common proportion category.

In meshblocks where no population was recorded in the 2006 census, or where there are no Metrocard holders within the meshblock, no calculation of the proportion of cardholders could be made. Furthermore, some of the meshblocks in the study area had a very low population level, meaning that even a few Metrocards being located within them would result in a high level of cardholders per meshblock. The resulting proportion could be noticeably high – in a small number of cases, the level of cardholders per meshblock exceeds 100%. This is particularly true of parts of the central city area, and can be partly explained by people who may have registered their card to their work address instead of their home address, thus inflating the proportion of cardholders in the meshblock where they work.

Meshblocks in some other parts of the city also have some surprisingly high values. One particular case involves some of the meshblocks around the University of Canterbury (see Figure 3.3 for location). In this instance, it is clear that the high number of students with Metrocards who live in Halls of Residence is responsible. However, these residents typically only live in the Halls for one or two years, so it is suggested that a significant number of Metrocards are still registered to the address of the Halls while cardholders have moved to another location. It is suggested that this unique situation of Halls of Residence being the location where many students live when they begin their studies, and therefore live when they register their Metrocards, leads to an inflated rate of Metrocard holders in these locations. Conversely, it could also be expected that 'student flat' areas where students typically move to, after completing their time in the Halls, would be underrepresented in the cardholder statistics, as cards would not be as regularly initially registered at these addresses.

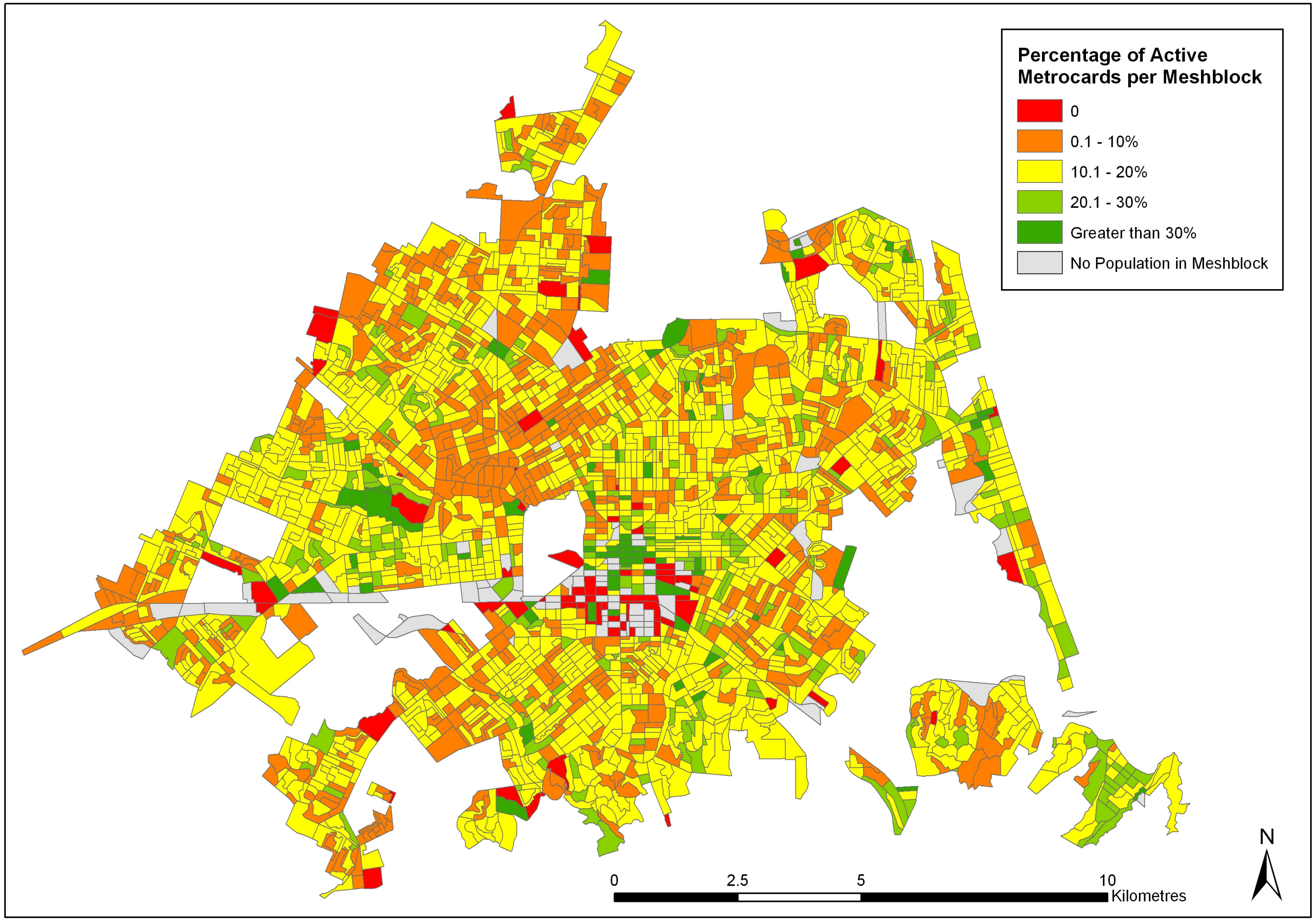

Figure 5.1: Shows the percentage of active Metrocard holders per meshblock in the study area.

5.2 | New Zealand Deprivation Index

This section compares the proportion of Metrocard holders per meshblock explored in Section 5.1 with the NZDep06 Index of Deprivation.

5.2.1 | NZDep06 Ordinal Scale

The ordinal scale values of the NZDep06 index are illustrated in Figure 5.2 for meshblocks within the study area. From this map, it is noticeable that there are more areas of high deprivation in the central city and eastern suburbs, while areas of low deprivation are common in north western suburbs and the Port Hills, located to the south of the city (location shown in Figure 3.3).

As the NZDep06 index is calculated for the whole country, the number of meshblocks within the study area which fall into each level of the ordinal scale are not evenly spread. As noted in section 4.2.4, there is a noticeably lower number of meshblocks in deprivation level 10 (the most deprived level) within the study area. Furthermore, the average population density of these areas differs. As shown in Table 5.2, less deprived areas have a much lower population density (2183.50 people per square kilometre for deprivation level one) than those in more deprived areas (3202.43 people per square kilometre for deprivation level ten). These numbers suggest that the population is more tightly packed in more deprived areas, and consequently there are a greater number of potential public transport users within a smaller area.

Table 5.2: Population, area and average density of meshblocks in each of the ten levels of the NZDep06 ordinal scale.

NZDep06 Index Ordinal Scale	Number of Meshblocks	Total Population of Meshblocks	Total Area of Meshblocks (SqKm)	Average Density of Deprivation Scale (people per SqKm)
Least - 1	299	37,935	21.59	2183.50
2	222	29,172	13.56	2534.30
3	242	32,847	14.91	2649.95
4	272	34,602	15.82	2671.03
5	277	36,036	15.51	2808.08
6	305	36,762	17.14	2705.13
7	262	29,229	12.42	2635.78
8	332	34,329	15.49	2717.91
9	313	33,972	15.13	2661.43
Most - 10	176	20,727	7.83	3202.43

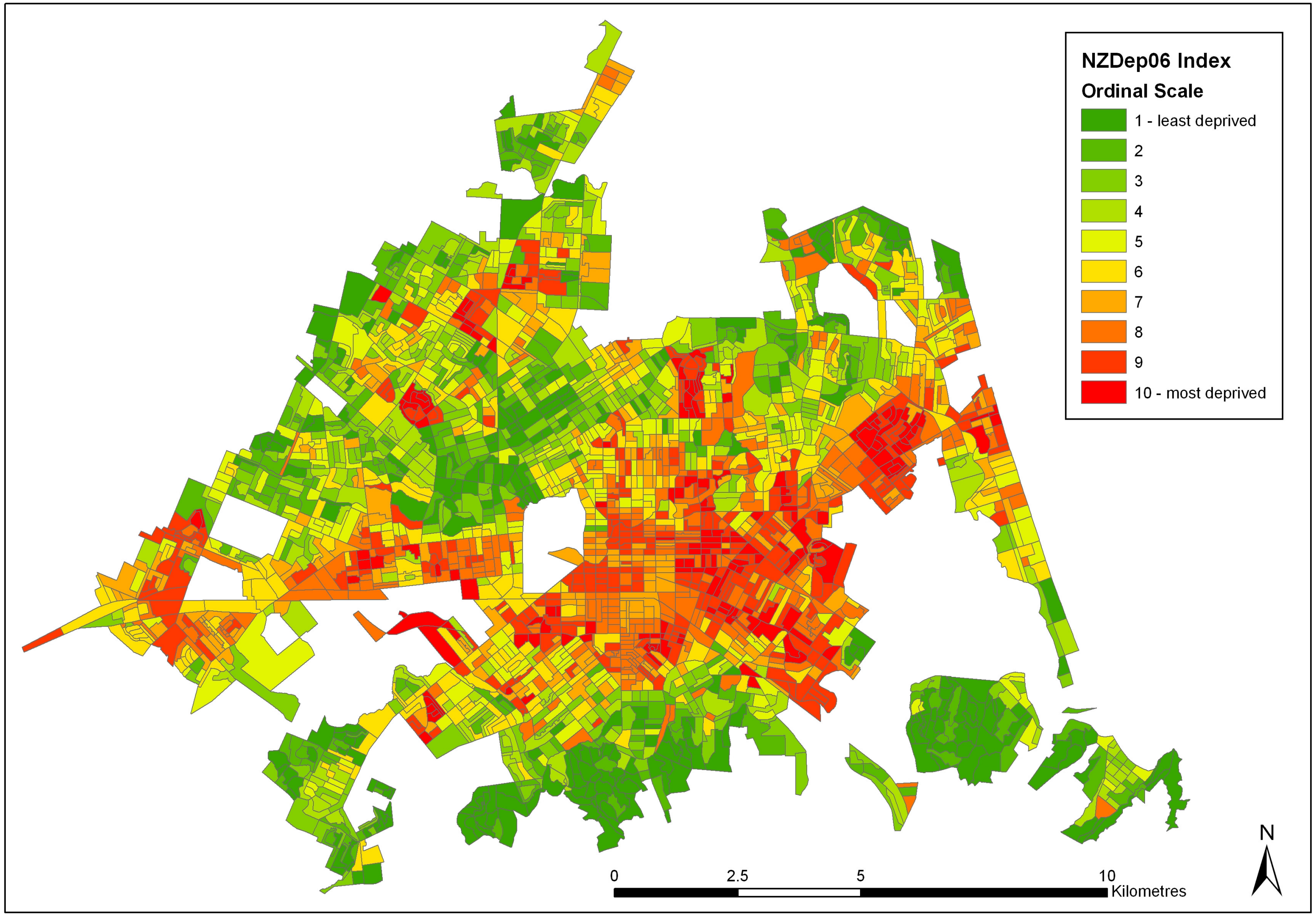

Figure 5.2: Illustrates the ordinal scale values of the NZDep06 index of deprivation within the study area.

5.2.2 | Cardholders in each Deprivation level

This section ascertains whether there was an observable link between the deprivation level of a meshblock and the proportion of cardholders in it. It is expected that there will be a link between these two variables, with more deprived areas having a higher reliance on public transport services, and hence a higher proportion of Metrocard holders per meshblock.

As a first point of investigation, the average number of Metrocards per meshblock for each deprivation level has been calculated, and in shown in Table 5.3. This shows that the proportion is much lower in areas of lower deprivation (for example, 11.85 cardholders per meshblock in NZDep06 level 1) than in areas of higher deprivation (for example, 16.50 cardholders per meshblock in NZDep06 level 9). The general trend shows an overall increase with increasing deprivation, as shown in Figure 5.3, although it is noted that this trend does not uniformly increase across all deprivation levels.

The statistical relationship between the proportion of cardholders per meshblock and the NZDep06 index has been calculated through correlation analysis. The Spearman's rho nonparametric correlation was used in this instance. A correlation coefficient of 0.166 was found, which indicated a statistically significant relationship at the 0.01 level, although the value was not particularly high. This relationship was expected, as it is clear from Figure 5.3 that there is a positive linear relationship between the two variables. Both of these results follow the expectation that the number of active Metrocards users will be higher in more deprived areas than it is in less deprived areas.

Table 5.3: The average number of Metrocards per 100 people in each of the ten levels of the NZDep06 ordinal scale.

Deprivation Scale	**Number of Metrocards in Deprivation Scale**	**Total Population of Deprivation Scale**	**Average number of Metrocards per 100 People in Deprivation Scale**
Least - 1	4,496	37,935	11.85
2	3,618	29,172	12.40
3	3,994	32,847	12.16
4	4,443	34,602	12.84
5	4,813	36,036	13.36
6	4,601	36,762	12.52
7	4,892	29,229	16.74
8	5,109	34,329	14.88
9	5,607	33,972	16.50
Most - 10	3,018	20,727	14.56

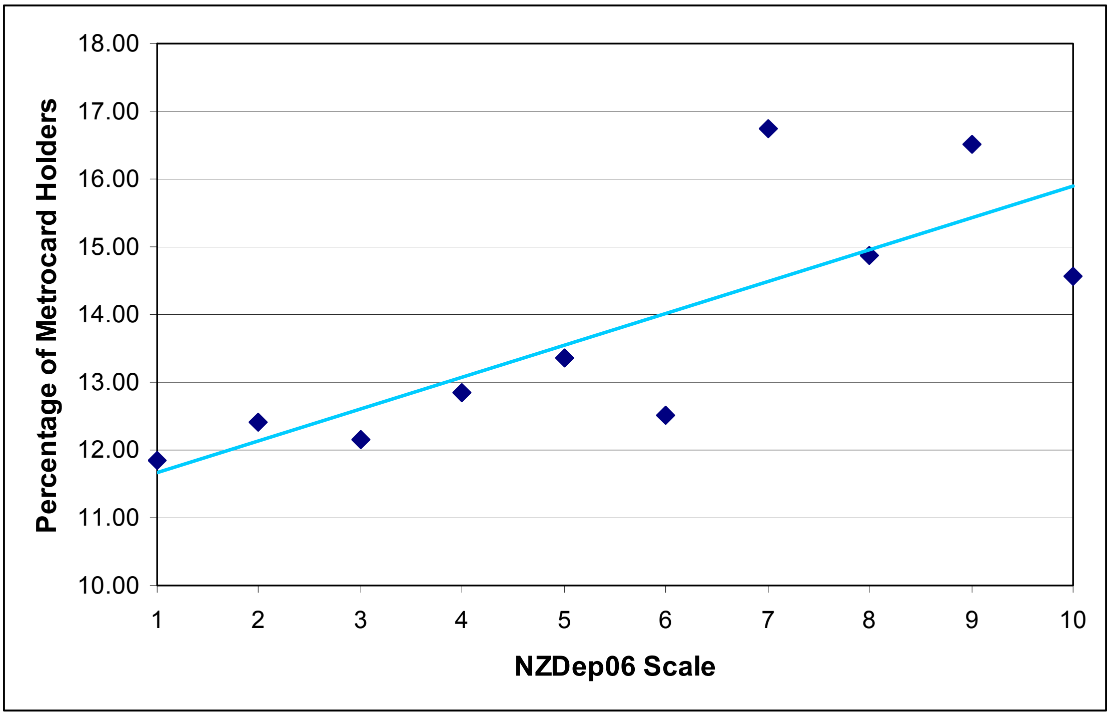

Figure 5.3: Graph showing the average number of Metrocard holders per meshblock for each NZDep06 ordinal scale level. The light blue linear trendline shows a positive relationship.

5.2.3 | Observed links between Metrocard holders and Deprivation levels

To gauge whether there is a link between the geographic location of deprived areas and higher levels of Metrocard holders, maps of high and low Metrocard holder levels and high and low deprivation levels have been compared.

Figure 5.4 shows areas with a low deprivation scale level (levels one to three). This map shows that there are several parts of the study area where there are particular clusters of low deprivation. These are along the Port Hills on the southern edge of the study area, at the northern and western peripheries of Christchurch, and to the northwest of the central city (in particular, the suburbs of Fendalton and Merivale) (refer to Figure 3.3 for suburb locations). The proportion of Metrocard holders per meshblock is again shown in Figure 5.5; however this version is presented in categories arranged by the standard deviation of values. For this analysis, areas with a low level of Metrocard use are considered to be those with a standard deviation of -0.5 or more (shown in red in Figure 5.5). While meshblocks with a low level of Metrocard use are found throughout the study area, there are particularly strong clusters found in northwest part of the city.

When the areas of low deprivation shown in Figure 5.4 are compared to the areas with a low percentage of Metrocard use (Figure 5.5), areas of similarity are noted to the northwest of the city, particularly in the suburbs of Fendalton and Merivale. However, there is a marked difference along the Port Hills area to the south of the study area. While there are a significant number of areas of low deprivation along this periphery, the level of Metrocard holders is in most cases not correspondingly low. These results suggest that while there are observed geographic correlations between Metrocard holders and deprivation in some areas, these are not found universally across the study area. It is also interesting to note that areas along the south of the city, which have a markedly different topography than the rest of the study area, in that these areas are hilly rather than flat, appear to have a higher level of bus usage than might be expected. The effect of topography on these factors had not previously been considered, but these observed findings suggest that it should be.

