Masters of Urban Resilience and Renewal 2021

University of Canterbury

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Co-benefits of implementing transport emission reduction actions in Christchurch

Acknowledgements

I would like to thank everyone who has helped me throughout my research project, I would not have been able to do it without you. Firstly, I would like to thank my supervisor from the University of Canterbury, Dr. Lindsey Conrow, for her time, knowledge, and guidance throughout this research project. Your invaluable feedback and dedication have been extremely helpful and is greatly appreciated. Thank you for giving up your time to help me and for the knowledge you helped me to gain.

I would also like to thank my family and friends for their support, encouragement, and help during my university studies. Your unending love, belief in me, and feedback have been invaluable, and I couldn't have done it without you all.

Abstract

Automobile dependency has become a key issue worldwide, resulting in declining air quality, traffic congestion, health issues, noise problems, and road injuries and fatalities. Alongside high levels of private vehicle ownership and use, the transportation sector has become a key contributor to total greenhouse gas emissions. In New Zealand, transport emissions have increased rapidly in recent decades, accounting for 21% of total annual emissions. In Christchurch, the transport sector accounted for 54% of total emissions for the financial year of 2018/2019. To reduce emissions from transport, a wide range of emission reduction actions have been established and implemented overseas. Many scholars focus on the impacts these actions have on reducing emissions, with a limited analysis of the other benefits they provide, especially regarding the effects they have on social connectedness, wellbeing, resilience, and accessibility.

This research project aims to address this gap by assessing the co-benefits of four transport emission reduction actions that are likely to be implemented in Christchurch by the Christchurch City Council. These actions are low traffic neighbourhoods (LTNs), reallocation of road space (road diets), road pricing (congestion charging), and mass rapid transit (MRT). All these actions produce a range of benefits alongside reducing transport emissions. This research will benefit my community partner, the Christchurch City Council, by providing a more in-depth analysis and assessment of the co-benefits the above actions will have. There will be a particular focus on how they will impact social connectedness, accessibility, wellbeing, and resilience, all of which are key to creating a healthy and resilient city. Three research questions underpin this research: Firstly, *what are the co-benefits of these actions? In particular, how do these actions impact social connectedness, wellbeing, and resilience?* Secondly, *how do these actions impact accessibility for commuting traffic where these actions could be implemented?* Finally, *what are the public's perceptions of transport and neighbourhood in environments in Christchurch, and would these actions impact how people choose to travel in the Greater Christchurch area?*

A co-benefits framework is used to answer the research project aim. This framework assessed the proposed actions against a range of benefits and were scored accordingly through a weighted scoring system. The survey is used to investigate the public's current travel mode

choices, current views on the effectiveness of these modes, neighbourhood environments and their impact on social connectedness and travel in Christchurch, and whether the identified actions will encourage a modal shift towards more sustainable transport choices. ArcGIS Pro was used to show where these different actions could be implemented in Christchurch and the impact, they are likely to have on accessibility for commuting traffic and how they might impact different socioeconomic groups.

Results from this co-benefits framework showed that LTN's produce the greatest co-benefits, particularly on the social aspects of the framework while congestion charging scored the lowest overall. Spatial analysis revealed that LTN's, road diets, and MRT will improve accessibility for those commuting by sustainable modes and will reduce transport poverty and transport disadvantage. Congestion charging will improve access for sustainable modes but may worsen transport poverty and transport disadvantage if mitigation measures are not implemented. The survey results indicate that all four actions will cause a mode shift to more sustainable modes in the Greater Christchurch area.

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1.0 Introduction

Transport has a large impact on the environment, social connectedness, wellbeing, and resilience. In 2016, Christchurch had the worst air pollution in New Zealand (Morahan et al., 2021). The transport sector was a large contributor to this, accounting for 54% of total emissions in Christchurch (Morahan et al., 2021). If the current transport trends continue, carbon dioxide emissions from private vehicles and buses will increase by about 45% by 2048 (Morahan et al, 2021). This will significantly reduce people's quality of life and negatively affect the environment. It is, therefore, of great priority to find ways to reduce transport emissions in Christchurch to create a more healthy, resilient, and socially connected city.

In 2018, the Ministry of Transport produced a framework outlining a set of five outcomes for New Zealand's transport system. These five outcomes include: inclusive access, healthy and safe people, economic prosperity, environmental sustainability, and resilience and security, all of which are the overarching themes of this study's co-benefit's framework. By working to achieve these five outcomes, the transport system can achieve its main purpose which is to help improve the liveability of places and enhance people's wellbeing (Ministry of Transport, 2018).

The transport system has a significant impact on many social aspects of life, such as social connectedness, accessibility, individual and community health and wellbeing, and resilience. It effects the way people travel, how connected people are to others, and how accessible amenities and resources are. It is important that the transport system connects everyone of all incomes to their neighbourhood and the wider city while facilitating and encouraging people to use sustainable modes, such as public transport and cycling. This is especially important in Christchurch where areas with the lowest levels of car ownership are exposed to the greatest levels of air pollution from vehicles (Pearce & Kingham, 2005). For instance, low-income households often live near busy roads. Moreover, people living in the more deprived areas of Christchurch are faced with higher mean annual levels of air pollution. By implementing transport emission reduction actions in Christchurch, this environmental injustice can be reduced, and even eradicated.

Reducing car dependency and increasing active transportation (walking and cycling) is not only beneficial for the environment, but also increases social connectedness and improves the wellbeing of individuals and communities. For example, Kingham et al. (2020) found that low traffic volumes, through the implementation of a temporary road closure, increased recreational use of a neighbourhood space in Christchurch, facilitating social interactions, and improving social connectedness. Additionally, Leyden (2003) found that walkable and mixed-use neighbourhoods have higher levels of social capital than car-orientated suburbs. Reducing transport emissions and creating a more socially connected society will strengthen urban resilience. Strengthening resilience is vital at both an individual and communal level for people and communities to cope and adapt to disruptions such as the current COVID19 pandemic. Transport resilience is a key part of this as a resilient transport system ensures that when a disruption occurs, people are still able to access key amenities and connect with others.

One way to reduce emissions is through policy and planning actions that aim to decrease the number of motor vehicle trips people make, the length they travel, and by causing a modal shift towards more sustainable transportation options such as walking, cycling and using public transport. While each intervention is aimed at reducing car dependency and emissions, they have additional benefits and drawbacks that impact decisions as to what actions will be taken and where. This study will focus on four key emission reduction actions that are likely to be implemented in Christchurch by the Christchurch City Council. These are low traffic neighbourhoods (LTN's), reallocation of road space (road diets), road pricing (congestion charging), and lastly, mass rapid transit (MRT). This research will take into account the environmental benefits these actions provide but will pay greater attention to the social impacts they produce. For example, how these actions impact social connectedness, wellbeing, and resilience. It is important to consider the range of benefits these actions provide as people are more likely to change their behaviour towards more climate-positive actions such as reducing their car use, if a range of other benefits are produced (Floater et al., 2016).

1.1 Study Area

The Greater Christchurch Area extends from Rolleston to Rangiora (Greater Christchurch Partnership, n.d.). It includes Christchurch City as well as all areas within the Waimakariri and Selwyn districts.

Christchurch City, itself, is known as the "garden city" because of its high proportion of parks, public gardens, and other recreational areas (Christchurch City Council, n.d.). It has a total population of 369,006 as of 2018 with 77.9% identifying as European and 9.9% identifying as Māori (Stats NZ, 2018). The average age is 37.1 years like that of New Zealand which has a median age of 37.4 years. 50.3% of people are employed full time while 3.8% of people are unemployed. As of 2018, Rolleston central had a total population of 3,258 and Rangiora central had a population of 36 (Stats NZ, 2018). In Rolleston central, 60.00% of people are employed full time, similarly, 63.60% of people in Rangiora central are in full time employment. The median age in Rolleston is 35.8 compared with Rangiora which has a median age of 34.5.

Christchurch has a high car dependency with 72.9% of people driving to work in 2018 (Stats NZ, 2018). This is higher than the New Zealand average of 69%. This is a significant problem as transport accounts for 54% of total emissions in Christchurch. Active travel uptake is low with only 9.5% of people walking, jogging, or cycling to work. Public transport use is much lower with only 4.2% of people taking public transport to get to work. Although Christchurch has a low percentage of public transport use and active travel, cycling to work is higher than the New Zealand average by 3.6%.

1.3 Community partner

My community partner for this research project was the Planning and Strategic Transport team at the Christchurch City Council (CCC). I completed my internship on this team and from this internship, my dissertation topic was conceived. My primary role in this internship was to conduct an evidence-based literature review on an extensive range of transport emission reduction actions with a strong focus on how these actions impact emissions, mode shift, trip length, and the number of trips made. From this large selection of emission reduction actions, my CCC supervisor gave me a list of actions to focus on for my study that are the preferred options to be implemented in Christchurch. In exploring this literature, I identified a gap concerning the co-benefits of these actions and how they compare. It is important to address this gap as it is vital to understand which actions provide the greatest benefits overall to ensure the most beneficial actions are implemented. A mixed-method approach is used to understand the co-benefits of the four transport emission reduction actions, how they may impact accessibility, and how people choose to travel in the Greater Christchurch area.

2.0 Literature Review

This literature review will begin by explaining social connectedness and how it impacts wellbeing and resilience, followed by transport's role in these. Next, each of the four transport emission reduction actions will be discussed, beginning with LTN's, followed by reallocation of road space, road pricing, and finally, MRT.

2.1 Social connectedness, wellbeing, and resilience

2.1.1 What is social connectedness?

Transport is known to impact social connectedness, and social connectedness is a main driver of wellbeing and resilience. The definition of social connectedness varies in the literature; however, this research paper will define social connectedness as the relationships people have, their sense of belonging, and how their social networks benefit the individual as well as society in general (Bel et al., 2009; Ministry of Social Development, 2016; Nimegeer et al., 2018). Ultimately, social connectedness is the social ties between people (Frieling et al., 2018). Social connectedness is impacted by a range of factors such as personality type, the strength of one's social identity and the social norms in one's network (Frieling et al., 2018). It is often measured by indicators such as the number of friends an individual has and how much contact they have with their friends and family. Equally, if not more importantly, it is about the quality of these relationships.

Frieling et al. (2018) state there are three key elements of social connectedness. These are socialising, social support and sense of belonging, all of which are protective factors that contribute to a person's wellbeing and resilience. Socialising refers to individuals coming together to enjoy each other's company. Social support is the support provided or available in times of need by one's social network. This can be emotional, instrumental, and/or informational support. A sense of belonging is about feeling connected and valued by others (Frieling et al., 2018).

2.1.2 What is social capital?

Social connectedness is an important factor in social capital which is a key contributor to an individual's and communities' wellbeing and resilience. One of the most widely used definitions of social capital is that from Lin (2001): "the resources embedded in social networks accessed and used by actors for actions" (pp 25). Several authors also explain it as the collaboration and coordination established through social networks, trust, and norms which provide mutual benefits for the community or social organisation helping them to function properly (Ministry of Social Development, 2016; Putman, 1993). Ultimately, social capital is the ability of a person or community to access and use resources because of the relationships they have (Lin & Smith, 2001).

Au (2019) argues that social capital can be understood and analysed at an individual or collective level. This research paper will focus on social capital at a community level. Several authors note that a community level perspective looks at the level of social networks, trust, social cohesion, and participation in a neighbourhood or community to determine the extent of social capital present (Aldrich & Meyer, 2015; Lin & Smith, 2001; Zugravu et al., 2021). These stocks of social capital are also key determinants of wellbeing and the extent to which people and places are resilient to stressors and shocks. As such, understanding the level of social capital in a specific place gives some indication of the level of wellbeing and resilience.

Several authors show that there are three main forms of social capital: bonding, bridging, and linking social capital (Au, 2019; Lin, 2005; Szreter & Woolcock, 2004). Bonding capital is the social relationships between a homogenous community such as family whereas bridging capital is the social ties between differing groups and identities (Au, 2019; Lin, 2005; McCrea et al., 2014; Sano, 2008; Szreter & Woolcock, 2004; Yila et al., 2013; Zugravu et al., 2021). Linking social capital is the vertical ties established by individuals to connect them with those who have more power or influence (Szreter & Woolcook, 2004; Yila et al., 2013). For example, this could be government agencies or banks which allow them to access resources, jobs, and services. Aldrich and Meyer (2015) argue that bonding, bridging, and linking social capital all provide different outcomes to individuals and communities all of which are important for wellbeing and resilience.

An important finding from Au's (2019) research is that as with any form of capital such as economic and human capital, there can be inequalities. For example, Putman (1993) and Yila et al. (2013) note that some networks and social norms that support and benefit one group may discriminate against another. As a result, social mobility can be reduced for some people which in turn restricts them from moving upwards in life and, thus, can have a negative impact on their wellbeing and ability to cope and adapt to stressors. Furthermore, Putman (1993) emphasises that social capital tends to accumulate meaning that those with social capital tend to gain more and are, therefore, able to move to higher positions in society. In contrast, those who are not well networked are further excluded from society and, therefore, lack the resources needed to reach new levels.

2.1.3 Social connectedness and wellbeing

To understand how social connectedness impacts wellbeing at an individual and societal level, we must first understand what wellbeing is. Allin and Hand (2014) note that wellbeing is a multi-dimensional concept and can be analysed at the individual or communal level. Michaelson et al. (2012) explains that wellbeing varies from happiness as it takes into account a range of factors, rather than just how 'happy' a person feels at a given moment. They argue that it is how someone feels, how they function, and how they view their lives. How someone feels relates to an individual's happiness or anxiety, how someone functions is based on an individual's sense of connectedness to others and their own capabilities, and finally, how someone evaluates their life relates to their life satisfaction (Michaelson et al., 2012). A person with a good overall wellbeing will typically be better able to cope and adapt to challenges and disruptions and will, therefore, be more resilient.