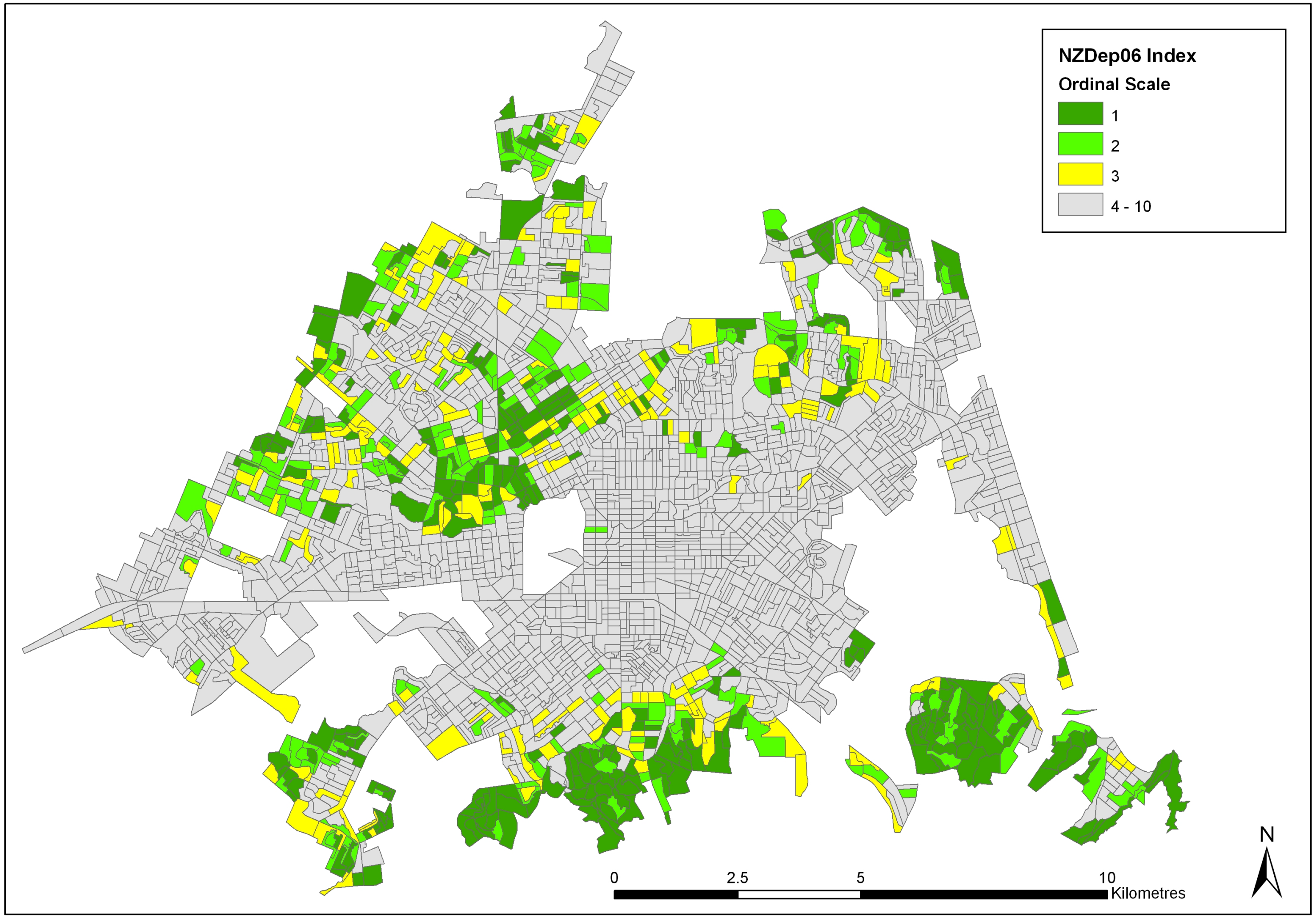

Figure 5.4: Map showing the lowest three (least deprived) ordinal scale values of the NZDep06 Index of Deprivation within the study area.

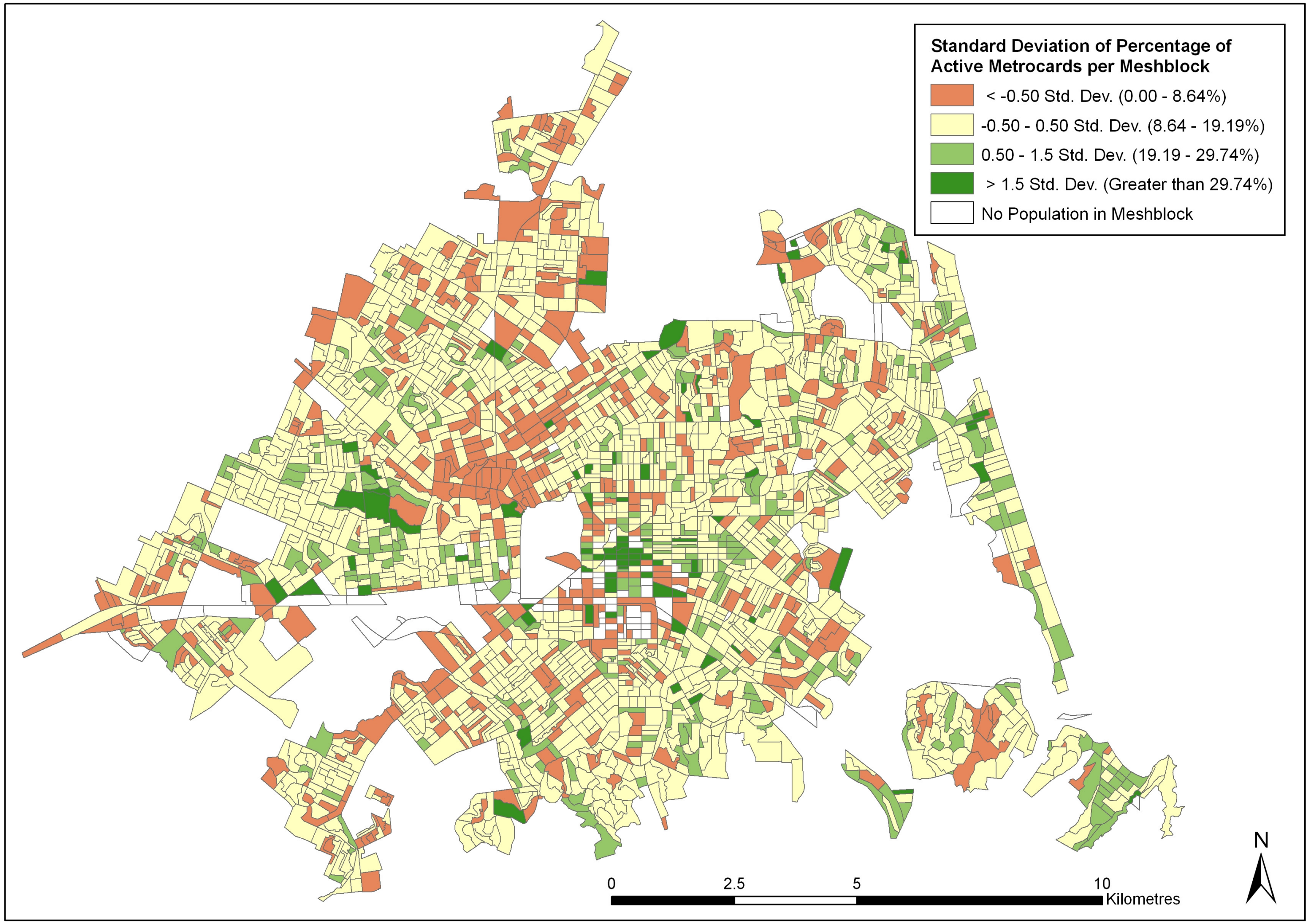

Figure 5.5: Map showing the percentage of active Metrocard users per meshblock, arranged by standard deviation groupings.

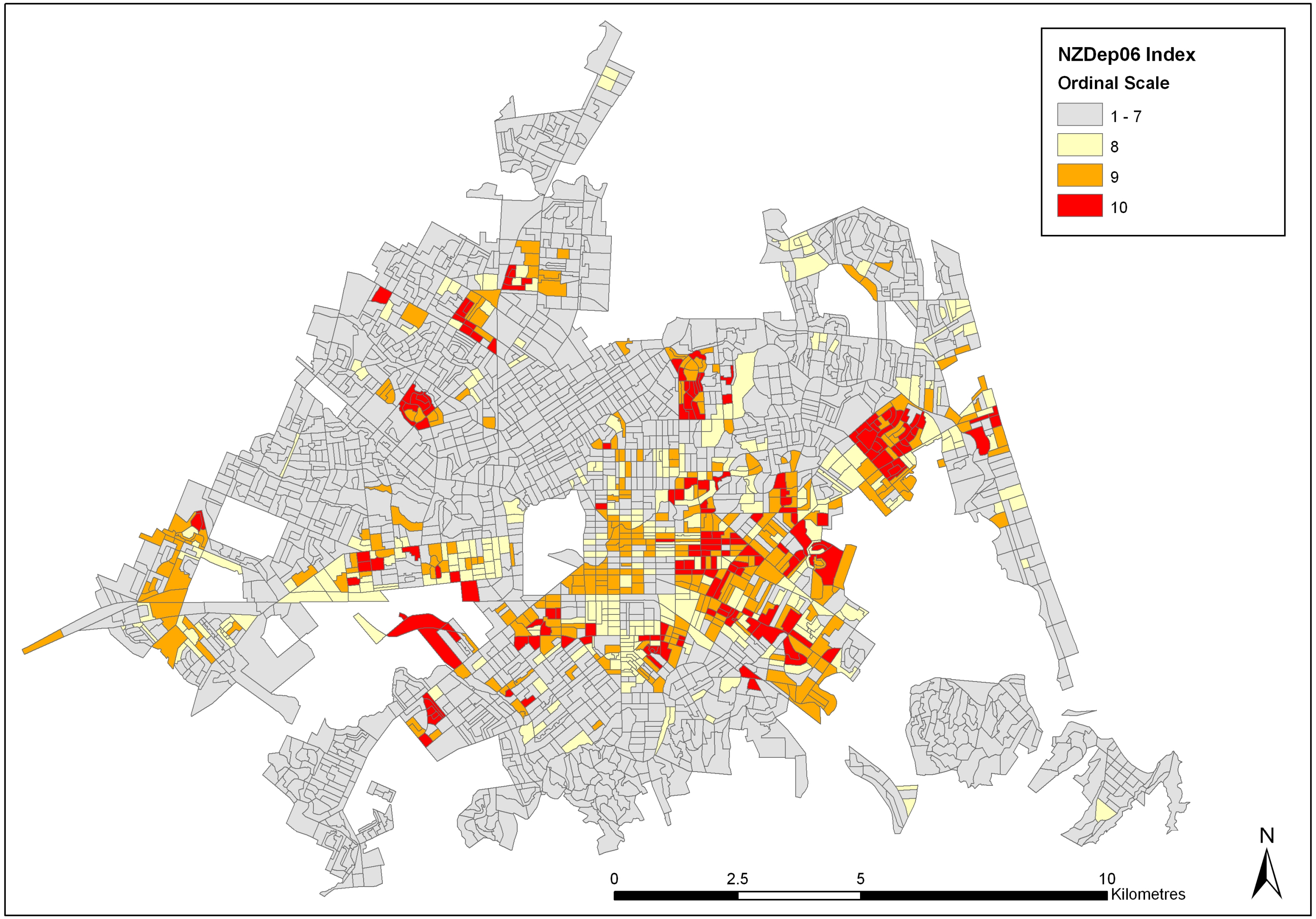

Figure 5.6: Map showing the highest three (most deprived) ordinal scale values of the NZDep06 Index of Deprivation within the study area.

The same observations have been made of maps showing high deprivation and high Metrocard holder levels. The meshblocks of highest deprivation levels (NZDep06 scale level eight or higher) within the study area are shown (Figure 5.6). These areas are more common to the east of the central city, notably in the suburbs of Linwood, Woolston and Aranui (refer to Figure 3.3 for suburb locations). Other clusters of deprived areas are found in Shirley, Papanui, Burnside, Riccarton and Addington, along with some industrial areas. In Figure 5.5, the areas with a high proportion of Metrocard holders are considered to be those in categories with a standard deviation of 0.5 and above (illustrated in the map in two shades of green). These are spread throughout the city, with a number of small clusters but few noticeable trends. However, there is a large number of meshblocks from the central city area which fit this description, and there are some other clusters in Sumner as well as in Ilam and Riccarton, around the University of Canterbury campus (refer to Figure 3.3 for location). It is interesting that the areas of high deprivation in Figure 5.6 show few links with the areas of high Metrocard holders observed in Figure 5.5. This suggests that, while there is a strong discernable link between areas of low deprivation and low public transport use, such a link is not as clear between areas of high deprivation and high public transport use.

5.2.4 | Links to Previous Research

While there has been little direct research about links between sociodemographic characteristics, such as deprivation, and public transport use, there has been much interest in the relationship between social exclusion and transport (Church et al., 2000; Hine & Mitchell, 2001; Lyons, 2003; Preston & Rajé, 2007; Stanley & Vella-Brodrick, 2009). International work suggests that people in more disadvantaged situations feel a lack of 'connection' (Church et al., 2000) because of a lack of transport options. The finding that in Christchurch there is a link between the deprivation of an area and the level of public transport use suggests that people in more deprived areas are making better use of services provided than those in less deprived areas, which is likely to assist in reducing this lack of 'connection', and hopefully assisting in the overall reduction of social exclusion.

Studies have also noted the link between transport disadvantage and the lack of access to a private vehicle (Johnson et al., in press; Currie, 2009). Vehicle access is one of the variables included in the NZDep06 index. It is expected that people living in more deprived areas have poorer levels of access to private vehicles, and the higher levels of public transport use seen are expected because of this. Again, these results suggest that people in such situations may be making better use of public transport services, thus potentially helping to reduce transport inequalities.

5.3 | Distance to Bus Stops and Bus Routes

It is expected that the distance a person lives from their nearest bus stop and bus route will have an impact on the regularity with which they use the service. For example, people who live in close proximity to a bus route may be likely to make more use of a particular service than those who live further away. A recent study in Auckland, New Zealand, has indicated that one of the factors associated with people being more likely to use public transport services is being living within 200 metres of their closest bus stop (Badland et al., 2010). Furthermore, it is also of interest as to whether a person's proximity to bus stops and bus routes has any correlation with other factors, such as deprivation. For instance, are people in higher socioeconomic areas less likely to use bus services if they live further away from them? It is presumed that people in these areas are likely to have access to other, more convenient transport options. Conversely, do people in lower socioeconomic areas travel further, on average, to use bus services (which may be the only transport option available to them). The impact of distance to bus routes and stops is investigated through visually observing spatial patterns, investigating the proportion of Metrocard holders who live within certain distances of bus stops and routes, and looking at the average distance of cardholders in meshblocks to bus stops and bus routes.

All results in this section are based on the Euclidian distance between two points – which is the direct distance 'as the crow flies', not taking into account such things as the road network and how this may affect the actual distance people need to travel to get to the bus route.

5.3.1 | Observed Links between the Distance to Bus Routes and Metrocard Usage

The bus network in the study area is illustrated against the percentage of Metrocard usage (again shown in standard deviation categories) (Figure 5.7). Areas with a high proportion of Metrocard use appear to be quite scattered throughout the city, not appearing to be particularly clustered in one area or around a particular bus route. However, one notable cluster is a group of meshblocks in the flat part of the seaside suburb of Sumner, at the far southeast of the study area (refer to Figure 3.3 for location). Sumner is a unique suburb of Christchurch as its surrounding topography means it has only one main transport corridor to the rest of the city. Therefore, most people from this suburb tend to commute in the same direction, rather than in dispersed directions to workplaces all over the city. It is also interesting to note that all the meshblocks with high Metrocard usage in Sumner are directly adjacent to the core bus route which serves the suburb, and are all in the flat part of the suburb, rather than on the surrounding hills. Other places with clustered areas of high usage are found around the University of Canterbury (refer to Figure 3.3 for location) and in the central city. As previously noted, the high rates of bus use around the University can be partially attributed to the high levels of students living in Halls of Residence; and the high levels in the Central City are possibly due, in part, to the effects of a low resident population combined with Metrocards being registered to work addresses. However, the high number and frequency of bus services to the central city, where most routes converge, may also play a part in explaining the high level of Metrocard holders in this area.

Areas with a low proportion of Metrocard holders are observed to be spread around the study area (Figure 5.7). However, there are more clusters found in the northwestern part of the city. An area of particular note is the suburb of Fendalton, where there are no core routes that run towards the city centre. Other areas with only bus non-core routes also appear to have lower levels of usage, although this link is tenuous, and it is noted that there are instances where meshblocks adjacent to core bus routes also have low usage.

The Port Hills at the southern edge of the study area show some interesting patterns. Some areas with no bus routes have low Metrocard usage, which is unsurprising as access to bus routes in such cases would involve walking up and down hills, and other transport modes are likely to be more desirable to avoid this. However, some other hill areas which are not directly served by bus routes do not appear to have a low proportion of Metrocard usage, confusing a possible link between topography and public transport usage.

Research in Melbourne, Australia, has found that there is a particular needs gap in public transport provision in areas on the fringe of the city (Currie et al., 2009; Currie, 2010). A similar issue is not particularly visible in Figure 5.7, where there appears to be good access to bus routes throughout the study area. However, it is likely that there are a number of meshblocks, which are not part of the study area, located in semi-rural areas just beyond the edge of the city where similar accessibility issues may be found.

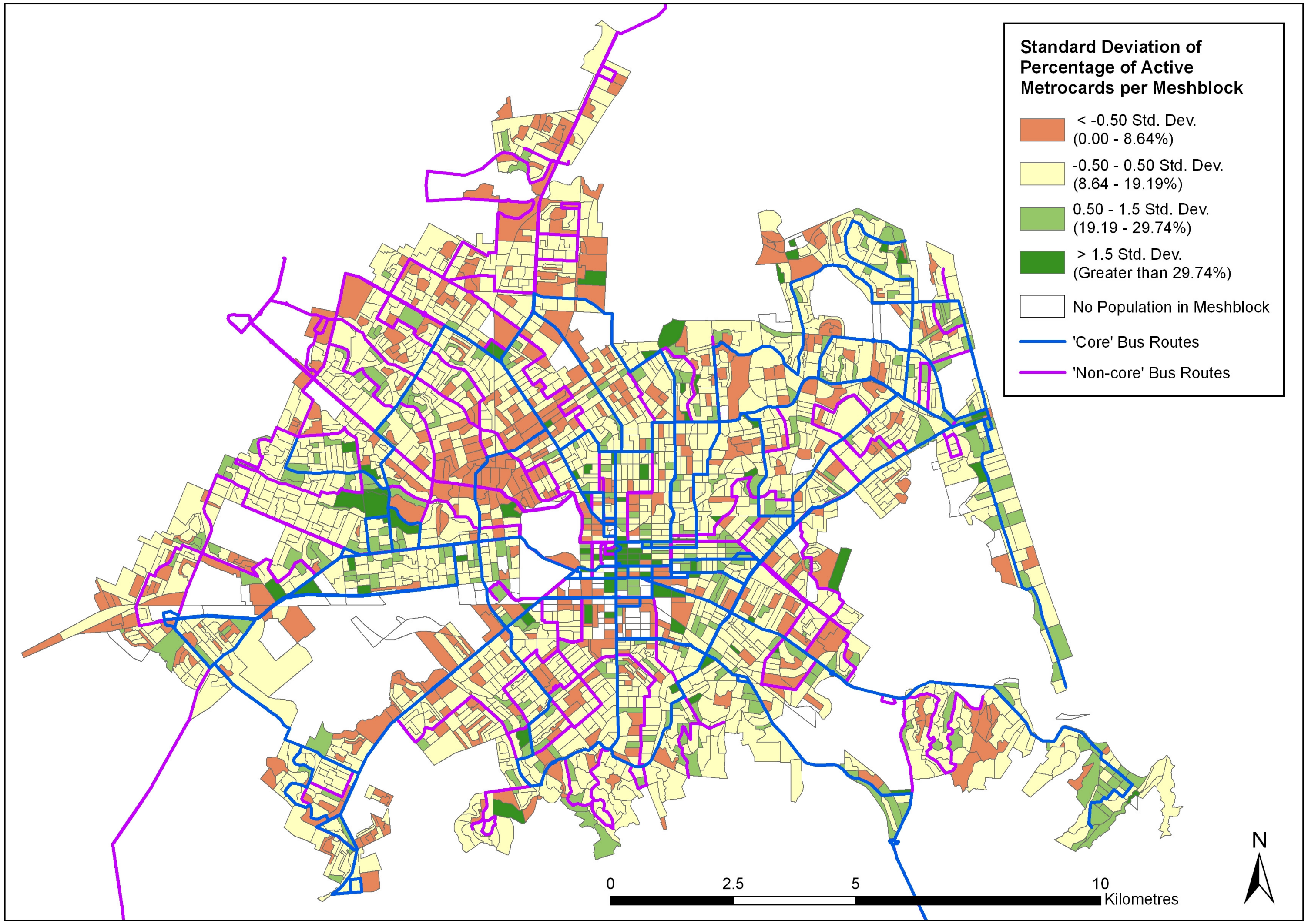

Figure 5.7: The percentage of Metrocard usage per meshblock is shown against 'core' and 'non-core' bus routes.

5.3.2 | Observed Links between the Distance to Bus Routes and Deprivation

The observed relationships of the proximity of bus routes to areas of high and low deprivation have also been investigated. Areas of high deprivation are shown against the Christchurch bus network (Figure 5.8). These areas tend to be mainly found in the eastern part of Christchurch, and most appear to be in close proximity to core bus routes. Furthermore, non-core bus routes appear to be located close to almost all of the areas in which core bus routes are not located. It may well be the case, however, that in the past bus route planning took into account areas of lower socioeconomic status, and this may well have led to a more comprehensive level of service being provided in these areas. There are also clusters of low deprivation in other parts of the study area, notably in Shirley, Papanui, Burnside, Riccarton, and Addington (see Figure 3.3 for suburb locations). With the exception of Burnside, these areas are close to both core and non-core bus routes and suburban shopping areas, indicating that, in parts of the study area where areas of high deprivation are in small clusters, these clusters tend to have good access to public transport services. Finally, there are some areas of industrial land use within the study area that have a high deprivation level (as well as a large number of such areas in Christchurch which are not part of the study area). These areas have generally poor access to bus routes, as no services are currently specifically designed to service industrial areas. Investigation into the provision of services in these areas is important in terms of increasing service provision in deprived areas of Christchurch.

Figure 5.9 shows areas of low deprivation and the bus route network. There do not appear to be many areas of low deprivation with no bus routes in relatively close proximity. The exception to this is some hill suburbs, particularly around Sumner, and some areas on the periphery of the city. These areas are relatively difficult to service in any case, because of topography and routing issues. Overall it is noted that appear to be fewer core routes in areas of low deprivation than there are in areas of high deprivation. This inequality in service provision may be reflective of greater demand for bus services in areas of high deprivation.

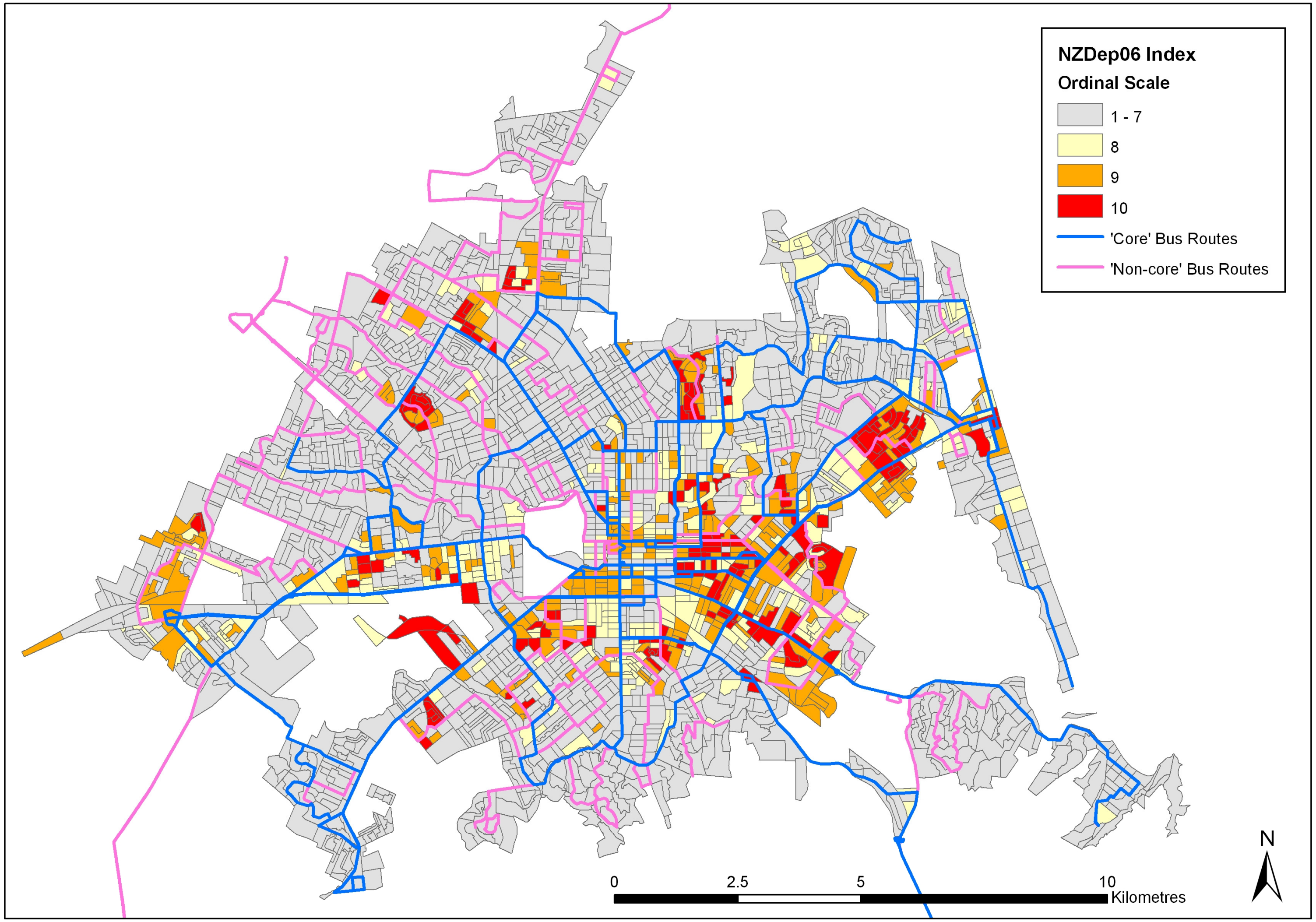

Figure 5.8: Meshblocks with a high level of deprivation are shown against 'core' and 'non-core' bus routes.

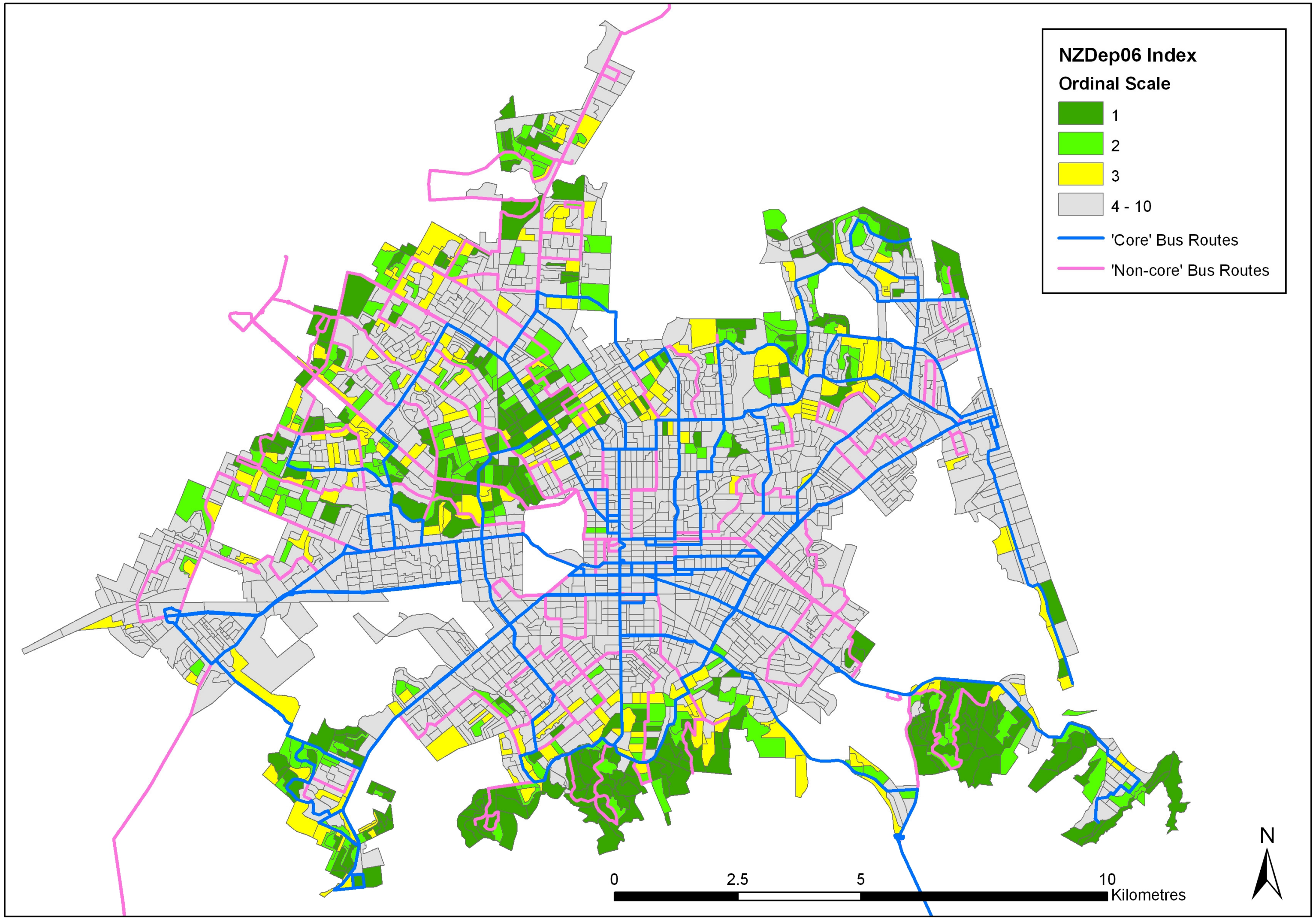

Figure 5.9: Meshblocks with a low level of deprivation are shown against 'core' and 'non-core' bus routes.

5.3.3 | Actual Distance to Bus Routes arranged by Deprivation Level

To quantify these observations, the percentage of Metrocard holders within 200 metres of their nearest bus route has been calculated for each deprivation level (Table 5.4). These results show that a greater proportion of cardholders in areas of higher deprivation live within 200m of their closest bus route than in areas of lower deprivation (80.82% for deprivation level 10 meshblocks compared to 63.32% for deprivation level 1 meshblocks). There is a generally upwards trend for the meshblocks in between. These results indicate that cardholders in more deprived areas generally live closer to bus routes, and hence may have a greater reliance on these services. However, they also may be reflective of the more comprehensive route network in more deprived areas, and could also be affected by different development densities in different deprivations (in particular, this may explain the significant difference between deprivation 1 and 2 areas – 63.32% compared to 71.20%).

Table 5.4: Shows the number and percent of cardholders in each deprivation level who live less than 200m from their closest bus route.

Deprivation Scale Level	Number Cardholders less than 200m from Route	Total Number of Cardholders in Deprivation Level	Percent of Cardholders less than 200m from route
1	2,847	4,496	63.32
2	2,576	3,618	71.20
3	3,106	3,994	77.77
4	3,321	4,443	74.75
5	3,756	4,813	78.04
6	3,589	4,601	78.00
7	3,979	4,892	81.34
8	4,168	5,109	81.58
9	4,517	5,607	80.56
10	2,439	3,018	80.82
Total	34,298	44,591	76.92

5.3.4 | Distance of Cardholder Addresses from Bus Routes and Bus Stops

This section details how many of the Metrocard holder addresses are located within 500 metres of core, non-core and all bus routes, and bus stops.

Table 5.5 shows the percentage of active cardholders who live within 50 metre increment distances of core routes, and Table 5.6 shows the same information for non-core routes. There are a significantly lower number of cardholders in close proximity to core routes than non-core routes (25.87% compared to 36.27% within 100m, 45.22% compared to 60.36% within 200m). These results are expected, as the core bus route network covers a much smaller spatial footprint than the non-core network, being generally confined to key corridors. However, it is of note that over three quarters (75.25%) of cardholders in the study area are within 500m of a core route, which is considered an easily walkable and accessible distance. It is also of interest that the highest percentage of each group lives in the closest proximity to a route (within 50 metres).

Table 5.5: Shows the number and percentage of active Metrocard holders who live within certain distances of 'core' bus routes.

Distance to nearest 'core' bus route	Number of cardholders in this category	Percentage of cardholders in this category	Cumulative percentage of cardholders
50m or less	7,276	16.32	16.32
50.1m – 100m	11,537	9.56	25.87
100.1m – 150m	16,516	11.17	37.04
150.1m – 200m	20,163	8.18	45.22
200.1m – 250m	23,479	7.44	52.65
250.1m – 300m	26,109	5.90	58.55
300.1m – 350m	28,459	5.27	63.82
350.1m – 400m	30,413	4.38	68.20
400.1m – 450m	32,133	3.86	72.06
450.1m – 500m	33,555	3.19	75.25

Table 5.6: Shows the number and percentage of active Metrocard holders who live within certain distances of 'non-core' bus routes.

Distance to nearest 'non-core' bus route	Number of cardholders in this category	Percentage of cardholders in this category	Cumulative percentage of cardholders
50m or less	10,206	22.89	22.89
50.1m – 100m	16,171	13.38	36.27
100.1m – 150m	22,325	13.80	50.07
150.1m – 200m	26,913	10.29	60.36
200.1m – 250m	30,510	8.07	68.42
250.1m – 300m	33,324	6.31	74.73
300.1m – 350m	35,370	4.59	79.32
350.1m – 400m	36,906	3.44	82.77
400.1m – 450m	38,259	3.03	85.80
450.1m – 500m	39,143	1.98	87.78

When the core and non-core bus networks are combined, it is found that 45.90% of cardholders live within 100m of a bus route, 76.34% within 200m, and 98.83% within 500m (Table 5.7). The percentage of users that live between 0 and 50m of a bus route is the highest category (22.89%), with the number of cardholders in each category showing a generally downward trend the further the distance is from the bus route. At first glance, these results suggest that proximity to a bus route is directly related to the number of cardholders. However, these results do not take into account the bus network itself. The interlaced and comprehensive nature of this network means that an address is more likely to be located at the shorter distance end of the category spectrum. For example, Figure 5.10 shows the parts of the study area which are within 200 metres of a bus route. This indicates that a significant proportion of the study area is in close proximity to a bus route, and in some cases several bus routes. Gaps in the coverage of the network can be partially explained in many cases by non-residential land uses, such as open spaces and industrial areas. Other gaps in service are explained by them being at the periphery of the city – which could be new developments without bus services at this point, or areas that are difficult to service; and hill areas where service provision is harder.

What these results do show, however, is that most Metrocard holders within the study area have good access to bus services, with the majority being within 150m of a bus route (64.21%), and almost all cardholders within 500m (98.83%). Due to the limitations of the information available, these particular results do not show whether Metrocard users actually live closer to bus routes, or if people who live close to bus routes are more likely to be Metrocard holders.

Table 5.7: Shows the number and percentage of active Metrocard holders who live within certain distances of all bus routes.

Distance to nearest bus route ('core' or 'non-core')	Number of cardholders in this category	Percentage of cardholders in this category	Cumulative percentage of cardholders
50m or less	13,110	29.40	29.40
50.1m – 100m	20,468	16.50	45.90
100.1m – 150m	28,630	18.30	64.21
150.1m – 200m	34,042	12.14	76.34
200.1m – 250m	38,136	9.18	85.52
250.1m – 300m	40,642	5.62	91.14
300.1m – 350m	42,218	3.53	94.68
350.1m – 400m	43,235	2.28	96.96
400.1m – 450m	43,778	1.22	98.18
450.1m – 500m	44,071	0.66	98.83

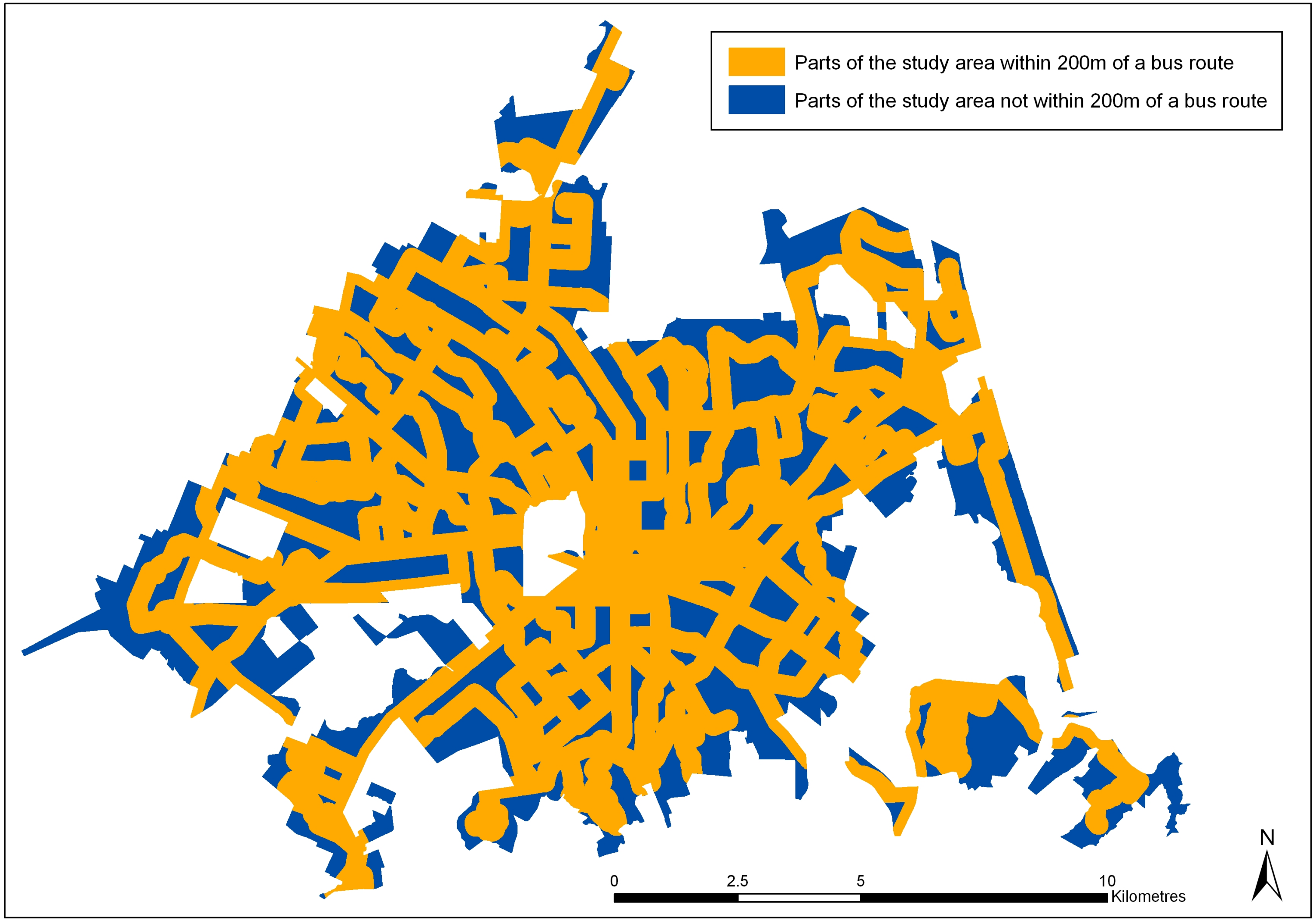

Figure 5.10: Shows the parts of the study area which are within 200m of a bus route.