Wiseman and Brasher (2008) define community wellbeing as the present social, environmental, and cultural conditions that impact both an individual's and communities' ability to flourish in life. Wiseman and Brasher (2008) further note that enhancing community wellbeing is not only important for the functioning of a community, but also for improving individual mental health outcomes. This is of vital importance with the COVID19 pandemic, wars, rising living costs, the more frequent and intense natural hazards, and many other global problems resulting in increased depression and anxiety (Dewa et al., 2021). Resilience is a key factor in maintaining and strengthening a community's wellbeing.

Social connectedness is vital to one's overall wellbeing. Many scholars note that being socially connected provides companionship, enjoyment, support, the assurance of one's worth, a sense of belonging and purpose, and better mental health (Glanz et al., 2008; Haslam et al., 2015; Ministry of Social Development, 2016; Satici et al., 2016). As a result, those who are more socially connected typically have a better overall wellbeing and have a greater ability to cope with stressors in their lives. Aldrich and Meyer (2015) state that this is because those who are more socially connected are more likely to be rescued, seek medical assistance, receive help from others, and take preventative actions (Aldrich & Meyer, 2015).

A number of studies have shown that social networks provide individuals access to new contacts which expands their knowledge and information, helping them to solve problems efficiently, while also giving them access to resources, especially ones needed to flourish (Glanz et al., 2008; Lin, 2005). The term 'flourishing' is often used to describe someone who has good overall wellbeing. Additionally, Poortinga (2012) found that social networks are a key aspect in maintaining health, dealing with stress, and reducing the effects of other health problems. Furthermore, Frieling (2018) found that close and supportive relationships have a causal effect with wellbeing. For example, a study by Adriaansen et al. (2011) found that high levels of perceived support showed increases in life satisfaction. Multiple studies have also revealed that mortality is linked to social connectedness (Berkman & Syme, 1979; Cohen, 1988; Uchino, 2004). For example, Berkman and Syme (1979) found that even after controlling for physical health, health practice, health behaviours and use of health services, that those who lacked social and community ties had higher mortality rates than those who were well socially connected. Pierce et al (2000) state that those who believe they have support available when needed may spend less time worrying about issues, helping to reduce anxiety and depression.

2.1.4 Social connectedness and resilience

Social connectedness is essential for an individual's and community's wellbeing. Additionally, it is also vital for an individual's and communities' resilience. The definition of resilience varies in the literature and across disciplines. However, this study will define resilience in individuals as an adaptive stress resistant or the ability to cope and thrive in the face of adversity (Ahern et al., 2008; Davydov et al., 2010). Likewise, community resilience is the ability of a community to adapt and respond to change in ways that ensures the community thrives (McCrea et al., 2014). A resilient community is, therefore, one which can cope with change and 'build back better'. A community which is more resilient tends to have better wellbeing at both an individual and community level (Ministry of Civil Defence & Emergency Management, 2019**).**

Social connectedness contributes to an individual's and communities' resilience by providing support and access to resources needed to thrive. For example, strong social networks are vital for a community's resilience by helping to create trustful relationships in the community which in turn helps the community to function efficiently (Ministry of Social Development, 2016). Aldrich and Meyer (2015) state that a well-functioning community will be able to cope better with disruptions. Furthermore, they argue that social networks contribute to resilience by providing access to resources such as information, and emotional and psychological support. Importantly, Yila et al. (2013) note that communities with strong levels of bridging, bonding, and linking social capital are more likely to cope better with hazards.

2.1.5 Transport's role in social connectedness, wellbeing, and resilience

The transport system plays a large role in how socially connected people are, their wellbeing and how resilient a person or place is. It does this by facilitating or restricting access to goods, services, support networks and other amenities, and by affecting how people choose to travel (Raerino et al., 2013). For example, Frieling et al (2018) state that access to transportation is a key factor that influences people's opportunities to connect with others by either acting as a barrier to forming and maintaining social connections, or by facilitating engagement and social interactions. Many scholars have found that living close to either a newly established or existing busy road is associated with lower physical and mental wellbeing (Anciaes at al., 2019; Foley et al., 2017; Nimegeer et al., 2018). Several authors note that this is because busy roads can result in noise disturbance and vibration, air pollution, loss of greenspace, loss of aesthetic appeal, and creating severance within local communities (Foley et al., 2017; Hart &

Parkhurst, 2011; Wiki et al., 2018). Conversely, Leyden (2003) found that neighbourhoods that are less car dependent and facilitate active travel modes are more connected and have greater social capital. By implementing transport emission reduction actions in Christchurch that reduce car dependency and encourage the uptake of sustainable modes of travel, social connectedness can be strengthened.

How people choose to travel can impact a person's wellbeing. For example, Jones et al. (2020) state that those who regularly use active transport modes, such as walking or cycling, tend to have better physical and mental health. This is because active transport provides exercise, increases neighbourhood social interaction, creates more opportunities for social engagement, and creates a cleaner and quieter environment (Jones et al., 2020). However, participation in active transport can vary across age, ethnicity, and gender. For example, Russel et al. (2021) reveals that in countries where cycling has a low uptake such as New Zealand, cycling tends to be unevenly distributed across gender with men being much more likely to cycle than women. Furthermore, they found that in New Zealand, Māori men have similar cycling rates to Pakeha men. However, Māori women have a low cycle rate of 1.6% so are much less likely to cycle regularly in comparison to Māori men (5.9%) and Pakeha women (2.5%).

2.1.6 What is transport resilience and how does it contribute to community resilience?

Transport resilience contributes to a community's overall economic and social resilience. Cheng et al. (2021) define transport resilience as the "ability of the transport network to withstand the impact of extreme weather, to operate in the face of such events and to recover promptly from its effects" (Introduction section, para. 1).

Mattsson & Jenelius (2015) state that transport resilience is critical for society to meet people's daily mobility needs and to provide a lifeline for post-disaster recovery and response. It is important that the transport system is resilient to ensure communities can quickly connect after a disruption through maintaining and restoring access (Waka Kotahi NZ Transport Agency, 2022). According to Xu et al. (2018) one way to achieve a resilient transport system is to ensure that there is redundancy in the network. Berdica (2002) defines redundancy as having a range of optional routes and means of transportation in place.

Victoria Transport Policy Institute (2019) further provide an overview of transport resilience and outline ways to increase resilience in the transport network. One important aspect identified to strengthen transport resilience was to increase transportation system diversity This means ensuring there are opportunities for people to walk, cycle, use public transport, and carshare, creating a multi-modal transportation system (Litman, 2021: Victoria Transport Policy Institute, 2019; Xu et al. 2018). Active travel infrastructure and public transport, therefore, can play a significant role in enhancing transport resilience. Ultimately, a resilient transport system is one which will always ensure access and for all people.

2.2 Accessibility

Chapman and Weir (2008) state that accessibility is about ease of access. Access can be defined as a person's ability to connect with others and with goods, services, and opportunities, allowing them to fully participate in society (Waka Kotahi NZ Transport Agency, 2022). Importantly, numerous studies show that those who have limited access are more susceptible to social exclusion which decreases one's wellbeing and resilience (Bernstein, 2016; Bailey & McLaren, 2005; Russel et al., 1984; Litman, 2003). Chapman and Weir (2008) note that some groups are more prone to social exclusion through accessibility issues. These are people on low-incomes, people without access to a car, people with disabilities, rural people, children and young people, older people, and minority groups and new migrants.

A key role of the transport system is to provide access for all. Accessibility is an important factor in social capital as those who able to easily access people and places will have greater means to enhance their social capital through the ability to participate in society and form social connections. Those who are more at risk of facing transport disadvantage and transport poverty consequently have reduced access, meaning that they are likely to have lower social capital than others which in turn will negatively impact their wellbeing and resilience. Raerino et al. (2013) and Rosier & McDonald (2011) define transport disadvantage as the inconsistency between transport and the location of services that reduces one's participation in society. Importantly, several authors note that transport disadvantage can reduce a person's quality of life (Currie & Delbosc, 2010; Social Exclusion Unit, 2003). Rosier and McDonald (2011) state that low-income households and people with disabilities are the most at risk of facing transport disadvantage. Ministry of Transport (2021) explains that this is because those on low incomes tend to live in areas that are dependent on car use and, therefore, face higher travel costs. Rosier and McDonald (2011) argue that many footpaths have not been well looked after making wheelchair access difficult for people with physical impairments. Additionally, public transport can be difficult to use for people with disabilities. Māori are also more likely to experience transport disadvantage as they tend to have lower incomes on average and often live in areas not well serviced by public transport (Ministry of Transport, 2021). Parker (1997) found that a lack of access to a car is a significant obstacle to gaining employment for Māori. This is because New Zealand has been designed in a way that favours cars as the main means of transportation. Raerino et al. (2013) emphasises that access to employment is strongly determined by car ownership. Consequently, being able to easily access employment is crucial as it impacts income and, in turn, health. For Māori, access to places linked to their cultural identity such as a marae (traditional Māori meeting place) are extremely important for their wellbeing. Participants in Raerino et al. (2013) study stated that accessing these sites was only possible by driving and that public transport did not cater for these journeys. A well-connected and reliable public transport system as well as safe cycle routes can reduce transport disadvantage for all by providing low-cost options.

Transport poverty is another important aspect in transport accessibility. Definitions vary among scholars and the term is often interchanged with terminology such as transport disadvantage, accessibility poverty, and transport related social exclusion. However, these terms all have different meanings. Ministry of Transport (2021) argues that transport poverty differs from transport disadvantage as it occurs when people pay more than they can reasonably afford to travel a certain way, most commonly this is using and owning a car. Several authors state that transport poverty encompasses both accessibility and affordability (Churchill & Smyth, 2019; Lucas et al., 2016; Pérez-Peña et al., 2021). For example, Lucas et al. (2016) argue that a person is transport poor if they have poor access to destinations needed to satisfy their daily needs, they have to travel for an excessive amount of time, the travel conditions are dangerous or unsafe, and they are faced with high transport costs. While Churchill and Smyth (2019) define it in a narrower sense as households finding it hard to meet the cost of transportation. The current car-dominated transport system in New Zealand and the lack of safe and reliable alternative travel modes to access health care, employment, and other amenities, means transport poverty is a significant problem. Jones et al. (2020) note

Māori have a greater likelihood of experiencing transport poverty than others as they tend to be over-represented among low-income households. This means they will have reduced access and, thus, fewer opportunities to participate in society.

Transport, therefore, impacts how socially connected people are, people's wellbeing, and the level of resilience in individuals and communities. There are a range of interventions used in New Zealand and overseas to reduce transport emissions and encourage people to switch to more sustainable and healthy modes. This research will focus on low traffic neighbourhoods (LTN's), road diets, congestion charging, and Mass Rapid Transit (MRT). These actions all aim to reduce emissions while providing a range of other benefits.

2.3 Low traffic neighbourhoods

2.3.1 What are low traffic neighbourhoods?

Low traffic neighbourhoods (LTNs) are a cost effective, area-based intervention that use planters, bollards, camera gates, or bus gates to remove or discourage through motor traffic from residential streets (Logan et al., 2021; Sustrans, 2020). These 'modal filters' can be temporary or permanent. The main purpose of a LTN is to make residential streets more inclusive, pleasant, and safer for people to walk and cycle, while also reducing local noise and air pollution (Sustrans, 2020). This is achieved by making it difficult for traffic to cut through residential streets from one main road to another while retaining access for all residents and visitors, and any other necessities such as emergency service vehicles (Logan et al., 2021; Rosehill Highways et al., n.d.). Ultimately, a successful LTN will make active travel modes more convenient than using a car for short trips for those who live in the area.

2.3.2 What are the benefits of low traffic neighbourhoods?

LTN's are now common schemes used throughout the Netherlands and England. They have been found to reduce car vehicle use, increase the use of active travel modes, and create safer environments and more socially connected neighbourhoods.

Numerous studies have shown that LTN's are effective at reducing car vehicle use. A study conducted by Adred et al. (2012) found that the LTN in Waltham Forest, London, significantly decreased motor vehicle traffic inside the neighbourhood. For example, evidence from Flow

(2016) and Weeks (2019) showed that after the LTN was implemented, motor vehicle trips decreased by 56% on 12 key residential roads in the village of Walthamstow from February 2014 to July 2016. Similarly, Lambeth Council (2022) found that the Railton LTN in Lambeth resulted in a 58% decrease in traffic volumes inside the LTN. Hackney's London Fields LTN showed similar results with Hackney Council (2021) revealing an average 44% traffic reduction inside the LTN. Furthermore, evidence from Lambeth Council (2022) and Hackney Council (2022) showed an 11% decrease in traffic volumes on the periphery of Railton's LTN and a 21% traffic reduction on the boundary roads of Hackney's London Fields LTN. Additionally, car flows decreased by more than 75% along key routes such as Railton Road. The majority of the boundary roads of Railton's LTN showed a reduction in traffic volumes. However, some locations had slightly increased traffic levels (Lambeth Council, 2022).

Not only have studies shown that LTN's reduce conventional car use but they also have been found to decrease the level of vehicle ownership. Aldred & Goodman (2020) found that levels of car and van ownership decreased by 7% from 2014 (pre LTN) to 2016 (LTN established) in London's LTN. These effects were found to be several times greater than in areas that only included interventions such as cycle lanes. A study conducted by Goodman et al. (2020) on active travel interventions, including LTN's, in the same areas between 2015 and 2019 found that the number of cars or vans registered in LTNs decreased by 6% after two years compared to areas with no LTNs.