The immediately previous results do not take into account whether the closest bus route to the residential address of a cardholder will be of use to them (for instance, a cross-suburban route would be of more limited use to someone who works in the central city where this route does not go, so the cardholder may have to travel further to access a route which does go to the central city). These results also do not take into account the location of bus stops. While a cardholder may live within a certain distance of a bus route, this does not mean that their closest bus stop will necessarily also be this distance away. Table 5.8 shows the percentage of active Metrocard holders in 50 metre increment distances from their nearest bus stop. Interestingly, the largest portion of cardholders is not in the less than 50m increment as it is for bus routes (the value for bus stops is only 11.45%, compared to 29.40% within 50m of a bus route). Instead, the large bulk of cardholders are found within the 50–100m (20.35%) and 100–150m (23.33%) increments. However, as for bus routes, the majority of users are still located within 150m of a bus stop (55.13%), and almost all cardholders are still located within 500m (98.46%). Figure 5.11 shows the parts of the study area that are located within 200m of a bus stop. This reinforces that, while the area covered is not as great as that within 200 metres of bus routes, the spread of coverage over the city is relatively consistent, and that areas without services are generally in locations where the provision of such services is challenging.

Table 5.8: Shows the number and percentage of active Metrocard holders who live within certain distances of a bus stop.

Distance to nearest bus stop	Number of cardholders in this category	Percentage of cardholders in this category	Cumulative percentage of cardholders
50m or less	5,106	11.45	11.45
50.1m – 100m	14,182	20.35	31.80
100.1m – 150m	24,585	23.33	55.13
150.1m – 200m	31,760	16.09	71.23
200.1m – 250m	36,709	11.10	82.32
250.1m – 300m	39,875	7.10	89.42
300.1m – 350m	41,633	3.94	93.37
350.1m – 400m	42,826	2.68	96.04
400.1m – 450m	43,535	1.59	97.63
450.1m – 500m	43,906	0.83	98.46

These results are interesting, as research in Auckland has shown that people are more likely to use bus services if they live close to bus stops, and if these services are perceived as being accessible (Badland et al., 2010). As shown in Table 5.8, over 70% of cardholder addresses in the study area are within 200 metres of a bus stop. It is noted that this is an Euclidian distance, and the practical distance to the closest bus stop may be further. Nonetheless, these results suggest that the majority of Metrocard holders within the study area have good level of accessibility to bus services.

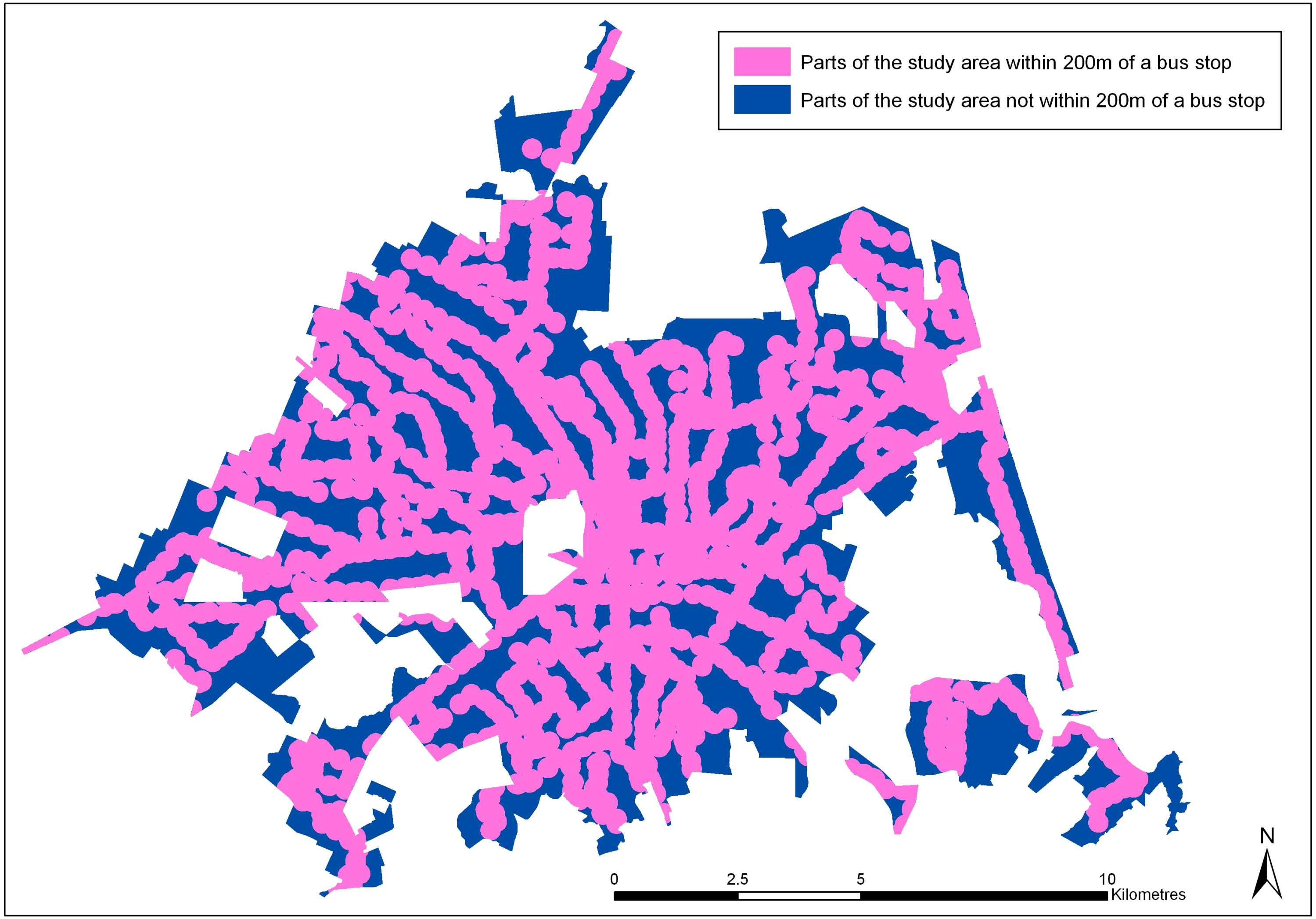

Figure 5.11: Shows the parts of the study area which are within 200m of a bus stop.

5.3.5 | Average Meshblock Distances to Bus Routes and Stops

The average distance of Metrocard holders in each meshblock to bus routes and stops has also been calculated. The shape and dimensions of the meshblock areas somewhat limit the usefulness of these results, as, for example, one edge of a meshblock may be directly adjacent to a bus route or stop, while another edge may be some distance away, and the average distances will be skewed by this. Nonetheless, it provides the opportunity to explore another aspect of how distance and bus use are related.

Figure 5.12 shows the average distance of cardholders in meshblocks to bus routes. Areas with clusters of meshblocks with a high average distance are found in some hill suburbs, particularly around Sumner, and in some parts of the periphery of the study area. There is also a number of areas that have a medium to high average distance that are located in areas between bus routes. Examples of such areas are found in Riccarton, Fendalton and Woolston, as well as a number of other suburbs (see Figure 3.3 for suburb locations). An almost identical result is presented in Figure 5.13, which shows the average distance of cardholders in meshblocks to the nearest bus stop. One notable difference is that the number of meshblocks in the highest category (greater than 2.5 standard deviations) is increased. This difference can be explained by bus stops being located at intervals along bus routes, so the distance for areas that are already a good distance from a bus route will often be located even further away from the closest bus stop.

The number of meshblocks on the periphery of the study area that are located a substantial distance from bus services indicates that access to services in these areas is poorer. This is consistent with results from Melbourne, which found a greater level of forced car ownership and transport disadvantage in areas on the fringe of the city (Currie et al., 2009).

Overall, these results reinforce the earlier findings that most regular bus users within the study area are located within easy access of public transport services.

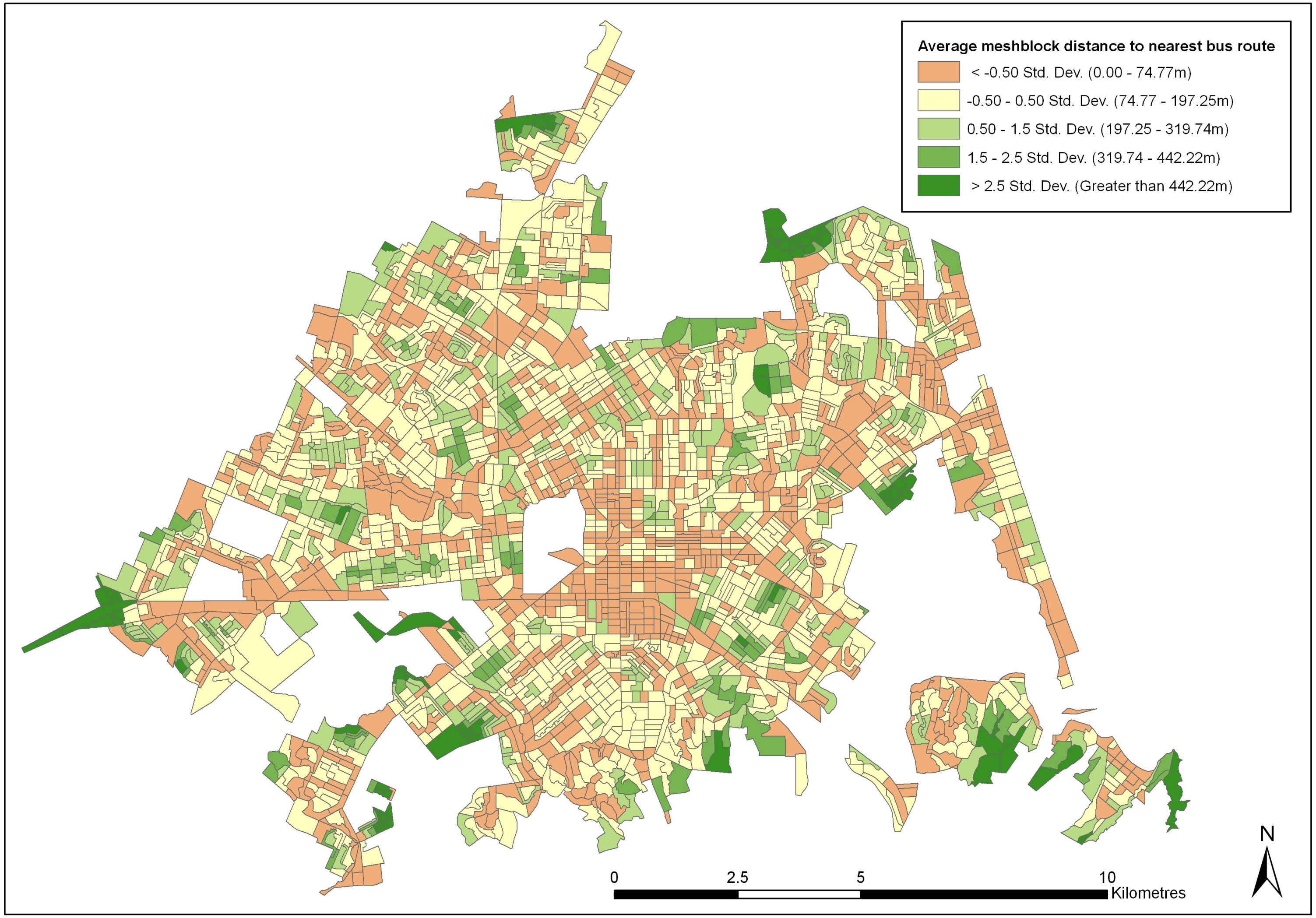

Figure 5.12: Shows the average distance of active Metrocard holders in meshblocks to the nearest bus route.

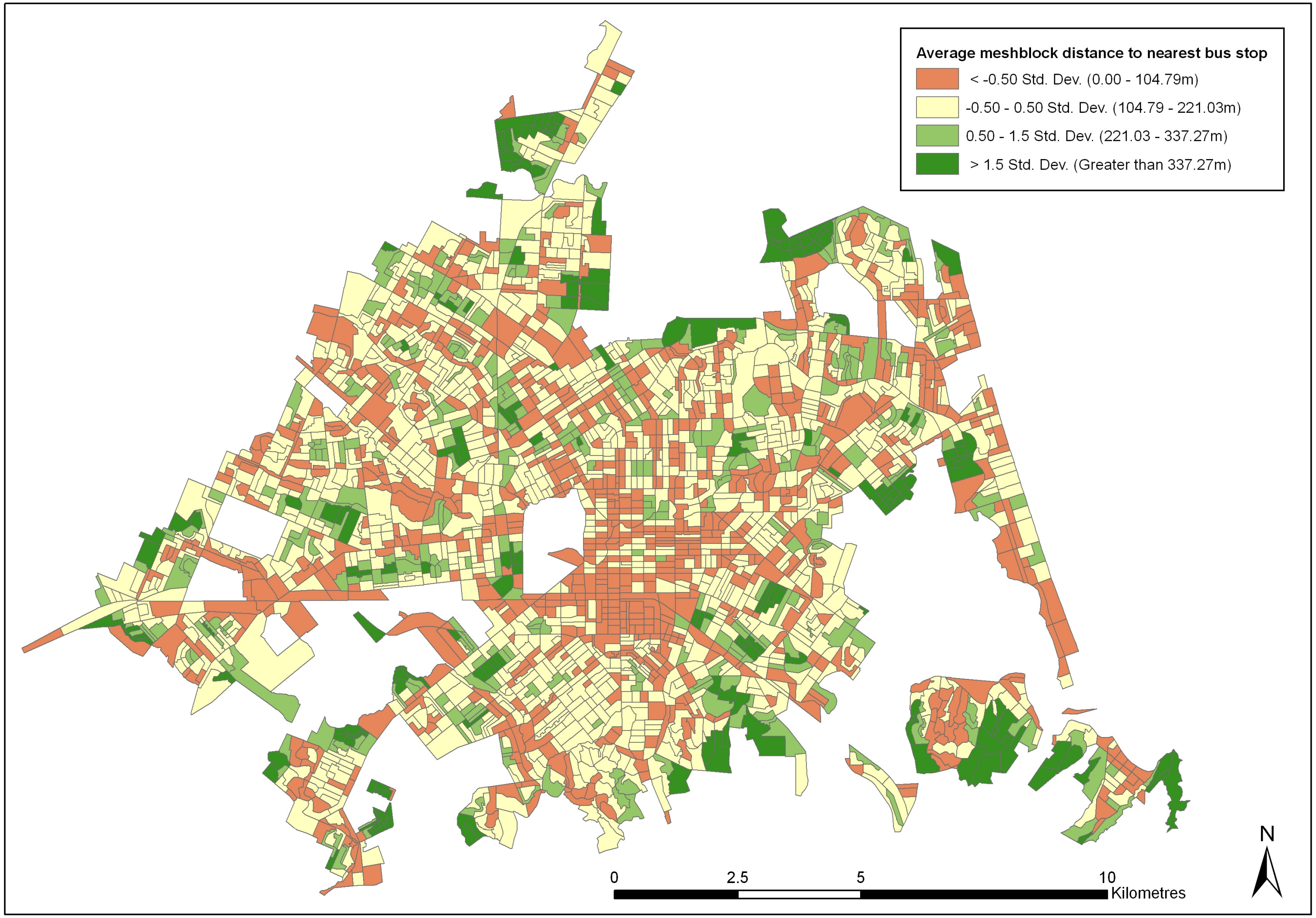

Figure 5.13: Shows the average distance of active Metrocard holders in meshblocks to the nearest bus stop.

5.4 | Regularity of Metrocard Use

This section looks at how the regularity with which Metrocard holders use bus services is linked to the deprivation level of the area in which they live, the distance to their nearest bus route and bus stop, and the land zoning of the area in which they live.

5.4.1 | Average Trips per Day in Meshblock Areas

The average number of trips per day for each meshblock is illustrated (Figure 5.14). This indicates that in general, Metrocard users in meshblocks in the east of the city take a higher average number of trips per day than people in the west of the city. Areas in the east of the city where the average number of trips per day is particularly high include Aranui, Shirley, Parklands, and Southshore (refer to Figure 3.3 for suburb locations). There are also pockets of areas in the west of the city with a high average number of trips per day, including parts of Hornby, Halswell and Papanui. The trend was generally reversed when identifying areas with a low average number of trips per day, with suburbs in the west of the city having a low number of trips per day, along with some hill suburbs on the southern periphery of the city. Suburbs with a low average number of trips per day include Fendalton, Ilam and Cashmere. The level in the south of the central city is extremely low. It should be noted, however, that a significant number of the meshblocks in this area, as well as some other mainly industrial parts of the city, have either no population or no Metrocard holders in them, and hence have a value of 0.

When comparing this map to others showing areas of low and high deprivation (Figures 5.4 and 5.6 respectively), it is clear that there is a link between the deprivation level of an area and the average number of trips per day. This is confirmed when the average number of trips per day is studied (Table 5.9). The lowest average is for cardholders in deprivation level 1 areas (with an average of 1.05 trips per day), and the highest level is found in deprivation level 10 areas (1.25 trips per day). There is a general upward trend along the deprivation levels in between, and the overall average number of trips per day is 1.15.

Table 5.9: Shows the average number of trips per day for Metrocard users who live in each NZDep06 index level.

NZDep06 Index Level	Average number of trips per day
1	1.05
2	1.09
3	1.10
4	1.13
5	1.12
6	1.19
7	1.14
8	1.22
9	1.20
10	1.25
Average across all deprivation levels	1.15

These results suggest that people in some areas of Christchurch, and indeed more specifically in less deprived areas, are more likely to hold a Metrocard which they use irregularly. For example, rather than using the bus on a daily basis, perhaps because of a reliance on it as the only available form of transport, cardholders in high socioeconomic areas may only use it once or twice a week. This suggests that they have a greater ability to use alternative forms of transport, maybe only choosing to use bus services when the weather suits or if they do not need to make further trips once they are at work. It may also indicate that people in higher socioeconomic areas tend to use bus services less for transit to work and more for other activities – for instance, for going into the central city for a ‘night out’ when they do not wish to take a vehicle.

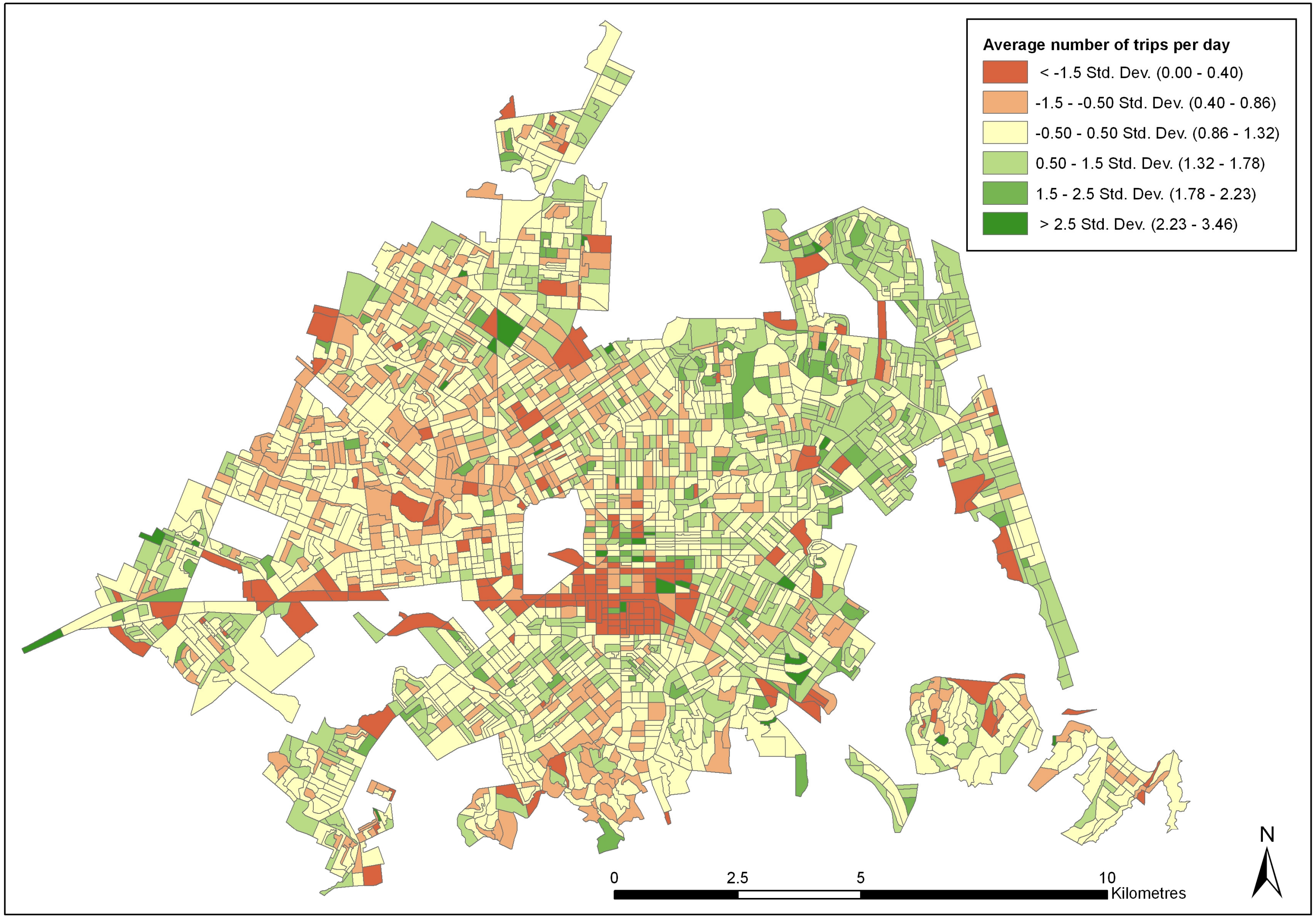

Figure 5.14: Illustrates the average number of trips per day for cardholders in each meshblock of the study area.

5.4.2 | Relationship between Number of Trips per Day and Distance to Bus Route

It is expected that there ought to be a relationship between the proximity a cardholder lives in relation to a bus route or bus stop and the average number of trips per day which they take, as people who live in close proximity to public transport services would be likely to make use of them more regularly. However, as shown in Table 5.10, there is no discernible pattern. All categories are within 0.05 trips per day of the average level of 1.15, with the exception of cardholders over 500 metres from a bus route, which unexpectedly shows a much higher level of 1.27 trips per day.

These results suggest that the distance a person lives from a bus route is not linked to the regularity with which people use bus services.

Table 5.10: Shows the average number of bus trips per day for Metrocard holders in 50m categories based on how far their residential address is located from a bus route.

Distance from Bus Route	**Average Number of Trips Per Day**
50m or less	1.15
50.1m - 100m	1.16
100.1m - 150m	1.15
150.1m - 200m	1.15
200.1m - 250m	1.11
250.1m - 300m	1.16
300.1m - 350m	1.13
350.1m - 400m	1.17
400.1m - 450m	1.15
450.1m - 500m	1.12
Greater than 500m	1.27

5.4.3 | Statistical Relationship between Metrocard Usage, Deprivation, Distance to Routes and Trips per Day for Metrocard Holder Address Points

This section investigates the statistical relationship between individual cardholder address points and a number of factors. Specifically, the correlations between the number of trips per day, distance to the nearest bus route and bus stop, and the deprivation level and average density of the meshblock in which the address point is located are calculated (Table 5.11). Previous results based on visual observations have suggested that there is a strong link between the number of trips per day and the deprivation of an area, but that there is no link between the number of trips per day and the distance to bus routes and bus stops.

Table 5.11: Shows the nonparametric correlations (Spearman's Rho) between a number of factors for the Metrocard holder address points within the study area. Significant correlations are highlighted.

	Number of Trips per Day			
Distance to the Nearest Bus Route	-.001	**Distance to the Nearest Bus Route**		
Distance to the Nearest Bus Stop	-.007	.837**	**Distance to the Nearest Bus Stop**	
NZDep06 Index	.060**	-.132**	-.138**	**NZDep06 Index**
Average Density of Meshblock Address is within	-.003	-.048**	-.082**	.317**

**. Correlation is significant at the 0.01 level (2-tailed).

As per the observed results, the number of trips a cardholder takes per day is shown to be correlated with the deprivation of the meshblock in which they live. This indicates that people who live in more deprived areas are more likely to use bus services more regularly than people in less deprived areas. Similarly, there was a strong link detected between the density and deprivation of the meshblock in which cardholders were located. This is also to be expected, as density is one of the factors which is included in the NZDep06 index. Notably, however, there was no significant relationship found between the number of trips taken per day and the distance to the nearest bus route or bus stop. Unsurprisingly, the statistical results show a strong link between the distance to bus routes and the distance to bus stops, as these two factors have very similar characteristics.

A significant but negative relationship is found between both the distance to nearest bus stop and bus route and the deprivation level and average density of a meshblock. This suggests that people in more deprived areas are located in closer proximity to public transport services, and that there is a more comprehensive network of bus services provided in more deprived parts of the study area. A further link is noted between density and distance. This is likely to be a factor of more dense areas within the study area being either located in the central city, where most routes converge and hence there is a high level of bus services, or being located around suburban hubs which themselves are generally located in key public transport corridors. This result indicates that the current network design provides a greater level of access to bus services in more densely populated areas, which is a desirable result in terms of service provision.

As expected from the observed results, no significant correlation is found between the number of trips per day and the distance to the nearest bus stop or bus route. There is also no link found between the number of trips per day and the average density of the meshblock in which an address point is located.

5.4.4 | Statistical Relationship between Metrocard Usage, Deprivation, Distance to Routes and Trips per Day at the Meshblock level

The statistical relationships between the proportion of Metrocard holders, the NZDep06 index, the population density, the average number of trips taken per day, and the average distances to the closest bus route and bus stop were also investigated at the meshblock level (Table 5.12). As in Section 5.4.3, strong correlations were found between factors that were expected to have a relationship – specifically the distance to the closest bus stop and the distance to the closest bus route; and between the density of a meshblock and the NZDep06 index.

Results from previous sections have indicated that there is a relationship between the proportion of Metrocard holders in a meshblock and the deprivation of that meshblock, and a link between the proportion of Metrocard holders and the distance to the nearest bus route and bus stop has also been noted. Strong correlations between the number of trips taken per day and deprivation have also been observed.

As shown in Table 5.12, there are some strong correlations between the proportion of Metrocard holders and all other variables. The positive correlation with the deprivation index confirms the previous observations that the number of people with Metrocards in an area is directly linked to the socioeconomic status of that area. There is a negative correlation between the proportion of Metrocard holders and the density of the meshblock. This indicates that the level of Metrocard use is lower in more dense areas. This may be partly due to areas of higher density are mainly located closer to workplaces, meaning that people in these areas have less need to travel by bus.

Table 5.12: Shows the nonparametric correlations (Spearmans Rho) between a number of factors for meshblocks within the study area. Significant correlations are highlighted.

	Proportion of Metrocard holders per Meshblock	**NZDep06 Index**	**Population density of meshblocks**	**Average number of trips per day for meshblocks**	**Average distance to nearest bus route for meshblocks**
NZDep06 Index	.184**				
Population density of meshblocks	-.040*	.158**			
Average number of trips per day for meshblocks	.159**	.222**	.012		
Average distance to nearest bus route for meshblocks	-.186**	-.138**	.011	-.024	
Average distance to nearest bus stop for meshblocks	-.188**	-.165**	-.042*	-.034	.846**

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

There is also a strong link between the proportion of cardholders in a meshblock and the average number of trips per day that cardholders in the same meshblock take. This result suggests that areas which have a greater level of people who use public transport services also have a greater level of people who use these services regularly (the two results in this instance are not directly linked, as the proportion of cardholders is calculated in terms of the population of the meshblock, while the average number of trips per day is taken across all cardholders within the meshblock). As such, the result indicates that some meshblocks in Christchurch are particularly active in terms of bus use, both in terms of residents holding a Metrocard and using the Metrocard regularly; while other areas appear to have a high level of occasional bus users.

Distance to both the closest bus routes and bus stops shows a strong negative correlation with the proportion of cardholders. This result is expected, and indicates that meshblocks which are located in closer proximity to bus routes and bus stops have a higher proportion of cardholders from the overall population. There is also a negative correlation between the proportion of cardholders and the density of the meshblock. As suggested previously, the greater service level of bus services in more dense parts of the city is likely to explain this relationship.

The deprivation level of a meshblock also appears to have a strong relationship with all of the other factors. There is a strong positive correlation with the number of trips taken per day, indicating that people in more deprived areas have a greater level of use of and are more reliant on public transport services. The strong negative relationship with the distance to the closest bus route and bus stop shows that meshblocks with a high level of deprivation are more likely to be located close to public transport services, confirming other previous observed results.

The final link is between the population density of an area and the proximity to the closest bus stop, showing that higher density areas are closer to bus stops. This link is quite weak, and interestingly no relationship was identified between the density of an area and the proximity of bus routes. Nonetheless, these results indicate that areas of greater density are likely to be located close to bus stops. This can be partly explained by the location of higher density areas in the central city and at suburban hubs which are both well serviced by bus services. The density of land areas is discussed further in Section 5.5.

5.5 | Living Zones

This section investigates the links between the proportion of Metrocard holders and the Christchurch City Council City Plan planning zones.

5.5.1 | Proportion of Metrocard users across all Zones

Figure 5.15 shows the different land zonings in the study area. As is obvious from this illustration, ‘Living’ zoned areas dominate the study area, with ‘Business’ areas confined to the central city, industrial areas, and suburban centres around the city (such as Riccarton and Papanui). ‘Cultural’, ‘Open Space’ and ‘Conservation’ areas are scattered throughout the city, while there are a few rural zoned areas around the periphery of the study area. There are also some land areas zoned as ‘Special Purpose’– these are land parcels which do not fit within another zoning category, and include hospitals, the former Wigram Airforce base and the Ferrymead Historic Park.

The total areas of land zoned in each category have been used to calculate the number of Metrocards per square kilometre in each zoning category (see Table 5.13). Across the entire study area, there is an average of just under 300 Metrocard holders per square kilometre. Unsurprisingly, the average number of Metrocards per square kilometre in Living zones exceeds the overall average (384.12 compared to 299.32), while the average in other types of land zonings is significantly less (for example, in Business zones the number is only 43.56 per square kilometre, while all other land zonings, except Cultural, are even less). This finding is as expected, as the vast majority of Metrocards are registered to the holder’s residential address, and hence are likely to be located in Living zones. The comparatively high level of cardholders in Cultural zones can partly be explained by the residential activities on some of these sites (such as School Boarding houses and University Halls of Residence).

Table 5.13: Shows the number of Metrocards per square kilometre in each overall zoning type.

Zone Type	Number of Metrocards in each Zone Type	Area of Zone Type in Km^2	Number of Metrocards per Km^2 in each Zone Type
Business	565	12.97	43.56
Conservation	7	3.97	1.76
Cultural	1,437	5.74	250.51
Living	42,506	110.66	384.12
Open Space	18	7.62	2.36
Rural	43	5.48	7.85
Special Purpose	15	2.54	5.90
Whole Study Area	44,591	148.97	299.32

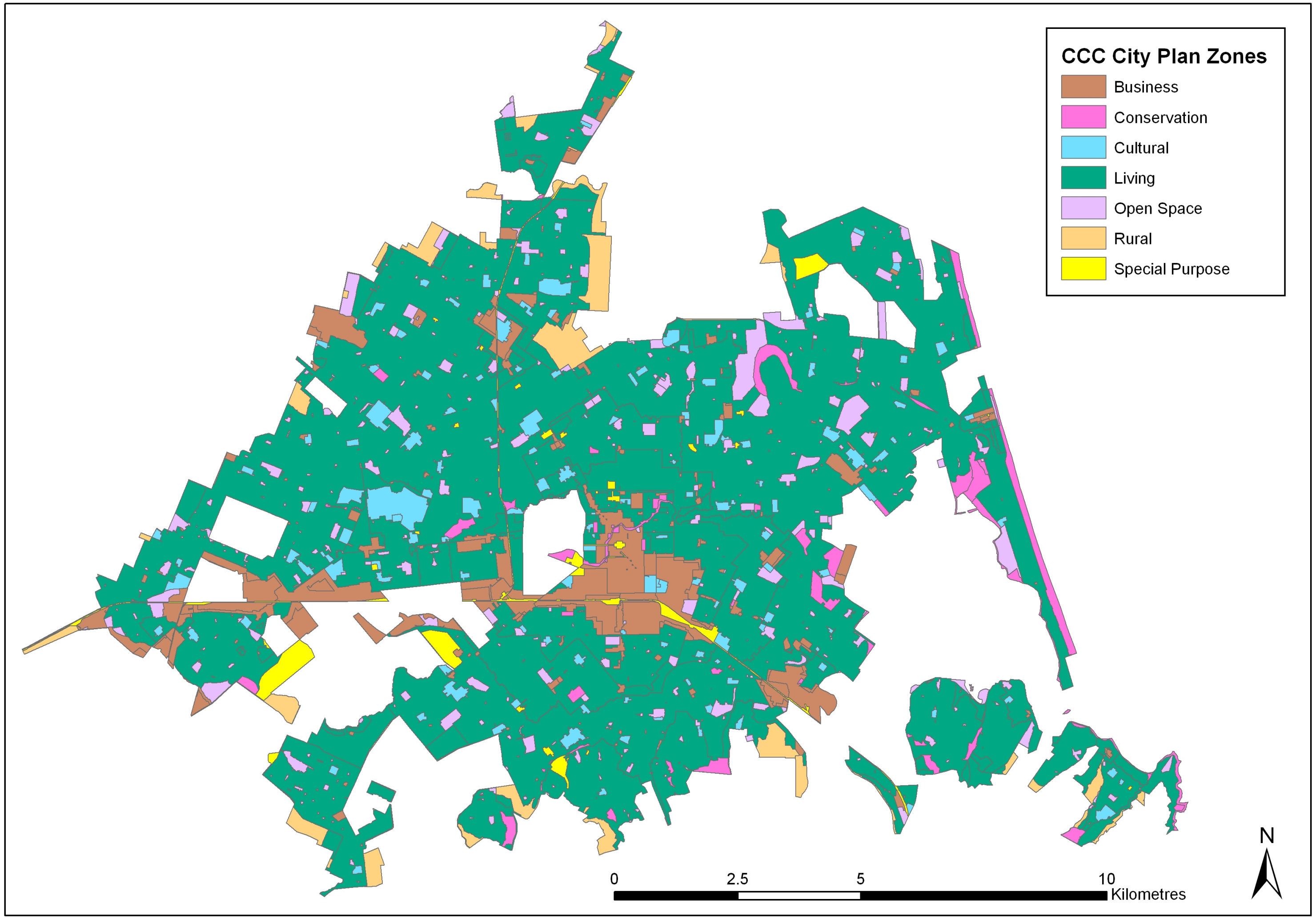

Figure 5.15: Illustrates the Christchurch City Council City Plan zoning groups in the study area.

5.5.2 | Proportion of Metrocard users in Living Zones

Figure 5.16 shows in more detail the areas zoned as one of the Living categories within the study area. These zones mainly radiate out from the city centre. The regulations imposed on Living zones mean that development in Living 4 areas can be the most dense, and Living 1 areas the least dense. Living 1 covers almost 70% of the Living zoned land within the study area (refer Table 5.14), but does not include most of the land close to the city centre. Living 2 land is regulated for slightly more dense development than Living 1, and is mainly found in a broad circle around the central city, as well as some suburban centres such as Riccarton, Hornby, Papanui, New Brighton and areas close to the University of Canterbury (see Figure 3.3 for suburb locations). Living 3 zones are located in similar areas to Living 2, but are closer to the city centre; as well being located in a small number of suburban centres. Living 3 zones are also found in small portions of new residential developments such as Northwood, indicating a desire of the City Council to increase the density of some suburban areas in the future. Living 4 zones are found almost exclusively within the central city area (with a very small zone also at New Brighton Beach) and allow for very high density development such as high rise apartment blocks. Living H zones are specifically for hill areas, but are otherwise quite similar to Living 1 areas. Living 1A areas are located on the outer suburban boundary, but again are otherwise similar to Living 1 areas. A number of very minor Living zones, such as deferred zonings, have been excluded from this analysis. These areas are generally still undeveloped, and hence have either a very low number or no cardholders within them.

The number of cardholders within each of the specific Living zones is shown in Table 5.14. The lowest value is found in Living 1A zones, followed by Living H, Living 1, Living 2, Living 3 and finally Living 4 zones. These results show that the number of cardholders per square kilometre is greater in Living zones which allow for higher densities of development, and which are generally closer to the city centre. This result is unsurprising, particularly as these areas are likely to have a higher population per square kilometre by virtue of the higher density of development allowed. Unfortunately, the incompatibility of population data for City Plan zones means that a calculation of population density in each living category cannot be made (this is because the study area boundaries are determined by census meshblocks, which do not specifically align with City Plan zones). However, the population density of meshblocks is detailed in the following Section (5.5.3).

The higher proportion of cardholders in zones which are regulated to allow for more dense development could also indicate a greater level of Metrocard use in areas closer to the city centre, as the majority of the land area of Living 2, 3 and 4 zones encircle the city centre. However, this also cannot be quantified due to the lack of population data. What can be gauged, is that the number of Metrocard holders per square kilometre is higher in more densely zoned areas, and therefore the service level of public transport services in these areas should also be higher to meet the greater demand. This is generally already the case in Christchurch, as most bus routes travel through the city centre, and therefore the Living 2, 3 and 4 zones close to the city centre already have a high level of public transport services available.