In addition to reducing car use, LTN's increase the use of active travel modes, which in turn can provide benefits to the economy. Aldred & Goodman (2020) conducted a longitudinal study from 2016 to 2019 on LTN's in London and found that residents in LTN's increased their average weekly walking from 76.4 minutes in 2017 to 155.2 minutes in 2019. Furthermore, Aldred & Goodman (2020) found that their average weekly cycling increased from 14.5 minutes in 2017 to 20.3 minutes in 2019. Additionally, Aldred and Goodman's (2020) study revealed that 3 years following the implementation of the LTNs, the neighbourhoods that were a LTN had the highest number of minutes of active travel over one week (an average of 134.2 minutes) compared to areas with only active travel interventions, such as cycle lanes (an average of 22.1 minutes). Evidence from Lambeth Council (2022) showed that the Railton LTN resulted in a 51% increase in cycling within the LTN and a 31% increase in cycling on the periphery. Walking and cycling provide a range of benefits such as improved physical health and mental wellbeing, but it also contributes significant benefits to the economy. Transport for London (n.d.) found that walking and cycling improvements can result in a 30% increase retail spending and walking and cycling can prevent billions of dollars' worth in health and environmental damage.

LTN's have been found to create safer environments by reducing road danger and causing a reduction in street crime. A study conducted by Aldred at al. (2021) found that within the Waltham Forest LTN, road injuries were substantially reduced by 70% for pedestrians, cyclists, and drivers. Furthermore, a study by Goodman and Aldred (2021) showed an 18% reduction in street crime inside the LTN after 3 years. In August 2020, the Lambeth Council published an Equalities Impact Assessment looking at the impact the Railton LTN had on a range of demographic groups such as age, disability, and religion, and on socio-economic status. Lambeth Council found that the LTN helps to create a more inclusive environment and reduces road danger, enabling more people to take part in active travel. Lambeth Council identified that low-income groups and disabled people would benefit the most from an LTN.

By creating safer environments and facilitating active travel, LTN's can help to create more socially connected neighbourhoods. Kingham et al. (2020) explored the idea of the effects of a temporary road closure in Fisher Avenue, Christchurch, on community wellbeing within the neighbourhood. The research found that with less traffic on the road, there was an increase in recreational use of the space. This facilitated social interactions, improving social connectedness in the neighbourhood.

Public support and perceptions of LTN's vary by place and scheme. Lambeth Council (2022) revealed both positive and negative perceptions of the Railton LTN after acquiring feedback from the community. Some perceived benefits the community noted included feelings of improved safety crossing the roads while cycling and walking, better access to local schools and facilities, and improved health and wellbeing. However, some concerns were raised such as the impacts the LTN has on the boundary roads and concerns about potential extended travel times for residents and emergency service vehicles. In London, a survey of 345 residents from LTN's was conducted. This survey found that 63% of respondents either agreed or strongly agreed that the LTN has improved their lives as Londoners (Sustrans, 2020). Logan et al (2021) conducted a survey on public attitudes of residents from four LTN interventions in England (King's Health schemes 1 and 4, Birmingham, Birds Hill area, Bournemouth, Westbury and Leopold Roads, Ipswich, and Trinity and Islington, Salford). Findings from Logan et al. (2021) study showed that 61% of respondents supported the LTN in their local area. Additionally, 50% agreed that their local LTN had not significantly altered their journey time to their frequently visited destinations. Furthermore, only 33% agreed that the LTN encourages people to change to alternative modes and 43% agreed that the LTN made living in their neighbourhood more pleasant. Despite this, 48% disagreed that the LTN helped create a sense of community.

2.3.3 What are the drawbacks of low traffic neighbourhoods?

In August 2020, the Lambeth Council published an Equalities Impact Assessment looking at the impact the LTN had on a range of demographics groups. Lambeth Council noted a potential negative equality impact was that of increased journey times for disabled or older people who depend largely on private vehicles to get places. However, increased travel time may be counteracted by increased neighbourhood road safety and improved accessibility for other transport modes.

2.3.4 Implementing a low traffic neighbourhood

A LTN will be most successful when the area includes many key local amenities such as greenspace, schools, shops, and public transport options to ensure intra-neighbourhood journeys rather than residents having to travel elsewhere to access these resources (Sustrans, 2020). Importantly, a LTN must be planned as an entire area, a size of around 1-1.5km, that is bounded by main roads (Rosehill Highways et al., n.d; Sustrans, 2020). Furthermore, Sustrans (2020) note that it is crucial to ensure that the boundary roads can cope with heavier traffic volumes. This is because immediately following the introduction of a LTN, it is common for there to be a short-term increase in traffic along these boundary roads.

LTN schemes should be implemented in areas where there is the greatest need and where the LTN will have the greatest impact. According to Sustrans (2020), this should be done in areas with the poorest air quality, highest deprivation levels, highest traffic volumes, poorest access to greenspace, high collisions rates, greatest number of schools, high levels of obesity, low car ownership, low public transport accessibility, and where there is local support for the scheme.

After identifying an area to implement an LTN, measures to stop through traffic are needed (Sustrans, 2020). This can be achieved by modal filters, diagonal filters, bus gates, banned turns including no entry or no exits, one-way streets, and pocket parks. The location of these modal filters and travel restrictions can be decided by starting at one boundary road and moving through the neighbourhood to another boundary road (Sustrans, 2020).

To minimise the cost of implementing an LTN, Sustrans (2020) suggests that the number of filters should be kept to a minimum. Another important aspect to consider is ensuring residents can drive to their closest boundary road to limit inconvenience. To do this, filters should be in the centre of the neighbourhood. If the LTN is bounded by a cycling corridor or local high street, filters should be located closer to that boundary (Sustrans, 2020). Importantly, all modal filters should contain lockable bollards to ensure emergency services can get through when required.

2.4 Reallocation of road space: road diet

2.4.1 What is reallocation of road space?

Reallocation of road space includes a range of initiatives such as the living streets initiative, shared streets initiative, bus priority, road diets, pedestrian improvements, and the provision of cycle lanes (Fleming et al., 2013). This paper will focus on road diets as an initiative of reallocation of road space.

A road diet consists of reducing the number of road lanes, most commonly, from four lanes to three lanes. Typically, this road conversion results in one lane each way and a two-way turning middle lane (FHWA, 2017; Lyles et al., 2012; Noland et al., 2015; Thomas, 2013). Figure 2 shows an example of a basic road diet.

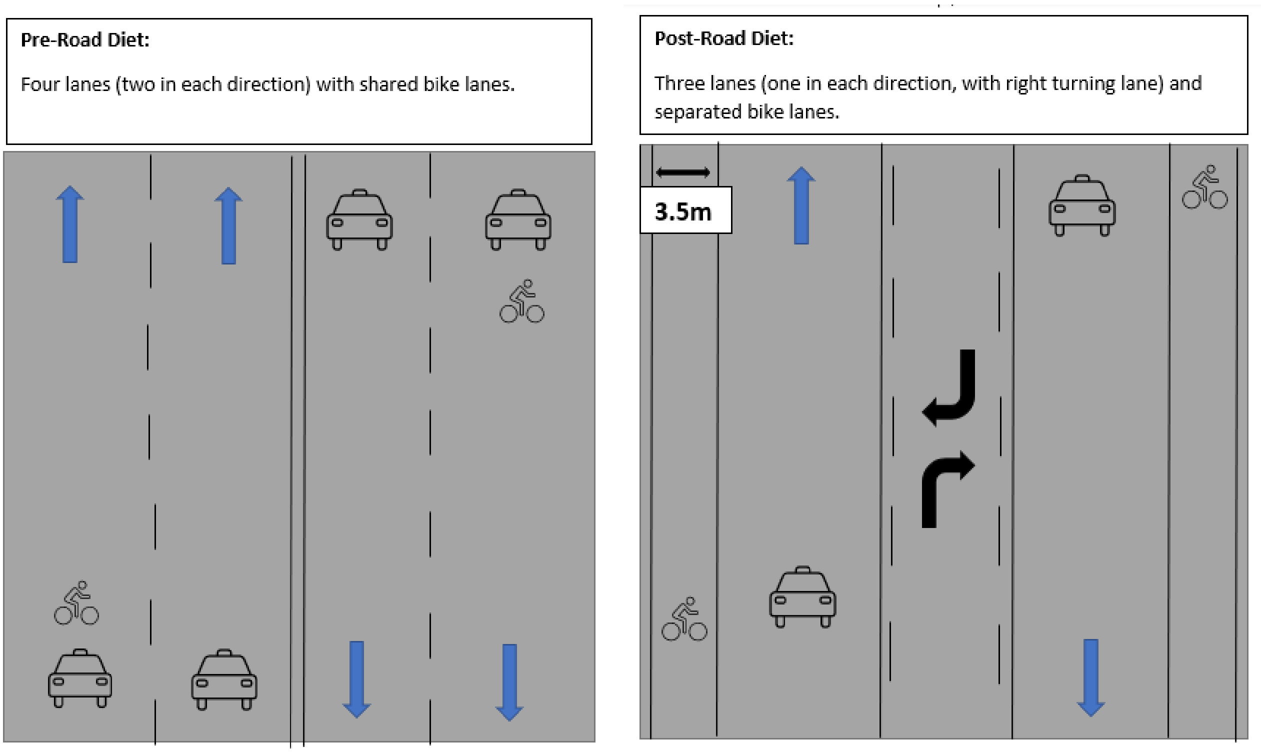

Figure 1: Diagram of a basic road diet

The space created from this lane reduction is often used to improve or add cycle lanes, implement safer pedestrian crossings, extend pedestrian walkway space, and incorporate more greenspace into the area. Reducing the number of road lanes and creating wider sidewalks creates more space to add trees or other greenery to the footpath for aesthetic purposes. How a place looks, and feels is an important contributor to one's wellbeing. Barbosa et al. (2007) and Houlden et al. (2018) note that including greenspace in urban environments provides a range of mental health and wellbeing benefits, such as feelings of happiness, increased attention span, and reduced stress levels. For example, Houlden et al. (2018) found that life satisfaction was much greater in urban areas where there was more greenspace present.

2.4.2 What are the benefits of road diets?

Road diets provide a range of benefits, including reduced traffic volumes, improved road safety, increased uptake of active travel modes, and creates a more community focused area that accommodates all transport modes.

Road diets can result in reduced traffic volumes. Nixon et al. (2016) found that implementing a road diet in Lincoln Avenue in San Jose, California, reduced morning peak traffic volumes by 23%, as well as reduced the overall traffic during the day by 6%. Tan's (2011) study on the 2.4km road diet along Edgewater Drive in Orlando, USA, found that traffic volumes decreased from 20,500 to 18,100 immediately following the road alterations. However**,** traffic volumes increased to 21,000 after some time.

The reduction in road lanes creates a safer and more inclusive environment for all road users, particularly pedestrians and cyclists. This is a result of easier crossing for pedestrians due to fewer lanes to cross, slower vehicle speeds, and separated cycle lanes. Creating a safer environment and a more aesthetically appealing one, pedestrians and cyclists are more likely to use the road for commuting purposes as well as encouraging recreational use and economic activity in the area. Huang et al. (2019) found that the road diet in Xinghai North Street, Xincheng City, which involved converting the four-lane road to three lanes, widening the cycle lanes from 2 metres to 3.5 metres on both sides of the road, and adding pedestrian crossings, showed that 88% of surveyed pedestrians felt that the crossing was safer. Similarly, Ohlms et al. (2020) found that of those who participated in a survey about the road diet along Lawyers Road in Reston, Virginia, 69% indicated the road felt safer. Tan's (2011) study on the road diet in Edgewater Drive showed a 23% increase in the number of pedestrians from 2,136 to 2,632 per day and a 30% increase the number of cyclists from 375 to 486 cyclists per day. The largest increase in pedestrians per day was the number of pedestrians crossing Edgewater Drive which showed a 56% increase from 738 to 1,151 pedestrians. This suggests that the reduction in road lanes created a safer environment for pedestrians to cross compared to the previous four lane road. Furthermore, Huang et al. (2019) conducted a survey on the road diet in Xinghai North Street, and found that of those who cycled, 73% said they cycled more. Likewise, a survey on the road diet along Lawyers Road found that 47% of respondents reported they cycled more often.

Along with creating safer environments for pedestrians and cyclists, a road diet also helps to reduce traffic speeds and, as a result, reduces the number of road crashes. Huang's et al. (2019) study on the road diet in Xinghai North Street showed a reduction in the average speed of vehicles from 50km/h to 45km/h. Similarly, Tan (2011) found that the road diet in Edgewater Drive reduced excessive traffic speeds (defined by researchers as over 60km/h) by 8 to 10% along the southern and northern end of the corridor while the middle section experienced only a slight reduction. Nixon's et al. (2016) study on the Lincoln Avenue road diet showed a significant reduction in speedsters along the road, with a 60% reduction in the number of 10+mph speedsters along the road. However, there was a significant increase in speedsters along the neighbouring streets and the non-diet segment of the road. Huang et al. (2019) also found an approximate 33% reduction in the number of conflict points from 218 to 145 along a Xinghai North Street. Similarly, Tan (2011) found that the road diet in Edgewater Drive reduced crash rates by 34% on the segment of the road that was altered. Harkey et al. (2008) estimated a 19% reduction in total crashes for road diet sites from California and Washington. Gates' et al. (2008) study on seven road diets in Minnesota showed an overall total crash reduction of 44.2%. An important finding from Ohlms' et al. (2020) study on the road diet in Lawyers Road in Reston was a 70% crash reduction. Pawlovich et al. (2006) found a 18.8% reduction in crash rate and a 25.2% reduction in crash frequency per mile at fifteen road diets in Iowa compared to the fifteen comparison sites. A cost/benefit analysis by Noland et al. (2014) estimated an average 19% reduction in crashes per year after the introduction of a road diet on Livingston Avenue in New Brunswick, New Jersey. This study estimated there would be an increase in travel time as the purpose was to slow traffic down to make the road safer. They concluded that the costs associated with increased travel time were far outweighed by the safety benefits of reduced traffic crashes.

2.4.3 What are the drawbacks of a road diet?

One drawback of road diets was the increase in traffic volumes shown in the Edgewater Drive case study (Tan, 2011). However, this did not appear in other studies. It is important to note that the original daily traffic count in this study was slightly more than 20,000, suggesting that this road is a key corridor which carries high volumes, and a road diet would not change the route people take. Furthermore, studies show that there is a high probability that implementing road diets on roads with more than 20,000 average daily traffic counts will result in congestion until people change the route they take (Burden & Lagerwey, 1999; Pawlovich et al., 2006). Increasing congestion counteracts the aim of road diets which is to increase safety, encourage active travel modes, and improve the quality of area.