Table 5.14: Shows the proportion of the study area each Living zone makes up, and the number of Metrocards per square kilometre in each Living zoning type.

City Plan Zoning Description	Number of Metrocards in Zoning	Total Area of Zoning (Km^2)	Proportion of Living Zone Area (%)	Number of Metrocards per Km^2 in Zoning
Living 1 (Outer Suburban)	28,697	76.77	69.38	373.80
Living 1A (Outer Suburban Boundary)	551	2.55	2.30	216.29
Living 2 (Inner Suburban)	5,240	11.22	10.14	466.98
Living 3 (Medium Density and Suburban Focals)	4,654	7.78	7.03	597.90
Living 4 (Central City and North Beach High Rise)	941	1.41	1.27	667.95
Living H (Hills)	2,262	9.25	8.36	244.51
Total	42,345	110.66		*Average:* 427.91

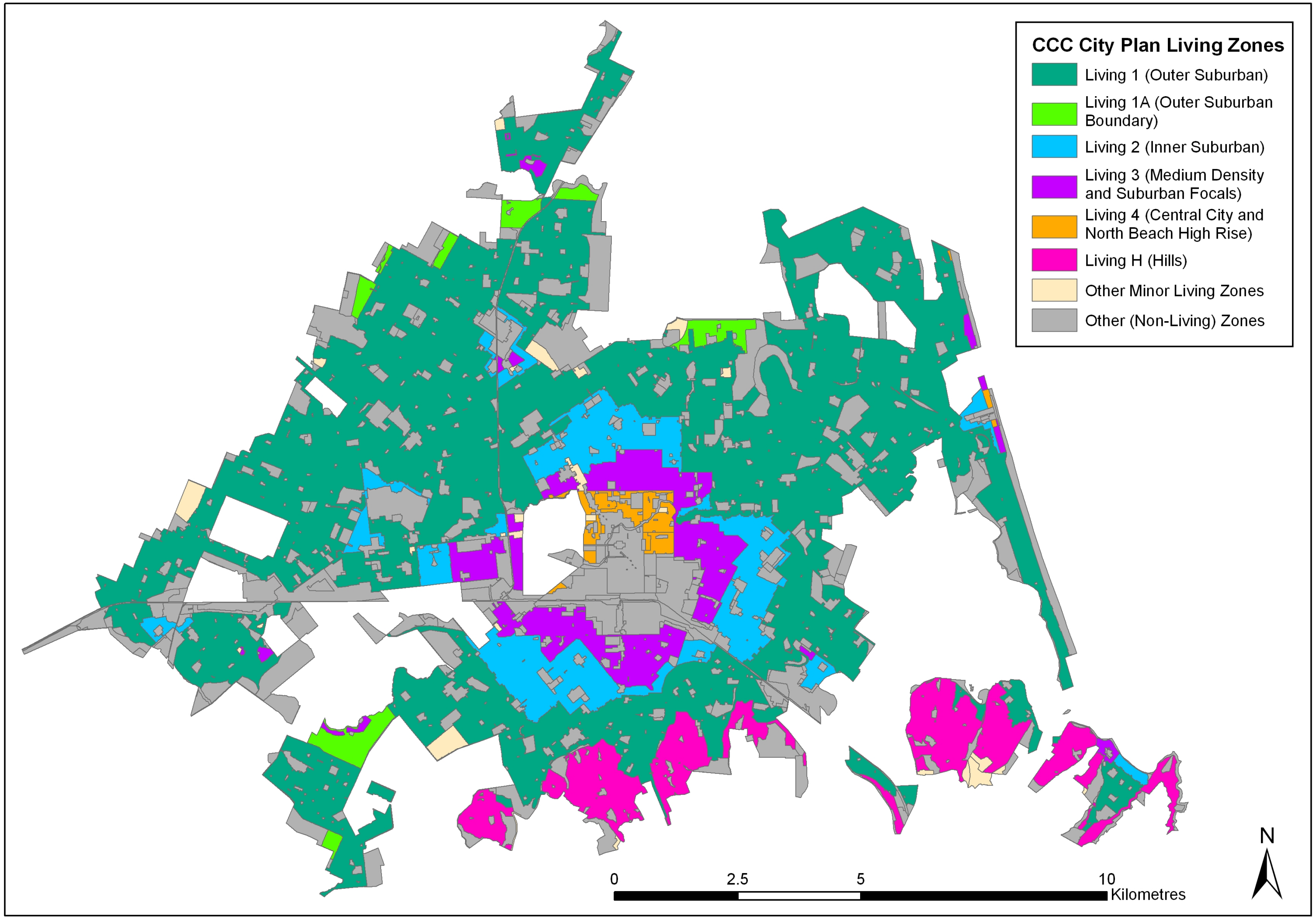

Figure 5.16: Map of the Christchurch City Council City Plan Living zoned areas in the study area.

5.5.3 | Density of Meshblocks

The population density of meshblocks within the study area is shown in Figure 5.17. While patterns in most of the outer suburbs are relatively similar, the population density in the southern part of the central city and other industrial areas is significantly lower. Many of these areas have no usually resident population at all. Furthermore, a number of meshblocks on the periphery of the study area, which are often on the urban-rural boundary, also have a lower population density. This includes a number of hill suburbs which are located along the southern edge of the city. The areas of greatest density mainly form a ring around the central city. As previously discussed in Section 5.5.2, these areas are zoned Living 2, 3 or 4, and are regulated to allow for a greater density of residential development. The higher population density observed in these areas is therefore consistent with expectations, and supports the previous observation that the higher number of Metrocards found in these areas is related to a greater density of population.

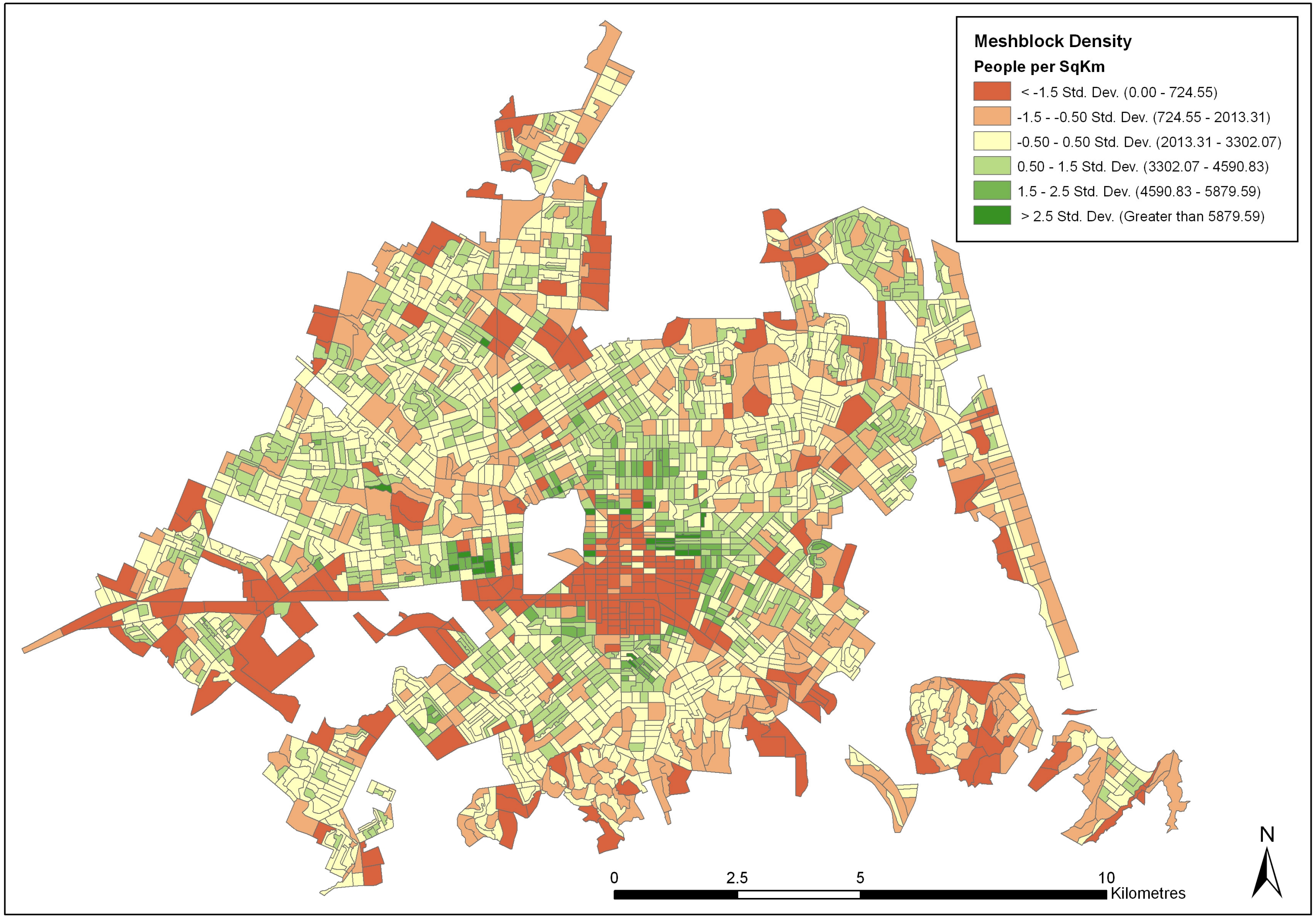

Figure 5.17: Illustrates the density of meshblocks within the study area.

5.5.4 | Relationship between Number of Trips per Day and Living Zoning

Further investigation has considered whether there is a link between Living zones and the average number of trips taken per day by Metrocard holders (see Table 5.15). Results indicate that cardholders in Living 4 and Living H zones take considerably less trips than cardholders elsewhere (1.04 and 1.03 trips per day respectively). Such results suggest that cardholders in these areas tend to use the bus services less frequently than users in other zones. This is to be expected in Living 4 zones, as central city residents are more likely to live close to their place of work, so bus travel for these users may be more common for activities other than work, which would lead to a lesser number of average trips than a daily commute would. The low result in Living H areas may be reflective of the lower deprivation level of these areas (as discussed previously, the hill suburbs within the study area tend to have a lower deprivation level, and a lower deprivation level has previously been shown to be linked with a lower average number of bus trips per day).

It is also noted that the Living 1A and Living 3 zoned areas have a higher level of trips per day than other zones (1.28 and 1.20 respectively). In the case of Living 3, this may be because these zones are generally located close to the city centre or in suburban hubs which have good access to public transport, leading to a higher level of use. Living 1A areas are primarily located on the periphery of the city, and this high result was unexpected. Results from Section 5.3 indicate that areas on the periphery of the city are generally located a greater than average distance away from bus routes and stops.

Table 5.15: Shows the number of trips per day for Metrocard holders arranged by Christchurch City Plan Living zones.

City Plan Zoning	**Average number of trips per day**
Living 1 (Outer Suburban)	1.17
Living 1A (Outer Suburban Boundary)	1.28
Living 2 (Inner Suburban)	1.17
Living 3 (Medium Density and Suburban Focals)	1.20
Living 4 (Central City and North Beach High Rise)	1.04
Living H (Hills)	1.03
All included Living Zones	*1.12*
All Zones	*1.15*

5.5.5 | Links with previous research

Research investigating the links between transport and land use have provided mixed results (van Wee, 2002), and across European cities, there is a wide variation in the respective levels of use of public transport and private vehicles for commuting (Schwanen, 2002). In Madrid, increased urban sprawl has lead to an increase in car travel for work related journeys (García-Polamares, 2010). A similar relationship has been found in this study in Christchurch, as the levels of bus use are lower in land areas which are zoned for less dense development, such as Living 1. Historically, this lower level of public transport use can be attributed to the way in which outer suburbs developed, with the prevalence of the same automobile-orientated policies which have been recognised in Auckland (Mees & Dodson, 2007) leading to similar car dominated urban form as that described in cities in the US (Muller, 1986). It is unsurprising, therefore, that this research has indicated that there is a link between the population density of an area and the proportion of Metrocard holders in the same area (and hence also a link with the density of development which the zoning of an area allows for). The link between density and public transport use has been questioned in some cases (Mees, 2009), but this link appears to exist in Christchurch. It has not been possible to directly investigate the link between mixed land uses (e.g. combined residential and commercial in an area) and public transport use that has been observed overseas (Cao et al., 2009) in Christchurch, however the high proportion of Metrocard use in the vicinity of the central city indicates that it is likely that this is a factor in driving higher level of public transport use too.

5.6 | Principal Component Analysis

This section details the results of the principal component analysis. This was undertaken on 19 variables which showed a correlation with the proportion of Metrocard holders per meshblock. Information about the 19 factors and how they were selected is contained in Section 4.4.5.

The results of the varimax rotated principal component analysis are presented in Table 5.16. This shows the loadings of the 19 variables across four factors. These factors were identified by the analysis, and cumulatively explain 59.28% of the total variance observed. The factor loadings above .40 or below -.40 were assigned practical statistical significance, as it was desired that a variable should share 15% of its variance with the variance it was going to help label. Factors outside this range were excluded for clarity reasons. The factor loadings are shown in Table 5.16, and the predominant characteristics based on the values of these factor loadings are described in Table 5.17.

Factor one accounted for 27.05% of the variance observed, and included factor loadings greater than .40 for eight of the variables. Predominant attributes of this factor included:

- being engaged in full time study
- being aged between 15 and 24
- being born overseas and having lived in New Zealand for less than ten years
- being of Asian ethnicity
- having lived in their current residence for less than a year and not owning this residence
- travelling by walking.

Such attributes can be associated with international tertiary students, and the hence the factor has been given the description 'International Students'.

The geographic spread of factor one across the study area is shown in Figure 5.18. A predominance of occurrence of this factor is seen in western Christchurch, with large clusters of high values around the University of Canterbury campus in Ilam (see Figure

3.3 for location). There is also a high value of this factor found in Riccarton and Burnside, which both have high levels of student housing, and in parts of the central city. This geographic spread reinforces the description of the factor as being clearly associated with tertiary students.

Table 5.16: Varimax rotated components for 19 selected variables. Note: all loadings less than .400 are not shown on the table for clarity reasons.

	Component			
	1	2	3	4
NZDep Index Deprivation Scale 2006		.707	.565	
Proportion of the working population who travel to work by Bus				
Proportion of the working population who travelled to work by Bicycle on the day of the Census			.467	
Proportion of the working population who travelled to work by walking on the day of the Census	.417		.530	
Proportion of population who are unemployed		.608		
Proportion of population who are not in the Labour force (e.g. Retired)				-.842
Proportion of households with access to no vehicles			.702	
Proportion of households with access to one vehicle			.683	
Proportion of population aged between 15 and 24	.815			
Proportion of population aged between 25 and 49				.836
Proportion of the population who have lived at their current residence for less than one year	.557			
Proportion of population born outside New Zealand	.763			
Proportion of population born outside New Zealand that have lived in the country for less than 10 years	.615			
Proportion of the population of Maori ethnicity		.799		
Proportion of the population of Pacific ethnicity		.747		
Proportion of the population of Asian ethnicity	.831			
Proportion of the population who do not own their own home	.492	.528	.557	
Proportion of the population participating in full time study	.852			
Proportion of the population participating in part time study				.416

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Factor two explains 14.96% of the variance, and includes five variables with values above .40. These variables included the NZDep06 index of deprivation, unemployment, not owning the residence lived in, and Maori or Pacific ethnicity. Collectively, these variables have been described as ‘Unemployed and Maori or Pacific Ancestry’.

Figure 5.19 shows the geographic distribution of factor two within the study area. It is noted that this is not as dominant in any part of the city as factor one is. Nonetheless, clear clusters of values are observed in parts of eastern Christchurch, as well as sporadically in other parts of the study area. Suburbs where high values are observed include Linwood, Aranui, Shirley, Papanui, Burnside, Riccarton, Hillmorton, and Woolston (refer Figure 3.3 for suburb locations). These areas are generally similar to the areas of high deprivation observed in Figure 5.6. There are also a number of areas with notably low values. These include areas in most suburbs on the western side of Christchurch, and the hill areas along the southern and southwest peripheries of the study area. These areas are similar to the areas of high deprivation identified in Figure 5.4. These links are unsurprising, as the NZDep06 Index was one of the variables most strongly recognised by this factor. However, these results do serve to reinforce the clear links between deprivation and the use of public transport services.

Table 5.17: Description of the four factors identified through principal component analysis.

Factor Number	Descriptive Label	Percent of variance	Predominant Characteristics
1	International Students	27.05	Travel (to work) by walking; 15 – 24 years old; own 0 or 1 vehicles; engaged in full time study; have lived at their usual residence for less than 1 year; do not own their home; born overseas; have lived in NZ for less than 10 years; Asian ethnicity.
2	Unemployed and Maori or Pacific Ancestry	14.96	Unemployed or not in the workforce; Maori or Pacific ethnicity; do not own their home; high NZ Deprivation Index scale.
3	Limited Vehicle Availability or Use	10.43	Travel to work by walking or cycling; own 0 or 1 vehicles; do not own their home; high NZ Deprivation Index scale.
4	General Workers	6.84	25 – 49 years old; in the labour force; engaged in part time study.

The third factor accounts for another 10.43% of the total variance. There are six significant factor loadings. As in the case of factor two, the NZDep06 index registers strongly, along with the proportion of people who do not own their home. This factor recognises a number of attributes to do with transport access, including having access to no or one vehicle and travelling to work by walking or cycling. The descriptive title chosen for this factor is 'Limited Vehicle Availability or Use'.

The geographic distribution of this factor shows high values in areas close to the city centre (Figure 5.20). Other areas with high values are found along key public transport corridors, such as those in Riccarton, Papanui, Addington and New Brighton (see Figure 3.3 for suburb locations). These results show strong links with areas with a Living 2, 3 and 4 zoning (Section 5.5.2) and areas with a higher population density (Section 5.5.3). It is also not surprising that areas with high values are either close to key public transport corridors, or are in close proximity to places of work, such as the city centre and suburban hubs. These results reinforce that people with poor access to vehicles tend to live in areas where vehicles are either not required or where viable alternatives are available.

The final factor (factor four) accounts for a further 6.84% of the total variance, and is described as 'General Workers'. There are only three significant factor loadings – a high level of participation in part time studies, the age bracket 25 – 49, and a strong negative value for not being in the workforce, which translates to a high value for people in the workforce. The geographic distribution of this factor is spread much more widely throughout the study area than the other factors (see Figure 5.21). In saying this, there is a cluster of high values directly to the north of the central city, and, to a lesser extent, directly to the south of the central city. A strong cluster of areas of low values is found in the western city, particularly around the University of Canterbury and in the suburbs of Fendalton, Ilam, Avonhead and Riccarton, as well as in some northeastern parts of the city (see Figure 3.3 for suburb locations). These results indicate that 'General Workers' who use bus services are spread throughout many parts of the city, but are predominantly located in areas close to the central city.