Another concern is the increase in speedsters along neighbouring streets after the introduction of the road diet in Lincoln Avenue (Nixon et al. 2017). This is a problem as increased traffic speeds, increases the likelihood of road injuries and fatalities. Furthermore, higher traffic speeds can diminish the appeal of a neighbourhood as a safe space to play, interact and actively move around. Although, this problem only occurred in this Nixon et al. (2017) study, this may have been because other studies did not investigate the effects of the road diet on nearby streets.

2.3.4 Implementing a road diet

For a road to be considered for a road diet several factors should be taken into account. These include traffic volumes (moderate volumes of 8,000 to 15,000 average daily traffic (ADT)), vehicle speeds, number of lanes, number of road accidents, travel time, bus stops and routes, freight usage, and accessibility (Burden & Lagerwey, 1999; Tan, 2011).

Importantly, Lyles et al. (2012) state the importance of ensuring the road conversion utilises the extra space to implement appropriate pedestrian and cycle infrastructure to ensure the full benefits are achieved. If pedestrian and cycle infrastructure are not incorporated in the overall design of the road diet, a modal shift is unlikely to occur.

2.5 Road pricing: congestion charge

2.5.1 What is road pricing, in particular what is congestion charging?

Congestion is a significant problem as it results in stop-start traffic which consumes more fuel and, thus, produces more emissions (Pike, 2010; Ministry of Transport, 2021). In New Zealand, congestion increases the average travel time by 20 to 31 percent in six metropolitan areas (Ministry of Transport, 2021). Road pricing can help reduce this congestion and reduce transport emissions by encouraging a behaviour change towards more sustainable modes.

Road pricing includes road tolls, congestion charging, cordon area tolls, high occupancy toll (HOT) lanes, and vehicle use fees (Victoria Transport Policy Institute, 2019). However, for this research project congestion charging will be the focus.

Congestion charging involves charging motorists a fee to drive in a particular area, such as a city centre, to reduce congestion during peak periods (Victoria Transport Policy Institute, 2019). The fee can be either fixed or vary over a day with higher prices at congested times (Victoria Transport Policy Institute, 2019). Congestion charging can help to reduce emissions such as nitrogen oxides and particulate matter in dense urban areas, thus improving air quality. Additionally, it can improve traffic flow which helps with the movement of goods, increasing economic productivity (Ministry of Transport, 2021).

There are four types of congestion charging: area based, cordon based, corridor based, and network based (Ministry of Transport, 2018). An area-based congestion charge is when vehicles cross a defined border triggering a charge whereas a cordon-orientated scheme charges vehicles in a particular area in which the charging rate may be fixed over the day, be time-dependent or distance dependent. A corridor-based scheme is where vehicles are charged to use one or more roads in a specific congested corridor or corridors. In comparison, a network-based scheme charges vehicles for traveling in a defined geographical area on all roads (Ministry of Transport, 2018).

Congestion charging reduces congestion, reduces emissions, and increases active travel modes such as cycling. Several metropolitan areas have implemented various congestion charging schemes. Case studies examined here will include Stockholm, London, Singapore, Milan, and Gothenburg.

Congestion charging was first introduced in Stockholm in 2006 for a trial period of seven months (Eliasson, 2014). After the trial period, congestion charging was stopped for a short period but because of its success it was reintroduced in 2007 and has been in place since. The system consists of 18 charging points forming a cordon around the city centre. Vehicle number plates are captured by cameras and an invoice for the total charge during the month is sent to the owner of the car (Eliasson, 2014). The London Congestion Charge was implemented in February 2003 covering an 8.4 square mile area (Pike, 2010; Transport for London, 2008). In 2007, a western extension was added, doubling the size of charging zone. Electric vehicles and low-emission alternative fuel vehicles are exempt from this charge. In Singapore, a congestion charging scheme was implemented in the CBD in 1975 (NZTA, 2014; Pike, 2010). This was a paper system in which daily licenses for vehicles entering the zone during peak periods were given out. In 1998, an Electronic Road Pricing system was implemented to replace the paper scheme. This system works by using In-Vehicle units (IUs) in which the units communicate with overhead gantries at charging points and deduct the charging amount from a smart card (Pike, 2010). Enforcement cameras are used to photograph vehicles which do not have an IU installed in order to charge a fine. In Milan, a congestion charge, known as Area C, was implemented in 2012. Area C is a restricted traffic zone in the centre of Milan, operating Monday through to Friday (OECD et al, 2017). In Gothenburg, Sweden, a congestion charging scheme was installed in 2013 (Auckland Council et al., 2020). The Cordon was implemented around central Gothenburg and several main roads, with 38 charging points.

2.5.2 What are the benefits of congestion charging?

One of the greatest advantages of a congestion charge is its ability to reduce congestion and improve the efficiency of the transport system. Eliasson (2014) found that since reintroducing the congestion charging scheme in Stockholm in 2007, there has been an approximate 20% reduction in congestion in and around the city. Similarly, findings by Pike (2010) revealed that the London congestion charge reduced congestion from the original cordon (8.4 square mile area) by 20 to 30% (70,000 fewer cars per day), and by 14% in the western extension (30,000 fewer cars per day). Additionally, the study by Eliasson (2014) found that outside the inner city of Stockholm, traffic volumes decreased by slightly over 5% and the number of vehicle kilometres driven in the inner city decreased by around 16%. Furthermore, a significant finding in the literature from Pike (2010) was that Singapore's congestion charge showed a substantial reduction in traffic in the charging zone with a 44% drop in traffic. However, other studies show a 13% reduction in traffic in the zone following the introduction of the Electronic Road Pricing system (NZTA, 2014; Theseira, 2020; Phang & Toh, 2004). Similarly, in the Gothenburg study, there was a 12% reduction in traffic across the cordon during charging hours. In the wider Gothenburg area car traffic volumes reduced by about 4% (Auckland

Council et al., 2020). Milan's congestion charge resulted in a 28% decrease in road congestion three years after its implementation (OECD et al., 2017). Furthermore, diesel and petrol vehicle use has decreased by 49% in the area.

Reducing congestion can also result in reduced greenhouse gas emissions. This reduction comes from both encouraging people to switch to more sustainable transport options as well as reducing the amount of stop-start traffic. Eliasson (2014) and the Federal Highway Administration (FHWA) (2021) showed that the Stockholm congestion charge resulted in a 10 to 15% reduction in emissions in the inner city and a 2-3% reduction in carbon dioxide emissions in the whole metropolitan area. Similarly, Pike (2010) and Transport for London (2008) found that the London congestion charge showed a 16% reduction in carbon dioxide emissions in 2006, which decreased by another 6.5% after the implementation of the western extension in 2007.

By improving traffic flows, congestion charging can reduce travel times. Eliasson (2014) found that travel delay times on Stockholm's arterials of the congestion charging scheme fell by one-third during peak morning times and by one-half during peak afternoon/evening times. This means travellers could be sure about the duration of their car trip.

Congestion charging can result in a mode shift. Pike's (2010) study revealed that Singapore's congestion charge, along with improvements to public transport and other associated policies, led to an approximate 20% increase in bus ridership. Conversely, FHWA (2021) showed that Stockholm saw only a 6 to 9% increase in public transportation usage after implementing the congestion charge. Likewise, public transport trips increased by 6% in Gothenburg. Transport for London (2009) found that the London congestion charge resulted in a 66% increase in cycling within the charging zone since it was introduced in 2003. Additionally, the number of low emission and electric vehicles registered for the exemption increased from 11,000 in 2005 to 18,000 in 2007 (Pike, 2010; Transport for London, 2008). This is a 63.6% increase in the number of electric vehicles and low emission alternative fuel vehicles, showing that a congestion charge can encourage a switch to more sustainable types of vehicles. Singapore's congestion charge resulted in increased carpooling and fewer solo motorists driving into the restricted zone (NZTA, 2014). Milan's congestion charge resulted in a 29% increase in surface and underground public transport usage (OECD et al., 2017).

With any type of policy, it is important to ensure some level of public acceptance. Public support of congestion charging varies from place to place. Table 1 shows the public acceptance of congestion charging before and after implementation in five European cities.

City	**Before**	**After**
Stockholm	21%	67%
Bergen	19%	58%
Oslo	30%	41%
Trondheim	9%	47%
London	39%	54%

Table 1: Public acceptance of congestion charging before and after implementation (Source: Auckland Council et al. 2020).

2.5.3 What are the drawbacks of congestion charging?

With any type of road pricing, such as a congestion charge, there can be distributional impacts as those on lower incomes will feel the effects more than those on higher incomes (Ministry of Transport, 2021). This creates further inequalities in society and has detrimental effects on people's wellbeing and resilience. Therefore, it is vital to consider how these inequalities can be mitigated.

Alongside equity issues, congestion charging has potential to increase traffic speeds. For example, Singapore's congestion charge resulted in traffic speeds increasing from 11mph to 21mph due to less congestion (FHWA, 2021; NZTA, 2014; Pike, 2010). Vehicles travelling at faster speeds have a higher crash rate (Aarts & van Schagen, 2005).

A challenge with congestion charging is gaining public acceptance. However, a key way to gain public acceptance is through making the public aware of the benefits it can achieve, such as reduced congestion and improved air quality.

2.5.4 Implementing a congestion charge

Key factors to consider when implementing a congestion charge are geography, traffic patterns, and other local factors (Pike, 2010). The location of the congestion charge should be where congestion reduction benefits can be maximised. A single charging rate is the simplest and is best used in places where there is no sharp morning or afternoon congestion periods. A system where charging price varies throughout the day is best in place where there a definite peak period. A flat rate system is another option where the consumer pays in advance.

A key aspect of implementing a congestion charge is working out which technology to use (Oehry, 2010). Some examples of such technologies are user self-declaration systems, manual, manned and barrier-controlled toll stations, and GPS/GSM-based systems. Another key factor to consider is where to place the charging points on the road while considering the aesthetic impact it will have on the area (Oehry, 2010). Furthermore, it is important to choose the right border where the congestion charge will begin (Oehry, 2010). For instance, it needs to be placed where a large proportion of the commuter traffic will be captured. It is important to consider the availability of public transport in the area to ensure an alternative travel option.

Discounts or exemptions should be considered for people with disabilities, emergency, electric, and low-emission vehicles, and those on lower incomes. Discounts could also be considered for those living in the area where the congestion charge is to be placed (Pike, 2010). This would help to improve public acceptance of the scheme.

2.6 Mass rapid transit (MRT)

2.6.1 What is Mass Rapid Transit (MRT)?

Mass rapid transit (MRT) is a high-capacity, modern and integrated public transport system that operates on an exclusive right-of-way (Morahan et al., 2021; Rahman, 2008). It is fast, frequent, and reliable (Ministry of Transport, 2021). Compared to other public transport options, MRT reduces travel time, has a greater range of service hours, increases capacity across the public transport system, improves service levels and comfort, has a more simplified route design, ticketing and boarding system, and is clearly identifiable (Morahan et al., 2021). These factors are extremely important in encouraging people to use public transport because service levels tend to be one of the biggest barriers to public transport uptake. MRT also produces less pollution than private vehicles. Additionally, a MRT system can grow a city's economy by encouraging more people to live in the city. Furthermore, a MRT system not only increases mobility options for people, but also creates employment opportunities (Abdallah, 2017). Overall, MRT has been found to be more reliable and efficient than other public transport systems and can create a more vibrant and economically flourishing city (Morahan, 2021).

MRT quickly moves large amounts of people every day and produces less pollution per person than private vehicles (Abdallah, 2017). Cities which have a mass transit network are more sustainable by being less dependent on personal car use. This leads to a reduction in greenhouse gas emissions. In New York City, nearly half of the population do not own or have access to a car largely due to the mass rapid transit operations (Abdallah, 2017). As a result, energy consumption per person in New York City is one quarter of the national average (Abdallah, 2017). Figure 2 shows an image of a bus rapid transit (BRT) system in Bogota, Colombia.

Figure 2: *TransMilenio Bus Rapid Transit in Bogota, Colombia* (Source: Hidalgo, 2004).

2.6.2 What are the benefits of Mass Rapid Transit?

MRT has been found to reduce conventional car use, cause a mode shift to public transport, reduce emissions, improve road safety, reduce social inequity, create more physically active individuals, and create an economically prosperous city.

MRT has been implemented in a range of cities worldwide. This study will focus on seven case studies; TransMilenio in Bogota, the MRT system in Taipei, MRT in Lima, MRT in Cali, MRT in Montevideo, MRT system in Greater Kuala Lumpur, and MRT in Auckland.

Established in 1999, TransMilenio is one of the largest bus rapid transit (BRT) systems in the world located in Bogota, Colombia. It carries 2.3 million passengers a day and about 250,000 passengers per hour during peak hours around Bogota (Global Infrastructure Hub, 2021). In 2002, the first phase of the BRT system was implemented and by 2012 the system had 12 lines running through the city. There are over 3,500 buses, each which carry up to 240 passengers and have a maximum operating speed of 28km per hour during peak periods. In 1996, Taipei established a MRT system and is the largest metro subway in Taiwan extending

110km (Ding et al., 2016). More than 1.5 million people use this system daily (Shiau & Peng, 2012). In 2010, Lima, Peru, implemented a single corridor MRT system with 28.6km of segregated busway, 35 stations, two terminals, and a central transfer station (Scholl et al., 2015). In 2014, Cali, Colombia, implemented a MRT system covering 49km (Scholl et al., 2015). In 2013, Montevideo, the capital of Uruguay, installed a MRT system extending 17.9km (Scholl et al., 2015).

In Auckland, New Zealand, rapid transit is a key part of the public transport system. As rapid transit is separated from the general traffic along corridors, it is unaffected by road congestion (Auckland Council, 2021). This helps to ensure efficiency and reliability. Auckland's rapid transit network carries 26 million passengers a year (Auckland Council, 2021). A large part of Auckland's rapid transit is the Northern Busway which was completed in November 2008 (Waka Kotahi NZ Transport Agency, 2022). This mass rapid transit system consisted of a 6.24km dedicated two-way bus road and another 2.5km of a single lane busway (Waka Kotahi NZ Transport Agency, 2022). This rapid transit system has provided faster bus trip times, new bus services and routes, improved facilities for cyclists and pedestrians, and 24-hour security.

MRT reduces the reliance on private vehicles and, in turn, increases public transport usage. Kwan et al. (2017) estimated that the implementation of the MRT system in Greater Kuala Lumpur, Malaysia, would reduce 228,000 vehicle trips as well as 4.2 million vehicle kilometres daily, with passenger cars accounting for 54% of this reduction in vehicle kilometres. Auckland's large-scale improvements to the Northern Busway rapid transit system resulted in a 12 to 14% increase in public transport usage over the corridor as well as a 4% increase in the use of the busway between 2006 and 2013 (Greater Christchurch Public Transport Futures Project Team, 2018). Ding et al (2016) found that the MRT system in Taipei decreased vehicle use rate by 23% in 2012 compared to the 1998 levels.

As a result of reduced conventional car use and an increase in the use of public transport, MRT systems reduce emissions helping to create a cleaner and healthier environment. Hidalgo (2004) found that the TransMilenio system decreased sulphur dioxide by 43%, nitrogen dioxide by 18% and particulate matter by 12% in the area near Caracas Busway. Ding et al. (2016) found that the MRT system in Taipei significantly improved both nitrogen dioxide and carbon monoxide levels. For example, in 2012, days with severe air pollution were reduced by 73% for nitrogen dioxide and 89% for carbon monoxide (Ding et al., 2016). Findings from Schipper et al. (2009) showed that Mexico City's first BRT line resulted in a 10% reduction in carbon dioxide along the corridor. This was a result of people switching from private vehicles to the BRT as well as reductions in bus emissions and improvements to energy standards. The BRT system in Cali, was estimated to decrease cardon dioxide emissions by 65-67% and PM2.5 by 66% (Inter-America Development Bank, 2015). In Lima, the BRT system reduced CO2 emissions by 78,600 to 204,500 tons per year from 2012 to 2015 (Inter-America Development Bank, 2015). Additionally, at the corridor level, PM2.5 had estimated reductions of 17% in 2012 and 19% in 2013. Montevideo showed no change or a slight increase in emissions. This was due to old and polluting transit vehicles as well as a decrease in the efficiency of the bus service such as more signals and stops. According to Kwan's et al. (2017) estimations, the two MRT lines in Greater Kuala Lumpur would reduce 242,200 tonnes of CO2 equivalent per year from private vehicle trips and PM2.5 would be reduced by 67,8000g per day. The two MRT lines would result in a net total reduction of 43,000 tonnes of CO2 equivalent per year. This is after taking into account the use of private vehicles in the stations which would offset 28% of the carbon savings, and accounting for the carbon dioxide produced by the system from electricity generation.

MRT is more efficient and reliable than that of other public transport and even private vehicles. TransMilenio decreased travel times by 25% along TransMilenio's Avenue Suba bus rapid transit corridor. For the whole transit system, travel times for passengers were reduced by on average 17 minutes (Global Infrastructure Hub, 2021). Hidalgo (2004) found that 83% of people answering a poll on TransMilenio indicated their main reason for using the system was the fast service. The BRT system in Cali, resulted in travel time savings of an average of 29% on the north-south link but system wide travel time savings were only 5-6 minutes on average (Inter-America Development Bank, 2015). In Lima, there was a 34% travel time saving on average. Conversely, passengers on the BRT system in Montevideo reported increases in travel times of 6 to 10 minutes due to passengers having to wait at a new terminal. (Inter-America Development Bank, 2015).

MRT can help to improve road safety and general neighbourhood safety. Prior to implementing TransMilenio, there were 52,754 traffic accidents and 1,174 traffic related deaths (Global Infrastructure Hub, 2021). Hidalgo (2004) found that after the installation of TransMilenio there was a 92% reduction in fatalities and a 75% reduction in injuries from road accidents because of a 79% reduction in collisions in the corridors served by the BRT. In Lima, there was a 65% decrease in traffic accidents along the BRT corridor while Montevideo showed a slight reduction in traffic accidents (13 to 10 per month) (Inter-America Development Bank, 2015). Hidalgo (2004) found that TransMilenio caused a 47% decrease in reported robberies in the areas by or near the BRT.

MRT can help reduce social inequity by improving access for all people, particularly the more vulnerable groups. TransMilenio was the first public transport system in Bogota to specifically target the more vulnerable groups such as those on low incomes, women, and people with disabilities (Global Infrastructure Hub, 2021). TransMilenio improved connectivity between low-income areas and the city centre. This increased accessibility for fourteen of the poorest boroughs. Furthermore, discounts were given to the more vulnerable groups (Global Infrastructure Hub, 2021).

MRT can produce a range of health benefits such as increased physical activity. Globally, at least 5.3 million deaths per year are associated with physical inactivity (Lemoine et al, 2016). Public transport such as MRT can be used to increase physical activity and, therefore, create healthier people and places. Lemoine et al. (2016) investigated the association between physical activity and the use of TransMilenio (BRT system in Bogota). The study was conducted from 2010 to 2011. This study found that the use of the BRT system was associated with 12 or minutes of moderate to vigorous physical activity than those who did not use the BRT system (Lemoine et al., 2016). Kwan et al. (2015) estimated 70 deaths could be avoided from the introduction of MRT in Greater Kuala Lumpur. 17.7% of these deaths are avoided because of improved air quality, 54.2% because of a reduction in traffic injuries and 30.4% because of increased physical activity among the MRT users (Kwan et al., 2015). The annual reduction in vehicle kilometres travelled would prevent 88 deaths and 6300 disability-adjusted life years (DALYs) per year from traffic injuries. While 90 deaths and 3200 DALYs would be reduced because of increased physical activity, with the largest reduction from cardiovascular disease (79 deaths and 2100 DALYs) (Kwan et al., 2017).

MRT can help achieve economic prosperity by providing people with easy access to jobs and services. Furthermore, with lower transport costs people can access key activity centres with ease (Inter-America Development Bank, 2015).

Public support of MRT varies from place to place. Lima's BRT system showed high public approval (between 60-82% depending on the survey) while Cali's system had a 56% public approval (Inter-America Development Bank, 2015). Montevideo had little public support due to a lack of mobility improvements as well as implementation issues (Inter-America Development Bank, 2015).

2.6.3 What are the drawbacks of mass rapid transit?

If MRT systems are not implemented along appropriate corridors that ensure access for the majority of people, particularly those who live in more deprived areas, it will not achieve its full benefits of helping to reduce social inequalities. Furthermore, if the appropriate corridors are not chosen, usage of the MRT system will be low and, as a result, there will be less of a mode shift.

2.6.4 Implementing Mass Rapid Transit

According to the international standard for BRT systems, the Institute for Transportation and Development Policy 2013 and 2014, there are five basic elements needed for a system to be a BRT system. These are a centre busway alignment, dedicated right of way, intersection treatments, off-board fare collection and lastly, level platform boarding.

Levinson et al. (2003) state there are three key themes to consider when implementing a MRT: land use, road network and bus operation. Land use includes considering things such as urban growth and expansion, locations of major employment centres, and residential developments in relation to potential MRT routes. Road network includes consideration around things such as congestion and street width continuity. Lastly, bus operation includes factors such as operating speeds, reliability, and past and future projected transit use. To encourage people to use mass rapid transit it must be plentiful, reliable, safe, affordable, and comfortable (Abdallah, 2017). It can be difficult to achieve this when driving appears to be more convenient, especially in Christchurch where car use is prioritised over other transport modes.

LTN's, road diets, congestion charging, and MRT, all contribute to reducing transport emissions while also providing a range of other benefits. These four actions contribute to social connectedness, wellbeing, and resilience differently. There is a gap in the current literature investigating how these actions specifically impact wellbeing and resilience, and which actions provide the greatest social and environmental benefits.

2.7 Research objectives

The aim of this project is to investigate the co-benefits of implementing transport emission reduction actions in Christchurch. This research will analyse four key transport emission reduction actions likely to be implemented in Christchurch. Three key questions underpin this research project. Firstly, *what are the co-benefits of these actions? In particular, how do these actions impact social connectedness, and in turn, impact community wellbeing and resilience?* Secondly, *how do these actions impact accessibility for commuting traffic in places where these actions are likely to be implemented?* Finally, *what are the public's perceptions of transport and neighbourhood in environments in Christchurch, and would these actions impact how people choose to travel in the Greater Christchurch area?*

3.0 Research Methodology

3.1 Literature Review

This research project used a mixed methods approach to gain both qualitative and quantitative data. These methods are a co-benefits framework, a survey, and spatial analysis using ArcGIS Pro.

3.1.1 Co-benefits framework

The term ‘co-benefits’ has started to come to prominence in academic discourses, particularly in climate change discourse. Dubash et al. (2013) state that a co-benefits analysis offers a way to investigate the strengths and weaknesses of a certain policy objective across a range of desired outcomes. Furthermore, Raymond et al. (2017) argue that a framework of co-benefits is useful for assessing certain actions against a range of benefits. Urge-Vorsatz et al. (2014) argue the importance of incorporating co-benefits or co-impacts into decision making frameworks. An important conclusion from Urge-Vorsatz et al. (2014) is that much of the current literature focuses on climate mitigation as the main benefit. They argue that this benefit should be seen as one of many benefits. For example, Urge-Vorsatz et al. (2014) propose a range of categories of co-impacts of climate change mitigation related investments such as health benefits, energy poverty and distributional effects, and provision of ecosystem services. Regarding transport, Litman (2017) argues that the co-benefits of transport emission reduction strategies are ignored with the focus primarily on emission reduction. In his research he outlines a range of benefits to consider when comparing various transport emission reduction strategies. For example, congestion reduction, improved physical fitness and health, and improved mobility options for non-drivers. Additionally, Victoria Transport Policy Institute (2019) constructed a benefit summary of reallocation of road space. It included a total of six benefits, such as road safety and environmental protection. For each benefit, reallocation of road space was given a score from very harmful to very beneficial.

3.1.2 Surveys

Several authors have emphasised the benefits of surveys in that they are useful for gathering information about people, their behaviour and attitudes and opinions (McGuirk & O’Neill, 2016). McGuirk and O’Neill (2016) note they are frequently used to gather data on matters such as quality of life, transport and travel, and social networks. Logan et al. (2016) conducted both online and paper copy surveys to understand public perceptions and attitudes toward LTN’s in four different locations: Birmingham. Bournemouth, Ipswich, and Salford. Results showed varied levels of awareness and support of local LTNs.

3.1.3 Spatial analysis using ArcGIS Pro

ArcGIS (Geographic Information Systems) is a tool often used to analyse accessibility such as access to public transit or to examine socio-economic distributions across various places. Andrews et al. (2020) used ArcGIS to understand spatial clustering of neighbourhood deprivation across the United States. Results showed that neighbourhood deprivation varied spatially across the United States with the highest deprivation scores found in Southeastern and Southwestern U.S. states. Additionally, Pyrialakou et al. (2016) used ArcGIS to assess three key elements of transport disadvantage: accessibility, mobility, and realized travel behaviour. Results showed that a large part of Indiana has low accessibility levels to a range of facilities such as hospitals, schools, and recreational opportunities. Moreover, the highest trip lengths were located in rural areas across Indiana.

3.2 Chosen Methods

Three methods were chosen to answer the research questions proposed in this project. These are: a co-benefits framework, survey, and spatial analysis using ArcGIS Pro. These methods have helped to provide in-depth answers to the research problems and address the gap in existing literature. The combination of these methods aimed to:

1) **Co-benefits framework:** Provide an in-depth insight into the strengths and weaknesses of each of the four transport emission reduction actions, particularly how they impact wellbeing and resilience.
2) **Survey:** Gain an understanding of travel choices and reasons for these in Christchurch and how neighbourhood environments impact social interaction and travel within neighbourhoods. Additionally, it was used to investigate if the four actions would change how people choose to travel in Christchurch.
3) **Spatial analysis using ArcGIS Pro:** Provide an insight into how the four transport emission reduction actions may impact accessibility for commuting traffic in the Greater Christchurch area, particularly how this may impact different socio-economic groups.

To conduct the survey, approval from the Human Ethics Committee (HEC) was required. This was because it involved asking people about their subjective wellbeing, neighbourhood environments, and travel choices. Questions regarding people’s subjective wellbeing are deemed a sensitive issue. To mitigate this, there was always the option skip the question or leave the survey. As a result, HEC approved this method. A copy of the HEC confirmation form is listed in Appendix 1.

3.2.1 Co-benefits framework

The co-benefits framework is multidimensional, with each of the four actions assessed against a range of benefits split into the five overarching categories from the Ministry of Transport's Transport Outcomes. These categories are environmental sustainability, inclusive access, economic prosperity, healthy and safe people, and resilience and security. The transport outcomes were included in this framework to show how these actions relate to the Ministry of Transport's goals for the New Zealand transport system. Inclusive access is about ensuring there are better travel options and creating a more efficient transport system. This is to ensure that more people can access social and economic opportunities, especially those on low incomes and people with disabilities (Waka Kotahi NZ Transport Agency, 2019). Economic prosperity is about ensuring efficient movement of people and products. Environmental sustainability is about protecting and reducing the impact of the transport system on the environment by increasing the uptake of sustainable travel modes. Healthy and safe people is about improving public health through the use of active transport modes and public transport. Lastly, resilience and security outcomes focus on providing more transport choices.