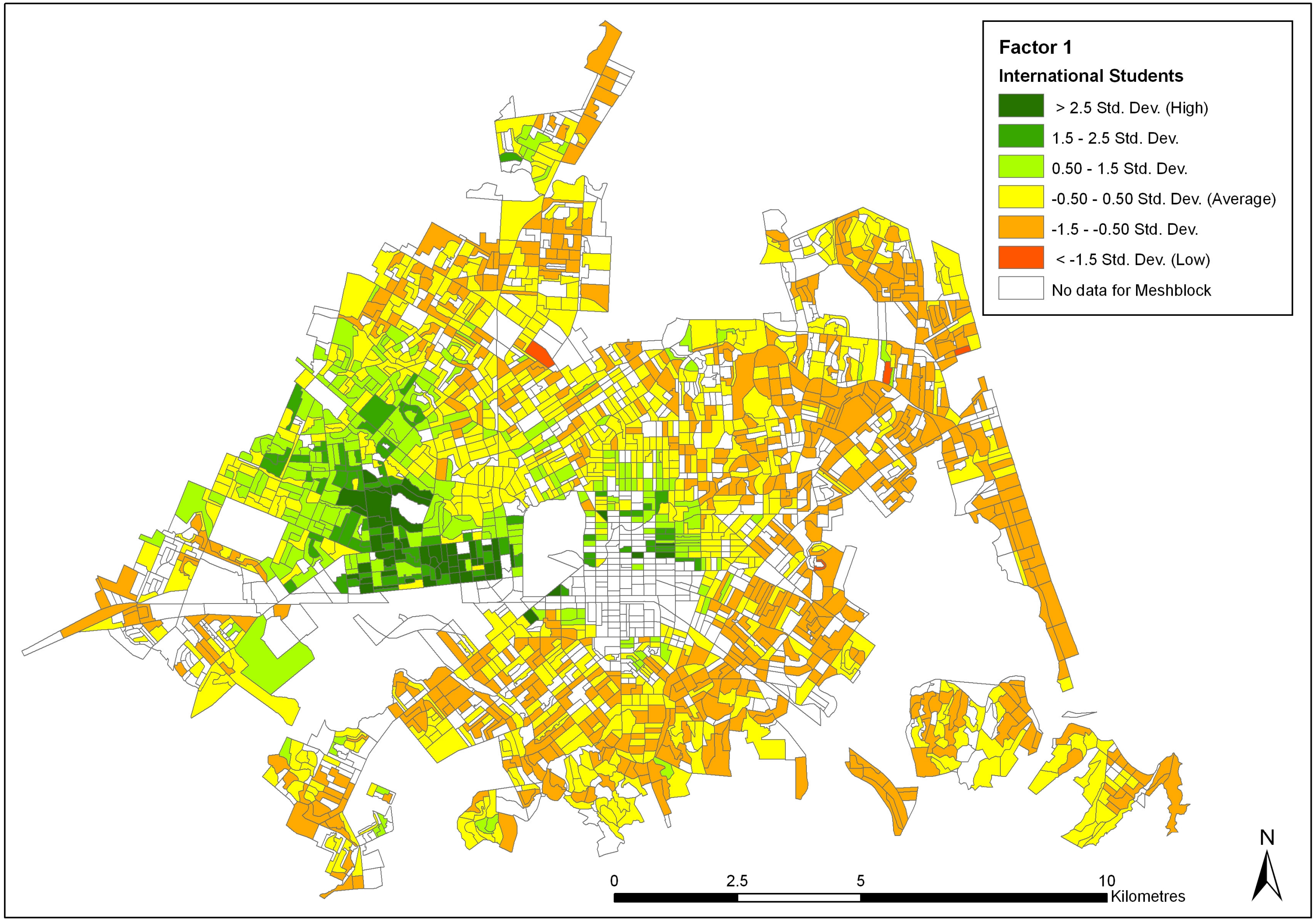

Figure 5.18: Illustrates the spatial distribution of factor 1 (international students) across the study area.

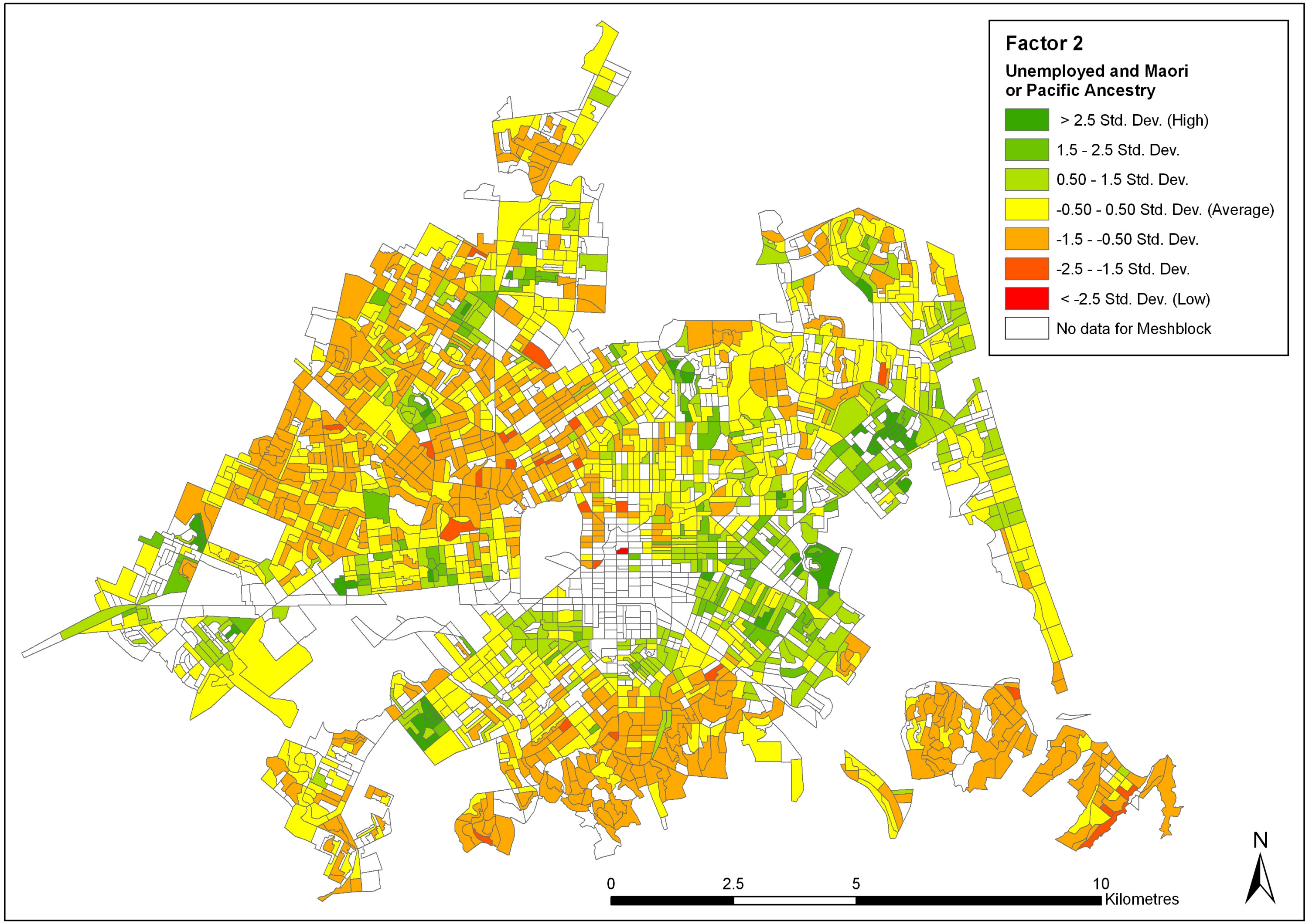

Figure 5.19: Illustrates the spatial distribution of factor 2 (unemployed and Maori or Pacific ancestry) across the study area.

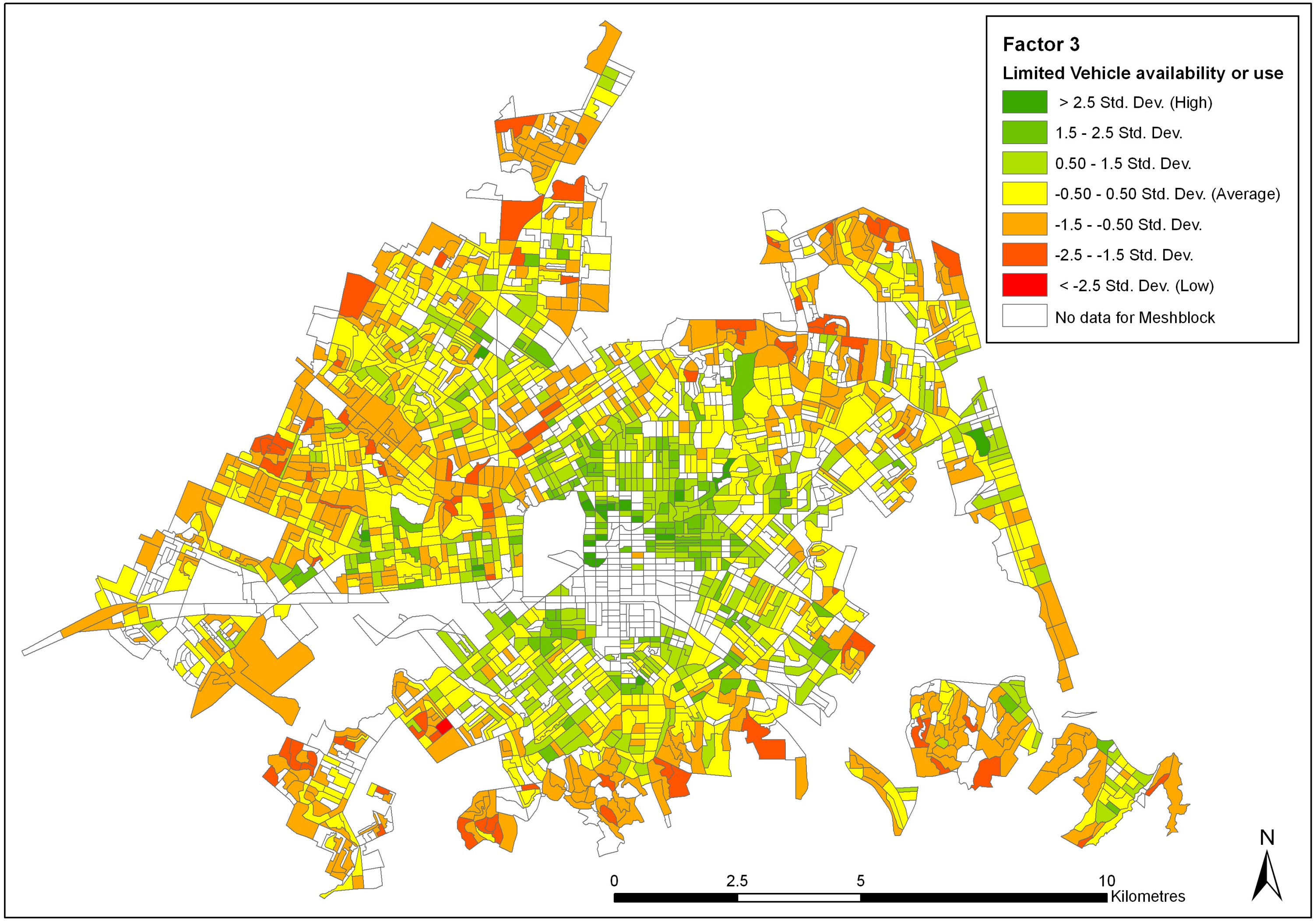

Figure 5.20: Illustrates the spatial distribution of factor 3 (limited vehicle availability or use) across the study area.

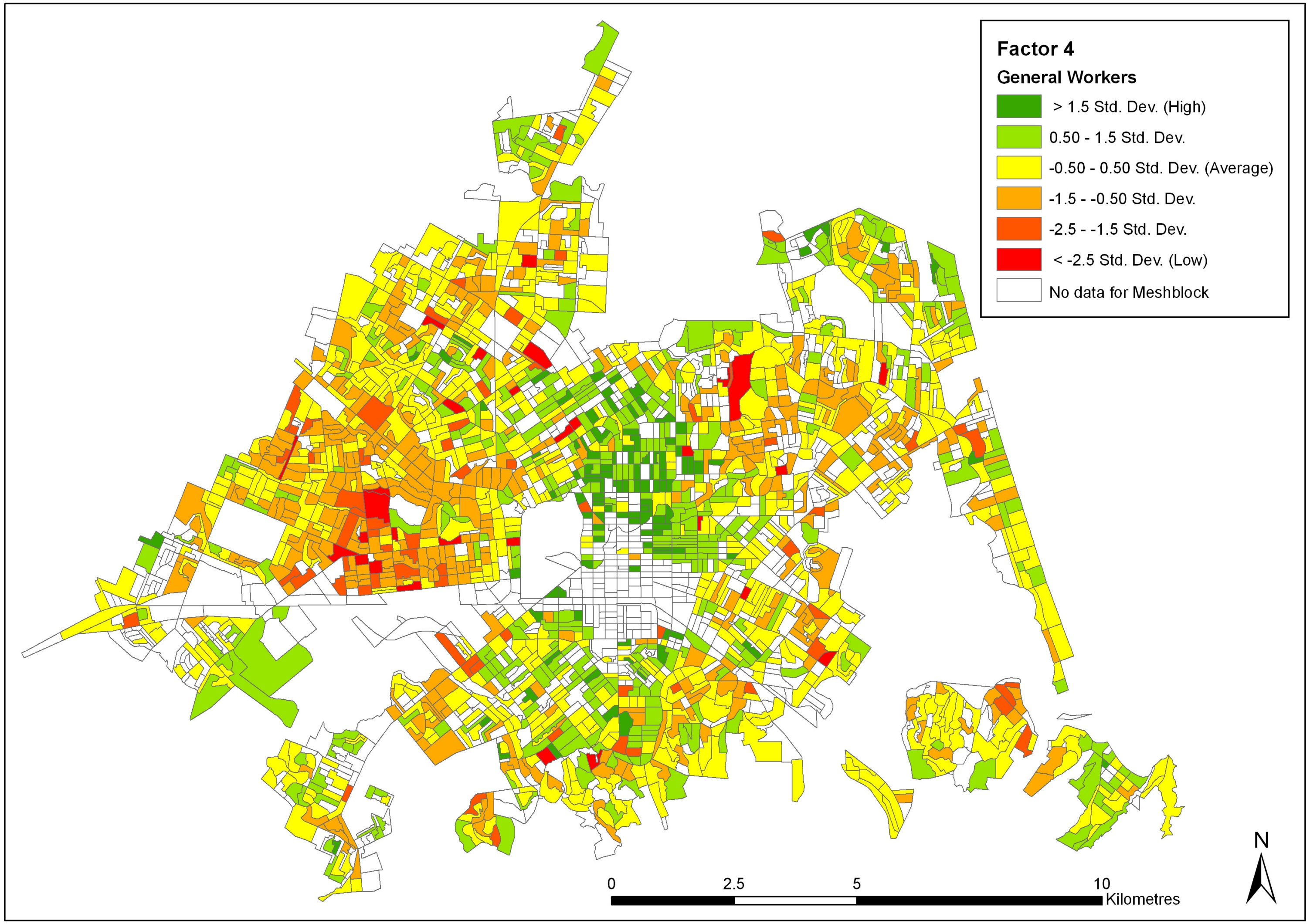

Figure 5.21: Illustrates the spatial distribution of factor 4 (general workers) across the study area.

5.7 | Regression Analysis

The final statistical analysis involved taking the principal component analysis a step further, and identifying how well the four retained factors predict public transport use in different parts of the city. This allows for identification of the areas where public transport use is over-predicted and under-predicted by the model.

The dependent variable in this regression was the proportion of Metrocard holders per meshblock, and the independent variables were the four factors retained in the principal component analysis. The adjusted R squared value of the regression was .115 (Table 5.18), meaning that this analysis only explains just over 10% of the proportion of Metrocard use, which was disappointing.

Table 5.18: The results of the regression analysis.

R	R Square	Adjusted R Square	Std. Error of the Estimate
.342	.117	.115	6.3567

The models' residual were subsequently mapped (see Figure 5.22). Based in this figure it can be observed that the majority of meshblocks are within 1.5 standard deviations of the mean value. Areas where there is an under-prediction of the level of Metrocard use (defined in this case as meshblocks with a value of -1.5 or more standard deviations below the mean) do not appear to be clustered, with the exception of a small group in the northern part of the central city, an a group in a small portion of Fendalton (see Figure 3.3 for suburb locations). Meshblocks with an over-prediction of bus use (+1.5 or more standard deviations above the mean) are found around the University of Canterbury, in some parts of the Port Hills, and in Sumner. There are also further instances scattered randomly throughout the study area.

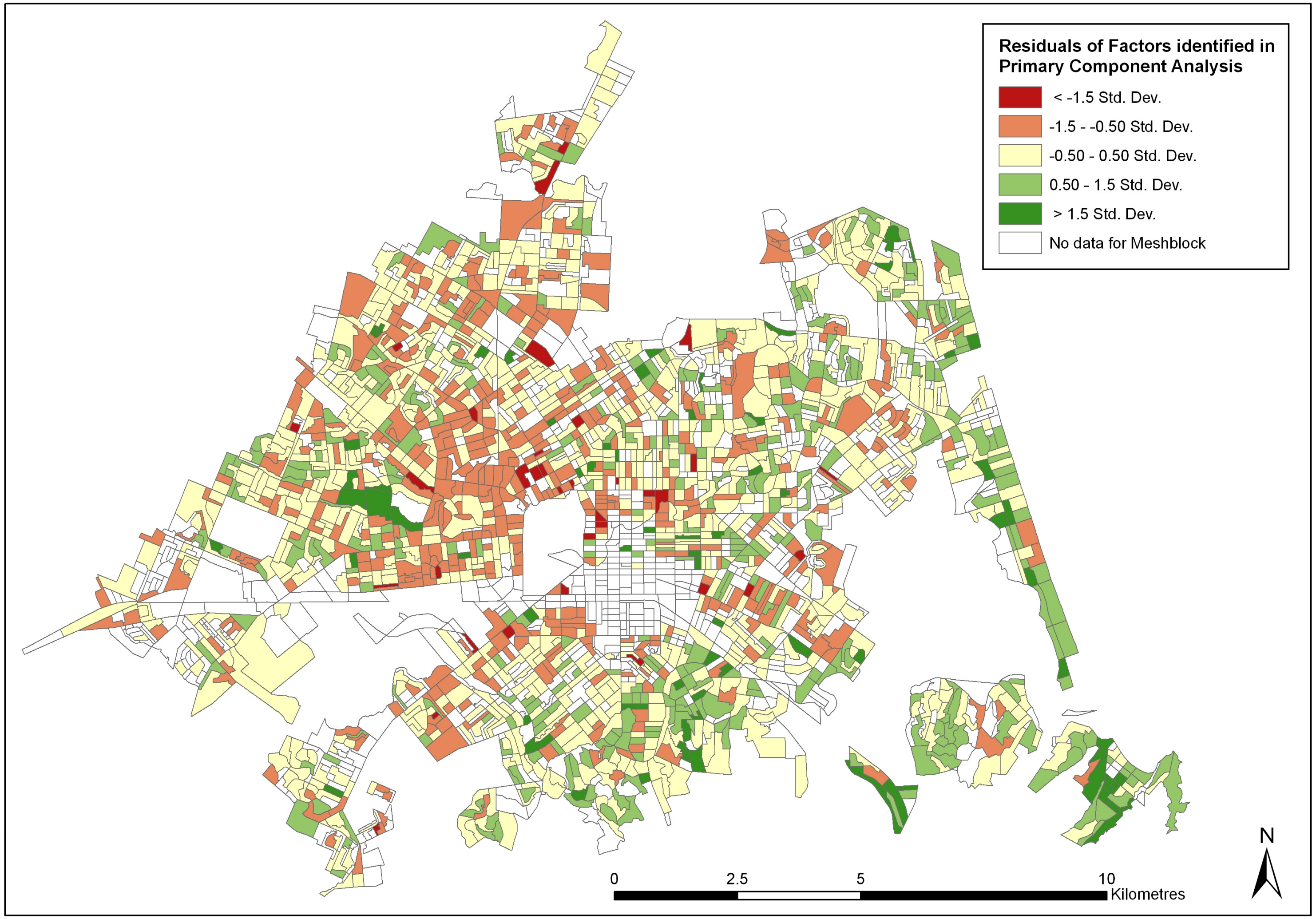

Figure 5.22: Map showing the result of the residual regression analysis across the study area.