The four actions are assessed against eleven co-benefits. These are emission reduction, decreased congestion, modal shift, reduced conventional car use, improved access, improved mobility options for people who experience transport poverty/transport disadvantage, reduction in traffic accidents, public support of action, improved neighbourhood social connectedness, improved physical fitness and health, and finally, transport resilience. These actions were scored accordingly for both the level of impact they have and the level of evidence supporting the action. For the level of impact they have on each co-benefit, the action was given a score from 1 meaning low impact (less than 5% reduction/increase) to 3 (20% or more increase/decrease) meaning high impact. Similarly, for the level of evidence, the action was given a score from 1 meaning little amount of evidence supporting the action to 3 meaning high amount of evidence supporting the action. Taking the scores from both the level of impact and the level of evidence for each co-benefit of the action, the two results were added together and divided by 2 to get the mean. From there, each score for each co-benefit was multiplied by the weighting of the given co-benefit. The co-benefits which directly relate to and affect wellbeing and resilience were given a higher weighting of 1.5 than the other co-benefits. The reason for this is that one objective of this study is to investigate the co-benefits of these four actions focusing primarily on the social benefits these actions provide. The co-benefits that were given a higher weighting are improved access, improved mobility options for those who face transport poverty/transport disadvantage, improved neighbourhood social connectedness, improved physical fitness and health, and lastly, transport resilience.

The eleven co-benefits were chosen based on common themes/terms mentioned in the literature while many are based on Litman's (2017) co-benefits for transport emission reduction strategies that look beyond just the environmental benefits.

3.2.2 Survey

The online survey was created and published on Qualtrics with a total of 48 questions regarding wellbeing, transport choices, neighbourhood environments and demographics. The survey was published in November 2021 and closed on the 23rd of February 2022. It was distributed on Facebook pages and through community groups in Christchurch.

For many of the questions in the survey, a Likert scale was used. A Likert scale is used to measure people's attitudes towards something (McLeod, 2019). It is most commonly a five-point scale (it can sometimes be seven points) which is used to assess how much an individual agrees or disagrees with a statement or their positive to negative feelings regarding a question or statement (McLeod, 2019). Each of the five responses are allocated a numerical value for the attitude to be measured. For example, 1 equals strongly disagree and 5 equals strongly agree. Likert scales are beneficial as they allow for degrees of opinion rather than just a yes or no answer.

To begin the survey, four questions were used to gain a basic understanding of people's subjective wellbeing. These were about a person's satisfaction with their life nowadays, how happy they felt yesterday, how anxious they felt yesterday and to what extent they feel the things they do in their life are worthwhile. A Likert scale was used for these questions. These four questions about subjective wellbeing were taken from the Office for National Statistics' in the United Kingdom (the new economic foundation, 2012). The new economic foundation (2012) suggests asking wellbeing questions at the beginning of the questionnaire to ensure the answers are unaffected by other questions in the survey.

The primary focus of the survey was regarding transport in Christchurch such as people's current transport choices, their reasons for these and what improvements they would like to see that might encourage them to use more sustainable travel modes. Another aspect of this section was to gain an insight into whether road pricing would change how people choose to travel.

Another key focus of the survey was on neighbourhood environments in the Greater Christchurch Area and how neighbourhoods' impact social connectedness and movement within these areas. Questions in this section included if people believe their neighbourhood is designed to prioritise active travel modes and how traffic in the neighbourhood impacts how they use the space and interact.

As a result, qualitative and quantitative data was gained regarding transport choices in Christchurch, people's wellbeing, neighbourhood environments, and how these impact social connectedness.

3.2.3 Spatial analysis using ArcGIS Pro

ArcGIS Pro was used to create a number of maps showing the location of the actions in the Greater Christchurch area, deprivation levels and the total number of people travelling to work/education by sustainable modes or private transport. To do this, the first task was to identify where each action could be implemented in the Greater Christchurch area using traffic count data, the congestion map from Waka Kotahi New Zealand Transport Agency, implementation suggestions from scholars, 2018 deprivation levels by SA2, and crash data from the Crash Analysis System by Waka Kotahi.

For this study, a LTN was placed in the statistical areas 2 (SA2) of Papanui North, Northcote, and Northlands, an area of $1.61 km^2$, as shown on the map below.

Figure 3: Location of LTN in Christchurch

The roads bordering the LTN are Harewood Road, Greers Road, Northcote Road and Main North Road. These roads are often busy and congested roads, particularly Main North Road and Harewood Road. Sisson Drive, Langdons Road and Vagues Road are also often congested.

Papanui North has a high deprivation score of 9 based on the New Zealand 2018 Census average deprivation by SA2. It is suggested that LTNs are implemented in areas with high deprivation. Waka Kotahi NZ Transport Agency's Crash Analysis System (CAS) was used to gather road crash information. This site captures where, when, and how road crashes occur in New Zealand. This LTN area showed a high number of road accidents with a total of 3 fatal crashes, 81 serious crashes, 378 minor crashes, and 897 non-injury crashes. The area contains shops, schools, and greenspace making an appropriate area to implement a low traffic neighbourhood as it has many of the amenities needed for people to live locally, reducing the need to travel further distances, and reducing the need to use a private vehicle.

This study implemented a road diet along Harewood Road as shown on in figure .

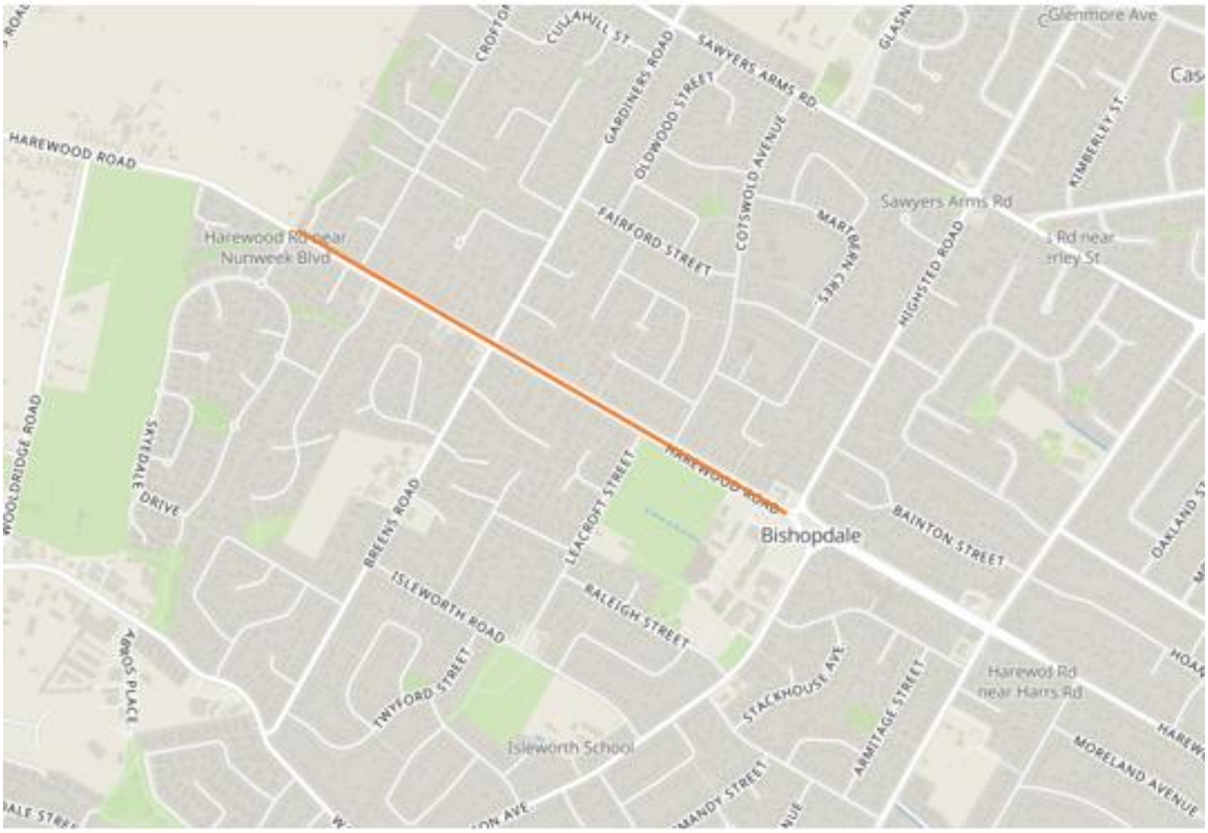

Figure 4: Location of a road diet in Christchurch

The road diet includes the following SA2's: Bishopdale West, Bishopdale North, and Harewood. According to Burden & Lagerway (1999), for a road diet to be implemented, the roadway should include a range of factors such as moderate volumes of 8,000 to 15,000 average daily traffic (ADT), roads with safety issues, popular or essential bicycle routes, and commercial reinvestment areas.

Harewood road is a key local corridor connecting State Highway 1 to Papanui and the central city and gives access to many neighbourhoods. The road diet segment of the road stretches 1.2km and has a speed limit of 50km. It has a moderate traffic volume between 12,000 and 18,000 ADT making it an appropriate option for a road diet. Additionally, the road has 8 bus stops, 4 in each direction. It is right near Bishopdale mall and near Nunweek park, a big greenspace and sports ground. All these aspects of the road make it an appropriate road to convert from four lanes to three lanes with cycle and pedestrian infrastructure improvements.

This study implemented a cordon-based congestion charge scheme in Christchurch central city. The area is bordered by Montreal St, Barbadoes St, Salisbury St, and St Asaph St, a 1.67km^2 area, as shown in figure 5.

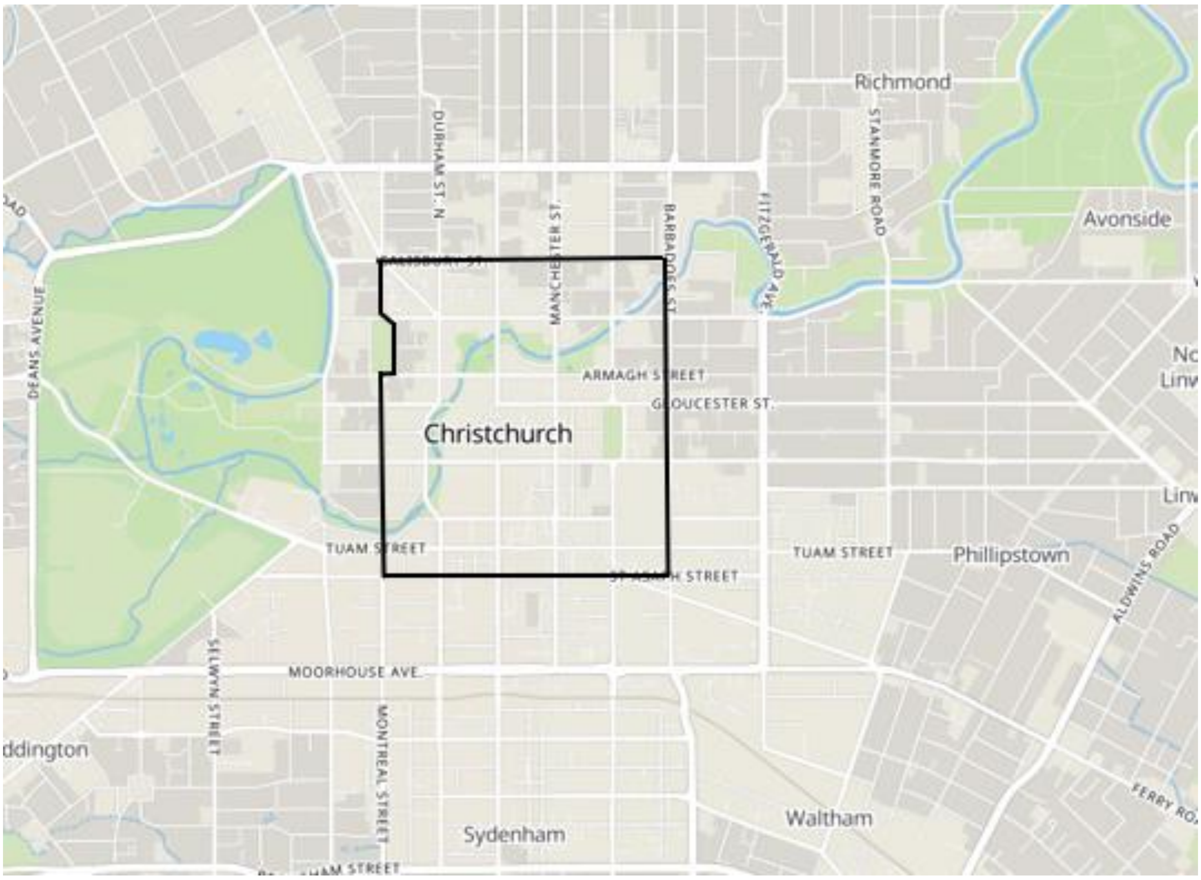

Figure 5: Location of a congestion charge in Christchruch

Implementing a city centre cordon congestion charging scheme will not significantly reduce congestion and emissions across the wider area but will show localised improvements in both congestion and emission reduction (Auckland Council et al., 2019). A congestion charge in city centre is relatively straight forward, however, for improvements to be seen across the entire transport system in Christchurch, further expansion will be required. This, however, is a good starting point and allows easy options for expansion such as extending to Fitzgerald Ave, Bealey Ave, Moorhouse Ave, and Park Terrace. This area faces high levels of congestion, especially along Hereford St, Armagh St, Colombo St, and Manchester St. Central city has good public transport in place as well as good cycle infrastructure. This will help support a shift to more sustainable modes of transportation.

The location of the MRT route was from the Public Transport Futures Business Case for Greater Christchurch – Mass Rapid Transit Interim Report. This report detailed three scenarios for implementing MRT in Greater Christchurch. These three scenarios are heavy rail route, street running limited stops route, and street running corridor route. The street running limited stop route was chosen for this report. Figure 6 shows the map of the Street running limited stops option.

Figure 6: Street Running Limited Stops (Image: Waka Kotahi NZ Transport Agency, 2021, MRT Interim Report).

This MRT option aims to achieve higher speeds to reduce journey time by stopping less often, about every 3.2km, while using the existing arterial routes (Waka Kotahi NZ Transport Agency, 2021). Analysis was done for the three scenarios, taking into account forecast growth, altered settlement and employment patterns, and the scheme characteristics of each scenario. For the street running limited stops option it estimates there will be a 39% increase in public transport mode share and a 63% increase in the labour pool available to central city employers within a 30-minute public transport journey. Moreover, it has the potential to increase public transport ridership from 20 million trips per year in 2028 to 39 million per year by 2048, carrying 33% of all the public transport trips, which is more than the other scenarios (Waka Kotahi NZ Transport Agency, 2021).

After establishing where each action could be implemented in Christchurch, the 2018 statistical areas 2 (SA2) were downloaded from Stats NZ as a geodatabase. This was used in all maps in ArcGIS Pro. Additionally, New Zealand deprivation data from 2018 by statistical area 2 was downloaded from the University of Otago website and was used as the base layer for all the maps. The NZ deprivation score 2018 are based on 9 Census variables such as people with no access to the Internet at home, people aged 18-64 receiving a means tested benefit, and people aged 18-64 who are unemployed (Environmental Health Intelligence New Zealand, n.d.).

Data from the 2018 Census main means of travel to work by Statistical Area 2 and main means of travel to education by Statistical Area 2 were downloaded as a CSV file from Stats NZ. The data includes residential address, educational/work address, and the number of people commuting by different modes, such as public bus, walking, and driver of a private vehicle. From there, the work/education address name was filtered to only show the SA2 areas in which the action would be implemented in. Then the two Excel spreadsheets were made from this data for each action, one for sustainable modes and one for driving. Data that were -999 were changed to 3, as -999 was any number of people below 6 for that mode and address. To fix this, the median number was used. The total number of people commuting to work/education to these statistical areas by sustainable modes (public bus, walking, and cycling) and the total number of people commuting to work/education by driving (driver of a private car/truck/van, passenger in a car/truck/van, and drive a company car/truck/van) were calculated. The Excel files for both sustainable modes and driving were added to ArcGIS Pro on separate maps. In ArcGIS the data was summarised by usual residence address to get the total sum commuting from each residence address.

In ArcGIS Pro, the NZDep2018 by SA2 was added to and joined to the SA2 geodatabase. This was one layer on the map. The symbology of this layer was then changed from a single symbol to graduated colours based on the average deprivation score from 1 to 10. Another SA2 geodatabase was added and then joined with the CSV table of total number of people commuting to work/education by sustainable modes. The symbology of this layer was then changed from a single symbol to graduated symbol based on the total number of people commuting, with the larger circle representing a higher number of people commuting by sustainable modes. This was then repeated for driving on a separate map but in the same project file. A layout was produced for each map. This was then repeated for all the four actions. Additionally, a map was produced for each action showing the location of the action and the deprivation levels.

4.0 Results

4.1 Co-benefits Framework

Transport Outcomes	Co-benefits	Co-benefit weighting	Low Traffic Neighbourhood	Road Diet	Congestion charge	Mass Rapid Transit
Environmental sustainability	Emission reduction	1	2.5	2	2.5	3
Environmental sustainability	Decreased congestion	1	3	1.5	3	2.5
Environmental sustainability	Mode shift	1	3	3	2.5	2.5
Environmental sustainability	Reduced conventional car use	1	2	1	2.5	2.5
Inclusive access	Improved access	1.5	3	3	1	2.5
Economic prosperity	Improved mobility options for people who experience transport disadvantage/transport poverty	1.5	3	3	1	3
Healthy and safe people	Reduction in traffic accidents	1	2	3	1	3
Healthy and safe people	Public support of action	1	2.5	1.5	2.5	2.5
Healthy and safe people	Improved neighbourhood social connectedness	1.5	2.5	2	1.5	1.5
Healthy and safe people	improved physical fitness and health	1.5	3	3	1.5	2.5
Resilience and security	Transport resilience	1.5	2	2.5	1	2
	Total weighted score		33.75	32.25	23	33.25

Figure 7: Co-benefits framework

The co-benefits framework (shown in figure 7) reveals that LTN's scored the highest of all the actions with a total score of 33.75. However, this was closely followed by MRT which had a total score of 33.25. Road diets had a total score of 32.25 while congestion charging had the lowest score overall at 23. The framework clearly identifies the strengths and weaknesses of the four actions. For example, a congestion charge scores highly on the environmental dimensions such as decreased congestion but has less of an impact on the more social aspects such as improved mobility options for people who experience transport poverty and transport disadvantage. Conversely, LTN's scores highly on both the environmental and social dimensions of the framework.

4.2 Survey

Table 2: Ethnicity of respondents

Ethnicity	Percentage of respondents
European/ Pākehā	90.48%
Other (please specify)	4.76%
Māori	3.17%
Prefer not to say	1.59%
MELAA (Middle Eastern/Latin American/African)	0.00%
Asian	0.00%
Pacific peoples	0.00%

Table 3: Age of respondents

Age	Percentage of respondents
18-24 years old	17.19%
25-34 years old	12.50%
35-44 years old	23.44%
45-54 years old	17.19%
55-64 years old	17.19%
65-74 years old	6.25%
75 years or older	4.69%
Prefer not to answer	1.56%

Table 4: Occupation of respondents

Occupation	Percentage of respondents
Working full time	60.32%
Full time education (student)	12.70%
Retired	12.70%
Other (please specify)	7.94%
Working part time (less than 16 hours)	4.76%
Volunteering	1.59%
Part time education (less than 16 hours)	0.00%
Apprenticeship	0.00%
Internship	0.00%
Stay at home parent	0.00%

Table 5: Respondents income per annum

Income per annum	Percentage of respondents
Loss	4.26%
Zero income	0.00%
$1-$10,000	4.26%
$10,001-$20,000	6.38%
$20,001-$30,000	8.51%
$30,001-$40,000	6.38%
$40,001-$50,000	2.13%
$50,001-$70,000	8.51%
$70,001-$100,000	14.89%
$100,001-$150,000	25.53%
$150,001 or more	17.02%

83 people responded to the online survey. Of these 83 respondents, 65.63% identified as female and 34.38% as male. Table 2 shows that 90.48% identified as European/Pākehā while 3.17% identified as Māori. The highest number of respondents were aged between 35-44 years, however, the number of respondents for the different age groups were relatively even with the age groups 18-24, 45-54, and 55-64 all with the same number of respondents (17.19%) as shown in table 3. The majority of respondents are in full time employment (60.3%) and a relatively small proportion are in full time education (12.7%) (table 4). Table 5 reveals that the greatest number of respondents earn $100,001 or more (42.55%) while 27.66% earn under 50,000 per annum.

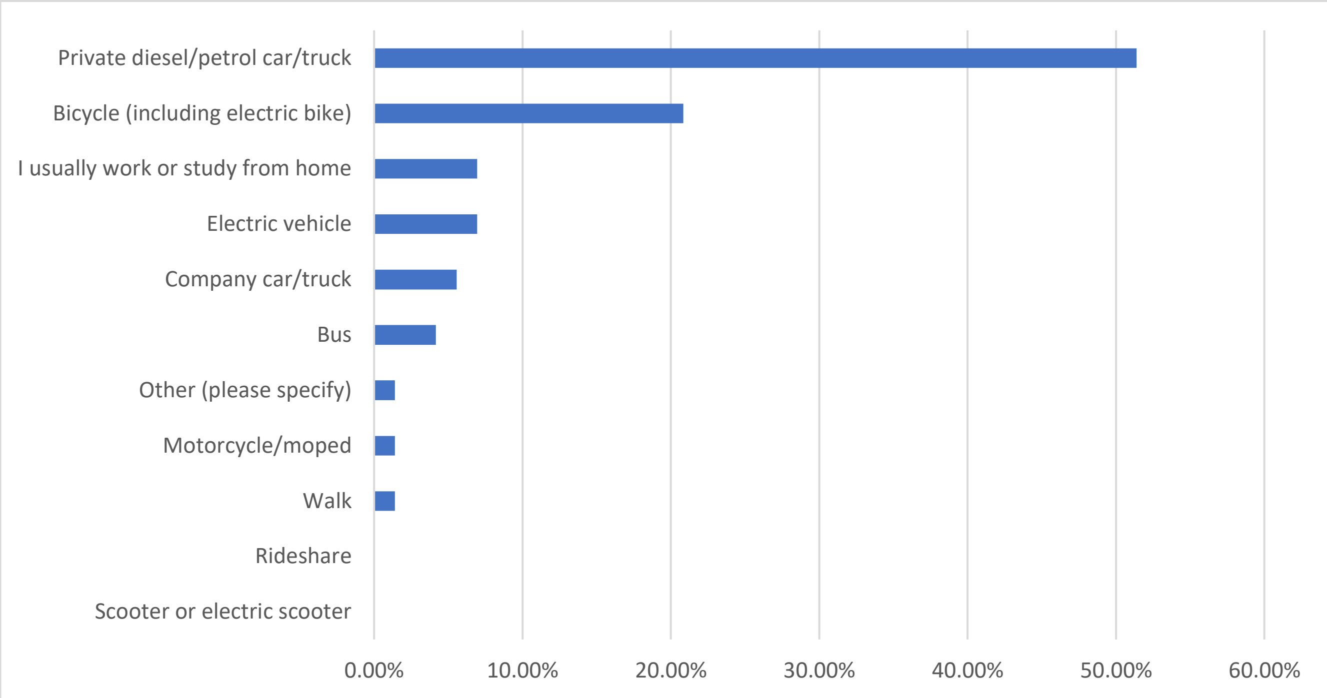

Figure 8*:* Respondents usual (i.e. most commonly used) mode of transport to their place of work, study or main daily destination.

Figure 8 shows that the majoirty of respondents use private diesel/petrol vehicles and electric vehicles to commute to their place of work, study or main daily destination (58.33%). The second most common mode of transportation was cycling (including eletric bikes) with 20.83% of respondents slecting this as their most common mode. A significantly small proportion of respondents use the bus or walk as their main mode of transportation. For most short trips (under 3km), the main mode of transportation was also a private car/truck (non-electric). This accounted for 30.43% of respondents. 26.09% of respondents walk when their destination is under 3km and 24.64% cycle.

The most common commute time for respondents was between 11 to 20 minutes, followed by 10 minutes or less. A small proportion had a 51-to-60-minute commute time (4.23%). The average number of minutes to work, education, or main daily destination was 19 minutes.

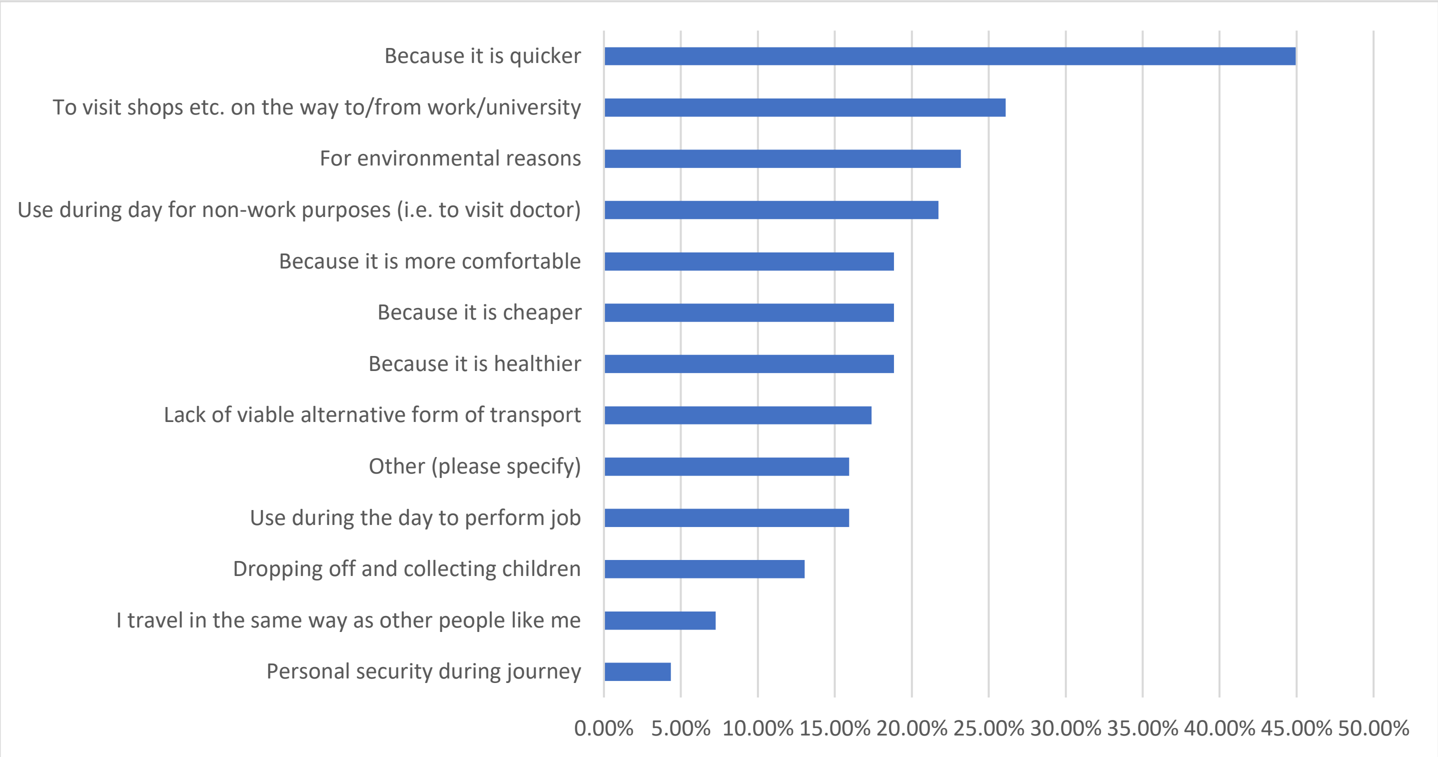

Figure 9: The main reasons respondents use their chosen travel method (respondents were able to select all that applied to them).