5.8 | Summary of Commuting Patterns in Christchurch

Previous research has suggested that most commuting by bus in Christchurch is by people commuting from suburbs to workplaces in the central city (Buchanan et al., 2006). The central city has also been confirmed as the biggest commuting destination, with almost 26,000 people listing a workplace in the Cathedral Square Census Area unit which covers most of the central city area (Statistics New Zealand, 2009). Both of these research projects looked at the commuting patterns of people travelling to work, based on data sourced from the New Zealand Census of Population and Dwellings. The research in this thesis included all Metrocard users, not just people commuting to work. The results of the principal component analysis have indicated that the factor which describes the largest portion of variation in the percentage of Metrocard use is 'International Students'. This does not mean that 'International Students' are the biggest users of bus services. It does indicate, however, that in areas where there are high levels of 'International Students' (Figure 5.18), bus use will be higher because of the presence of this group. 'General Workers' is the fourth largest factor, and accounts for 6.84% of the variance. This result indicates that the public transport system in Christchurch provides a good service for more than just commuters, and this should be considered when services are created, reviewed or altered in the future.

The public transport network also provides and important social service, as indicated by the second and third factors identified through the principal component analysis: 'Unemployed and Maori or Pacific Ancestry', and 'Limited Vehicle Availability or Use'. Providing a service which caters well for people who do not have other transport options is important, and as previously discussed helps to reduce social exclusion and transport disadvantage – hopefully meaning that the lack of 'connection' as described in London (Church et al., 2000) is not felt as strongly in Christchurch.

6 | Conclusions and Recommendations

6.1 | Research Conclusions

In Section 1.2, the aims and objectives of this research were set out. The overall aim of this research was to investigate the way in which sociodemographic and land use factors influence public transport use in Christchurch, New Zealand. Five objectives were set out in order to achieve this aim. These objectives are now revisited, and the conclusions for each are detailed.

6.1.1 | Objective One: Sociodemographic Factors

This objective sought:

- to find out whether regular Metrocard users are evenly spread across the Christchurch urban area, or whether they are clustered in certain parts of the city
- to use Metrocard address and usage information to ascertain how sociodemographic factors influence public transport use, and to investigate how this varies spatially across the Christchurch urban area

It was found that while there were regular Metrocard users located throughout the study area, the level of usage was noticeably higher in some areas. In particular, there were very high levels of use in the central city and in areas near the University of Canterbury. However, in both cases it was noted that these levels were caused by unusual factors not seen elsewhere in the study area, namely the low population of the central city and the high number of people living in Halls of Residence near the University. More generally, areas with a low level of Metrocard use were noted to be more common in the northwestern part of the city.

When these results were compared to the NZDep06 index of deprivation, it was found that there was an observable link between areas of high Metrocard use and areas of high deprivation. The link between areas of low Metrocard use and low deprivation was not as clearly observable, but a clear linear relationship was able to be plotted. Subsequent correlation analysis confirmed this, with a statistically significant relationship being found.

6.1.2 | Objective Two: Land Use Factors

This objective sought:

- to use Metrocard address and usage information to investigate what impact (a) residential land use zoning and (b) residential housing density has on public transport use

Residential land zoning was found to be linked to Metrocard use, in that areas zoned for a greater density of development had a higher proportion of Metrocards per square kilometre in them. However, as population data for these areas was not available, it was not possible to directly determine whether this was simply a reflection of the lower densities of housing development in these areas. Population densities were observed to be generally higher, however, in areas which were zoned for a greater residential density.

6.1.3 | Objective Three: Distance and Regularity of Use Factors

This objective sought:

- to determine whether the distance from a bus core route (15 minute or less weekday service intervals) or non core bus route (less frequent weekday service intervals) correlates in any way with Metrocard usage, and if this varies spatially across the Christchurch urban area
- to investigate whether the distance from a bus stop correlates in any way with Metrocard usage, and if this varies spatially across the Christchurch urban area
- to find out whether the regularity of bus use is evenly spread throughout the city, or if some geographic areas have higher proportions of regularity of use than others

In most parts of the study area, a clear link between the distance to the closest bus route and bus stop and the level of Metrocard usage was not able to be observed. However, there were a few areas where this was not the case, such as Sumner. When correlation analysis was carried out on these factors at the meshblock level, the proportion of cardholders per meshblock was shown to have a significant negative relationship with the average distance to both the closest bus route and closest bus stop. This result confirms that meshblocks with a lower average distance to the closest public transport services have a higher proportion of Metrocard holders, even though this result is not easily observable.

Areas of high deprivation were observed to be generally close to core bus routes, and this was borne out by the percentage of cardholders within 200 metres of a core bus route being found to be higher in more deprived areas. 76.34% of cardholders were found to be located within 200 metres of any bus route, with 98.83% within 500 metres. For individual cardholders, it was found that there was a statistically significant negative relationship between the distance to the closest bus stop and bus route and the deprivation level of the meshblock in which the cardholder is located. This result confirms that people in more deprived areas are located closer to public transport services, and is consistent with the previous observations.

It was observed that the average number of trips per day does show some variation across the study area, and that people in more deprived areas appear to have a higher number of trips per day than those in less deprived areas. This was confirmed by correlation analysis, which showed a statistically significant relationship between the number of trips per day of a cardholder, and the deprivation level of the meshblock in which they are located. However, the number of trips per day did not have a statistically significant relationship with the distance to the closest bus route and stop, indicating that regularity of bus use is not linked to proximity to bus services.

6.1.4 | Objective Four: Characteristics of Metrocard Users

> *This objective sought:*
> - to find out if there are any particular variables that are directly linked with Metrocard use, and therefore can be used as a proxy to determine expected usage patterns

The relationship between the proportion of Metrocards per meshblock and a number of variables was assessed through correlation analysis. A statistically significant relationship was found with a number of variables, including access to one or no vehicles; Maori, Pacific or Asian ethnicity; lack of home ownership; participation in full or part time study; and being unemployed or out of the workforce.

Using primary component analysis, it was found that four factors explained the majority of the variance in the proportion of Metrocard holders. These were, in order of the amount of variance explained:

- International Students (27.05%)
- Unemployed and Maori or Pacific Ancestry (14.96%)
- Limited Vehicle Availability or Use (10.43%)
- General Workers (6.84%)

When regression analysis was carried out, it was found that there are only a few pockets of meshblocks throughout the city where this model significantly over or under predicts bus use. However, both the primary component analysis and the subsequent regression only explained around 10% of Metrocard use variance. This suggests that there are other factors at play which were not investigated in the models used in this research.

The final objective, making policy recommendations for improving public transport services based on the results of this research, is dealt with in Section 6.3.

6.1.5 | Summary of Findings

In summary, this research has reached the following conclusions:

- that there is a link between the sociodemographic characteristics of an area and the proportion of bus use
- that there is a link between the distance to the closest bus route and bus stop and the proportion of bus use
- that the regularity of bus use (number of trips taken per day) is higher in more deprived areas, and in areas of greater residential density
- that there is good bus service provision across the whole study area, but particularly in more deprived areas
- more dense forms of development is beneficial for increasing public transport use
- industrial parts of the city are poorly served by bus routes
- bus use is higher in areas where there are larger numbers of International Students
- use of bus services are greater in areas with larger numbers of people associated with more deprived characteristics, such as those who are unemployed or those who have limited vehicle access.

6.2 | Research Limitations

There are a number of limitations caused by practical issues, particularly to do with the nature of the dataset used.

The Metrocard dataset has never been used for research purposes before. The main purpose of this dataset is to hold information from a revenue perspective, to make sure that the correct fares are deducted from the card and passed on to the bus operators. The information used in this research is important for the identification of cardholders, but supplementary to the main purpose of the dataset. As such, the quality of the data is not as high as it might have otherwise have been.

There is no compulsion for cardholders to advise Environment Canterbury of any change of address. Therefore the address in the database may not be the current address of the cardholder. This research has assumed that the numbers of people moving in and out of meshblocks who use public transport are likely to remain similar on the whole, but this can only be an assumption. Evidence in the research has proved that in some cases this is not true, such as meshblocks near the University of Canterbury with Halls of Residence located in them.

The geocoding process used was open to inaccuracies. Although these were mitigated as far as possible, some addresses were still not able to be matched due to poor or inaccurate information.

Distances used in the analysis were all Euclidian distances (as the crow flies). These do not take into account things such as the road network when calculating distance to the closest bus stop or bus route. The distance calculations also assumed that the closest bus route or bus stop would be of use to the cardholder. It is recognised that in some cases this would be true, particularly, for example, if the nearest service was a cross-suburban route and the cardholder normally required a route that travelled to the city centre (or vice versa).

The lack of data in some situations also limited the conclusions that could be made. This is particularly true of the in the case of Living Zones, where no population data was available to calculate the population density of each zone.

The number of trips taken per day calculation included all trips taken. In the cases where a person regularly needed to travel on two or more services to complete one journey, would generate multiple transactions for what is in effect only one journey. Conversely, a person could make a similar commuting trip but on one service the entire way, generating less transactions for their trips. This means that people who regularly transferred between two or more services would have an inflated calculation of number of trips taken per day.

Finally, the validity of this research was limited by some aspects of the analysis. In particular, the statistical analysis methods used yielded very low levels of accuracy, meaning that the results found are limited in the extent to which they can be used to explain relationships.

6.3 | Recommendations from Research

This section details recommendations for future policy planning stemming from this research.

6.3.1 | Sociodemographic Recommendations

This research has identified that there is a relationship between the proportion of cardholders in a meshblock, and the deprivation level of this meshblock. Consequently, it is recommended that future public transport planning takes into account the greater demands for bus services in more deprived areas with appropriate service levels. Services in more deprived areas are important to reduce the effects of transport disadvantage, so it is recommended that even if services are not very viable in some places, they continue to run to provide this socially important link.

At the same time, ways to provide more attractive services in less deprived areas should be investigated. Innovative ideas could be trialled that may be more attractive and useful for people in these areas, such as door to door dial-a-ride services.

The research has also indicated that groups other than regular commuters are highly represented in using public transport services. It is recommended that further investigation is carried out as to the influence of groups such as 'International Students' on the level of bus use in parts of the city. Furthermore, where there is evidence of particular groups heavily using bus services, consideration should be given to analysing whether the services provided meet the needs of these groups, and also whether new and innovative services could be provided to target certain specific markets.

6.3.2 | Land Use Planning Recommendations

This research has found that bus use is higher in land areas that are zoned for a higher density. It is recommended that policies which encourage a higher density of development along key public transport corridors continue to be pursued.

Whilst the excuse that public transport services are not as effective in less dense areas has been well used, it has been argued that this is not always the case (Mees, 2009). Therefore it is recommended that bus route planning in less dense areas (such as Living 1 and Living H) investigates the possibility of providing innovative new services to encourage patronage growth in areas of lower residential density.

Finally, it should be recognised that not all people using bus services wish to commute to the city centre. A form of service provision for people who work in (mainly industrial) areas currently isolated from existing bus services is recommended. Again, this might not be a traditional conventional bus service, but rather an innovative service tailored to meet the needs of people who may use it.

6.4 | Future Research Possibilities

This research has highlighted a number of avenues for possible future work.

A new ticketing system is being installed on Christchurch buses in 2010. This system will continue to use the existing Metrocards, but will be able to collect further information such as the GPS coordinates of the location where a cardholder boarded the bus. Future research may be able to use this extended database to incorporate the boarding information from cardholders with other factors used in this thesis.

There is much scope to do more research which would delve further into the reasons why people choose to use or not use bus services. Such motivations could be behavioural, so research from a psychology perspective would be of interest. Other research possibilities could be investigating the relationship between where people work and where they live, and what particular variables are associated with these locations; or how the types of job people have influences whether they will use public transport.

This research has only been able to scratch the surface in terms of investigating the relationship between public transport use and a range of other factors. However, it is hoped that this work might provide the genesis for more research projects in the future, that are able to delve deeper into exploring these complex and interesting relationships.

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Appendices

Appendix One: List of Bus Routes in Christchurch included in the Research

Core Routes

- 3 Avonhead – Sumner
- 5 Hornby – New Brighton
- 7 Halswell
- 28 Lyttelton
- 40 New Brighton via Wainoni
- 60 Parklands
- 70 Queenspark
- O The Orbiter
- M Metrostar (Halswell – New Brighton)

Other Core Corridors

- Papanui Road
- Cranford Street
- Main North Road (Northcote Road – Harewood Road)
- Colombo Street

Non-core Routes

- 3 Roydvale Ave
- 10 Airport – Cashmere
- 11 Styx Mill – Westmorland
- 12 Northwood
- 13 Redwood – Hoon Hay
- 14 Nunweek
- 15 Bishopdale – Bowenvale
- 16 Belfast
- 17 Bryndwr – Barrington
- 18 St Albans – Huntsbury

- 19 Burnside – Spreydon
- 21 Ilam – Mt Pleasant
- 24 Hyde Park – Bromley
- 29 Airport
- 35 Heathcote
- 46 Shirley
- 49 North Shore
- 51 Tower Junction – New Brighton via Aranui
- 66 Murray Aynsley
- 67 Dyers Pass
- 81 Lincoln
- 83 Hei Hei – Burwood
- 84 Russley – Avondale
- 90 Rangiora via Kaiapoi

Appendix Two: Environment Canterbury Confidentiality Clause

Metrocard data

Confidentiality Clause

In order to undertake your research, Environment Canterbury will provide you with information collected from the Metrocard system. During your research, and after its completion, you shall not disclose or use, in any manner whatsoever, any confidential or commercially sensitive knowledge or information, including patronage. You shall not disclose the identity of any cardholder, or any confidential, private or identifying information to any third party.

Signed: EPN Wright Date: 24/08/2010

Name: Edward Wright

Appendix Three: Human Ethics Approval

UC
UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Human Ethics Committee
Tel: +64 3 364 2241, Fax: +64 3 364 2856, Email: human-ethics@canterbury.ac.nz

Ref: HEC 2009/LR/67

10 August 2009

Edward Wright
Department of Geography
UNIVERSITY OF CANTERBURY

Dear Edward

Thank you for forwarding to the Human Ethics Committee a copy of the low risk application you have recently made for your research proposal "The influence of land use patterns and socio demographic distribution on public transport use in Christchurch, New Zealand".

I am pleased to advise that this application has been reviewed and I confirm support of the Department's approval for this project.

With best wishes for your project.

Yours sincerely

Dr Michael Grimshaw
Chair, Human Ethics Committee

University of Canterbury Private Bag 4800, Christchurch 8140, New Zealand. ***www.canterbury.ac.nz***

Appendix Four: List of the 60 independent variables included in the correlation analysis detailed in Section 4.4.5.

Population of meshblock
Area of meshblock
Population density of meshblock
NZDep Index Deprivation Scale 2006
Proportion of the working population who worked at home on the day of the Census
Proportion of the working population who did not go to work on the day of the Census
Proportion of the working population who drove themselves to work on the day of the Census
Proportion of the working population who travelled as a passenger in a private car to work on the day of the Census
Proportion of the working population who either drove themselves to work or travelled as a passenger in a private car to work on the day of the Census
Proportion of the working population who travelled to work by Bus on the day of the Census
Proportion of the working population who travelled to work by Motorcycle on the day of the Census
Proportion of the working population who travelled to work by Bicycle on the day of the Census
Proportion of the working population who travelled to work by walking on the day of the Census
Proportion of the working population who travelled to work either by walking or cycling on the day of the Census
Proportion of population who are employed in full-time work
Proportion of population who are employed in part-time work
Proportion of population who are unemployed
Proportion of population who are not in the Labour force (e.g. Retired)
Proportion of population whose employment status is unknown
Proportion of households with access to no vehicles
Proportion of households with access to one vehicle
Proportion of households with access to two vehicles
Proportion of households with access to three or more vehicles
Median age of population in meshblock
Proportion of population aged under 15
Proportion of population aged under 20
Proportion of population aged between 15 and 24
Proportion of population aged between 20 and 29
Proportion of population aged between 20 and 64
Proportion of population aged between 25 and 49
Proportion of population aged between 30 and 39
Proportion of population aged between 30 and 44
Proportion of population aged between 40 and 49
Proportion of population aged 50 years or over
Proportion of population aged 65 years or over
Proportion of the population who have lived at their current residence for less than one year

Proportion of the population who have lived at their current residence for 1 - 4 years
Proportion of the population who have lived at their current residence for less than 5 years
Proportion of the population who have lived at their current residence for less than 10 years
Proportion of the population who have lived at their current residence for 10 years or more
Proportion of the population who have lived at their current residence for 10 - 30 years
Proportion of the population who have lived at their current residence for 30 years or more
Proportion of population born in New Zealand
Proportion of population born outside New Zealand
Proportion of population born outside New Zealand that have lived in the country for less than 10 years
Proportion of population born outside New Zealand that have lived in the country for less than 20 years
Proportion of population born outside New Zealand that have lived in the country for more than 20 years
Proportion of population born outside New Zealand that have lived in the country for more than 40 years
Proportion of the population of European ethnicity
Proportion of the population of Maori ethnicity
Proportion of the population of Pacific ethnicity
Proportion of the population of Asian ethnicity
Proportion of the population of Middle Eastern, Latin American or African ethnicity
Proportion of the population who list their ethnicity as 'other'
Proportion of the population who own their own home
Proportion of the population who do not own their own home
Proportion of the population participating in full time study
Proportion of the population participating in part time study
Proportion of the population participating in any kind of study
Proportion of the population not participating in study