Figure 9 reveals that the top three reasons for respondent's current travel methods are because it is quicker (44.93%), to visit shops etc., on the way to/from work/university (26.09%), and for environmental reasons (23.19%).

When respondents were asked to list up to five key words or phrases about their commute experience, these responses were split up into positive and negative words about their commute experience. From there, these words were assigned a category such as ease and convenience, safety, and enjoyment. Ease and convenience were the main category for both positive (47.18%) and negative (53.33%) words, followed by enjoyment. 13.33% of negative words about respondent's commute experience were associated with safety and 4.93% of positive words about people's commute experience were associated with nature experience. Some comments from respondents are listed in verbatim below:

Easy, quick

Traffic, no parking

Noisy cold refreshing relaxing

Fun, varied routes, social, nature, sounds

Comfortable, calming, efficient, convenient

For respondents who did not cycle for transport at least once a week (66.67%), the main reasons were needing to carry shopping/other goods or equipment (31.82%) and the distance was too far (29.55%). A notable percentage of people chose 'other' (31.82%) which included reasons like not owning a bike, being retired, health reasons, time pressure, safety concerns, location, hair, and simply, not wanting to. Those who do not take the bus at least once a week (89.86%) mostly indicated the reasons were related to routes and service levels. Other key reasons included bus is too slow (36.67%), buses are not frequent enough (33.33%), and bus is too expensive (31.67%).

When asked what improvements would encourage respondents who did not currently cycle, most of the respondents selected improvements to cycling infrastructure. This included better footpath and road conditions (47.7%), pedestrian crossings and dedicated lanes (34.1%), slower traffic (27.27%), and more direct routes (20.45%). In a similar vein, improvements that would encourage those who do not take the bus focused on journey time (48.3%) and service level improvements (46.5%). Fewer interchanges/more direct routes (43.1%) and lower fares (41.4%) were also commonly selected by respondents. Other improvements suggested by respondents included synchronised interconnecting routes, buses going to industrial areas, more modern vehicles, disabled access, and available seating. Although, a small proportion of respondents take the bus at least once a week (10.14%), the majority indicated living in close proximity to a bus stop. For example, in terms of access to public transport, 57.8% of respondents live less than 0.5km from the nearest bus stop to their place of residence while 25% live between 0.5km to 1km to the nearest bus stop.

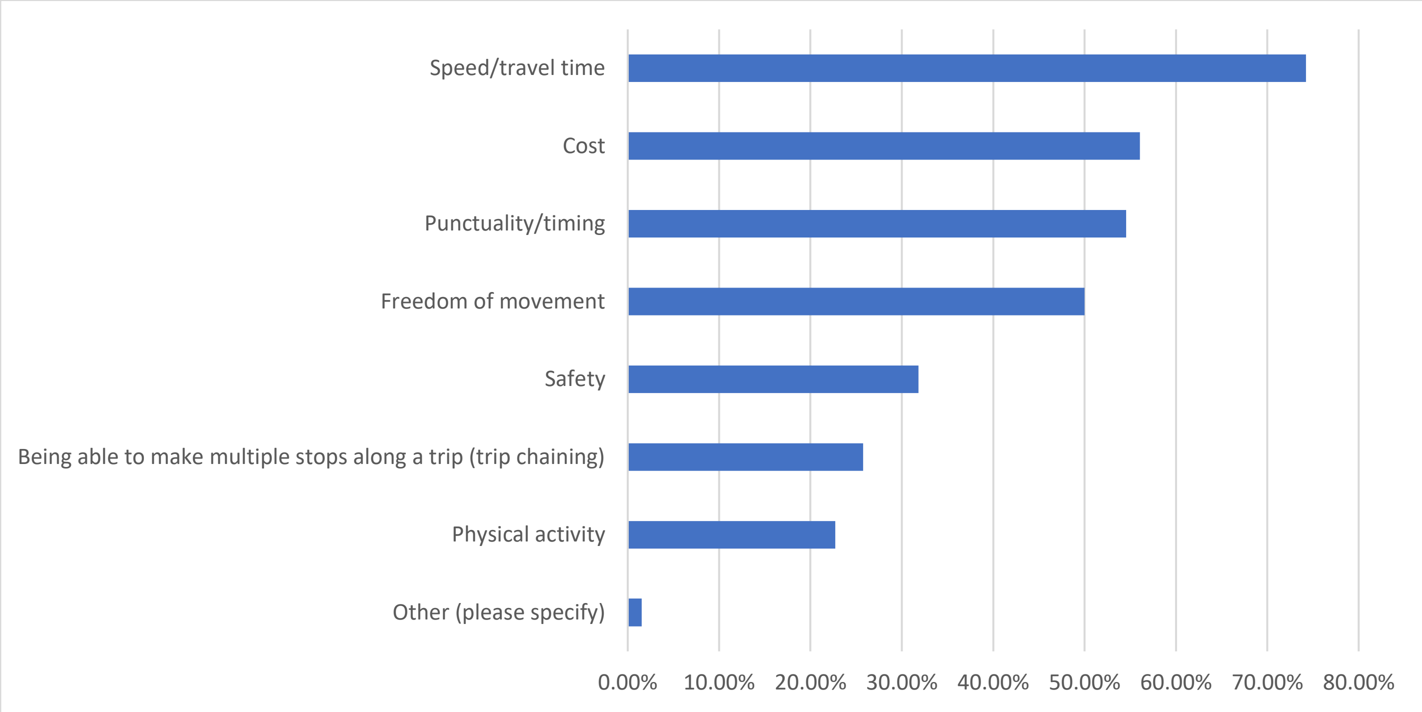

Figure 10: Practical aspects of commuting that are important to respondents (respondents were able to select up to three).

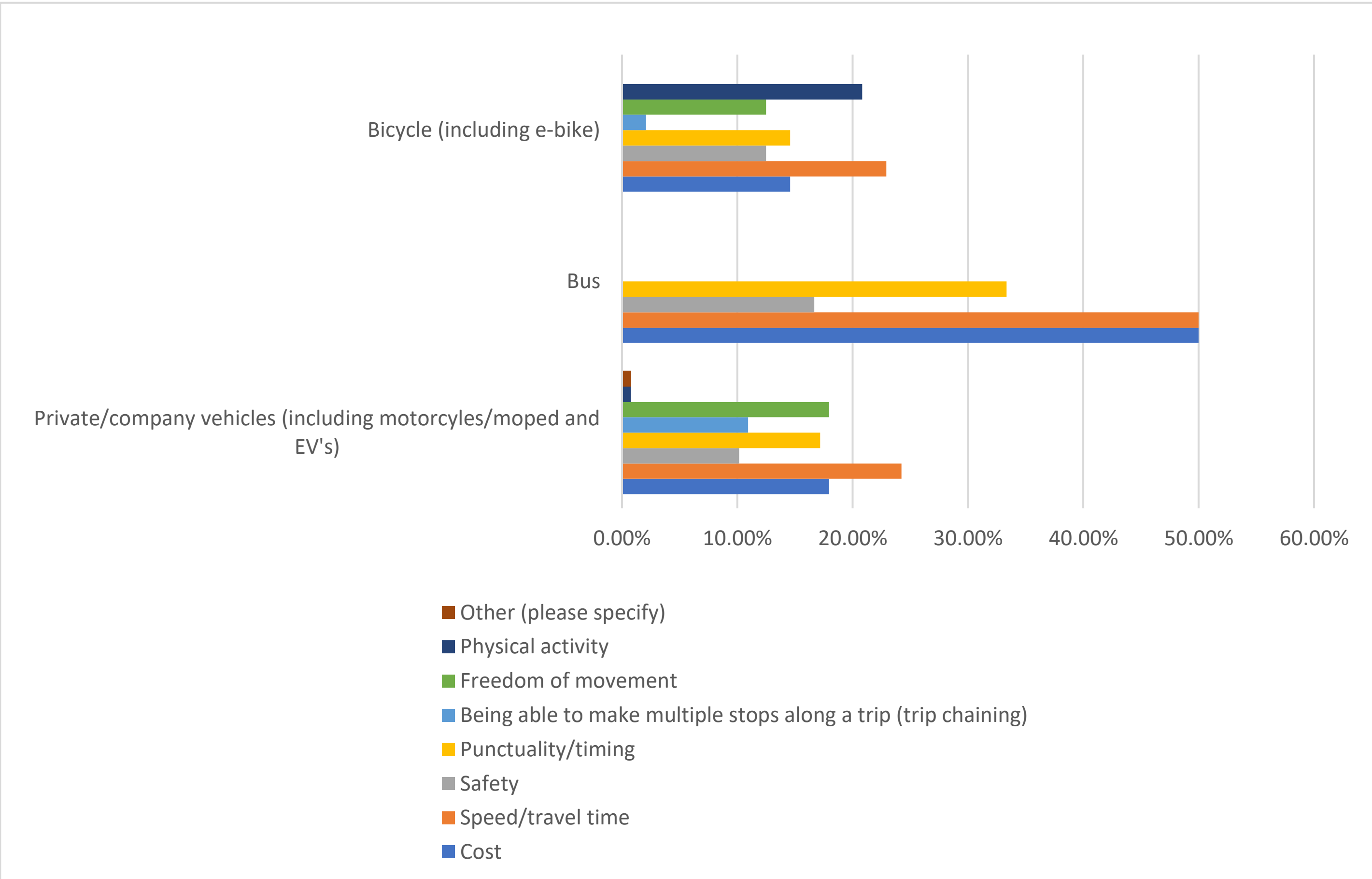

Figure 11: Most important practical aspects of commuting by mode.

Figure 10 shows that 74.24% of respondents selected speed/travel time as the most important practical aspect of commuting, followed by cost in which 56.06% chose this option. Punctuality/timing and freedom of movement were also key practical aspects of commuting. Figure 11 shows a the most important practical aspects for three different transport modes. Speed/travel time was the most important practical aspect for those who cycle, bus and drive. Cost was the second most important aspect for those who drive and those who use the bus. In contrast, physical activity was the second most important practical aspect for those who cycle.

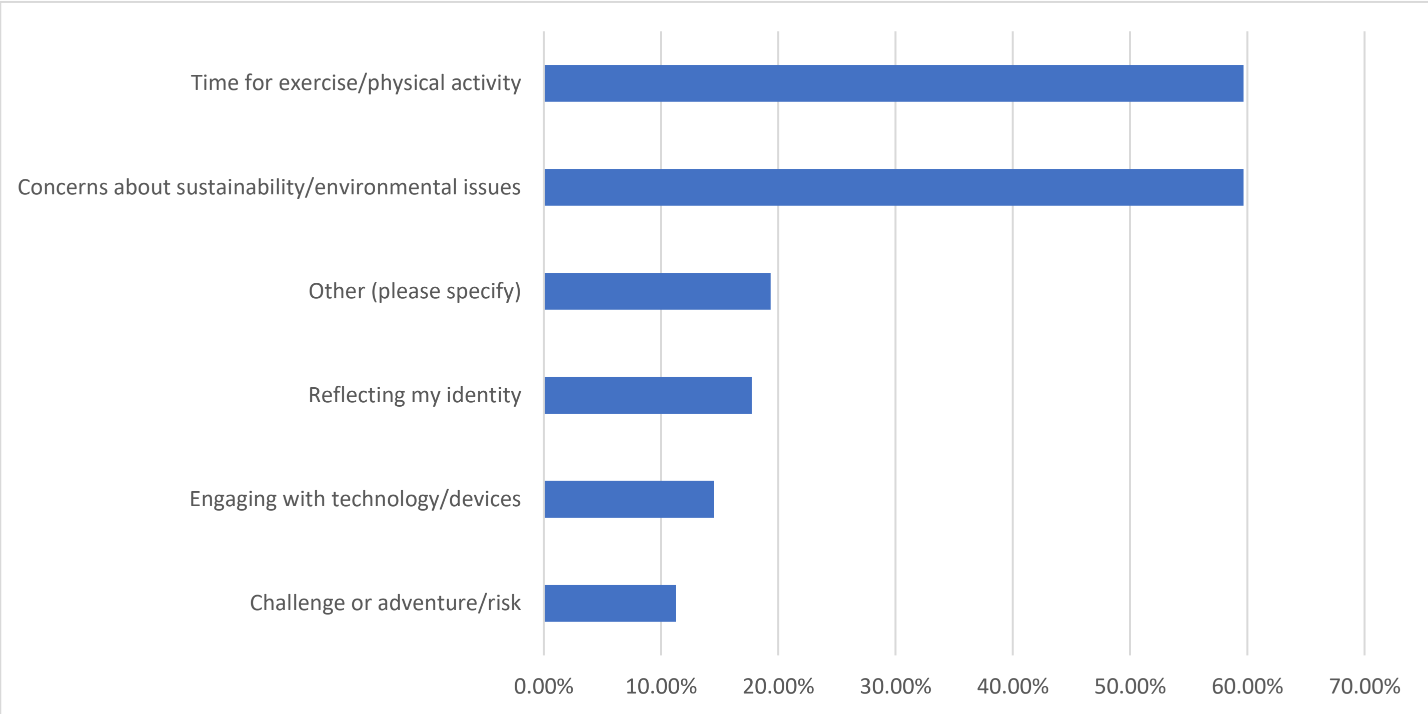

Figure 12: Personal aspects of commuting that are important to respondents (respondents were able to select up to three).

The most common personal aspects that were important for respondents when commuting were time for exercise/physical activity and concerns about sustainability/environmental issues (figure 12). 19.35% selected other which included convenience, flexibility, connection with nature in the city, ease, fun, freedom, privacy, cost, timing, and feeling safe.

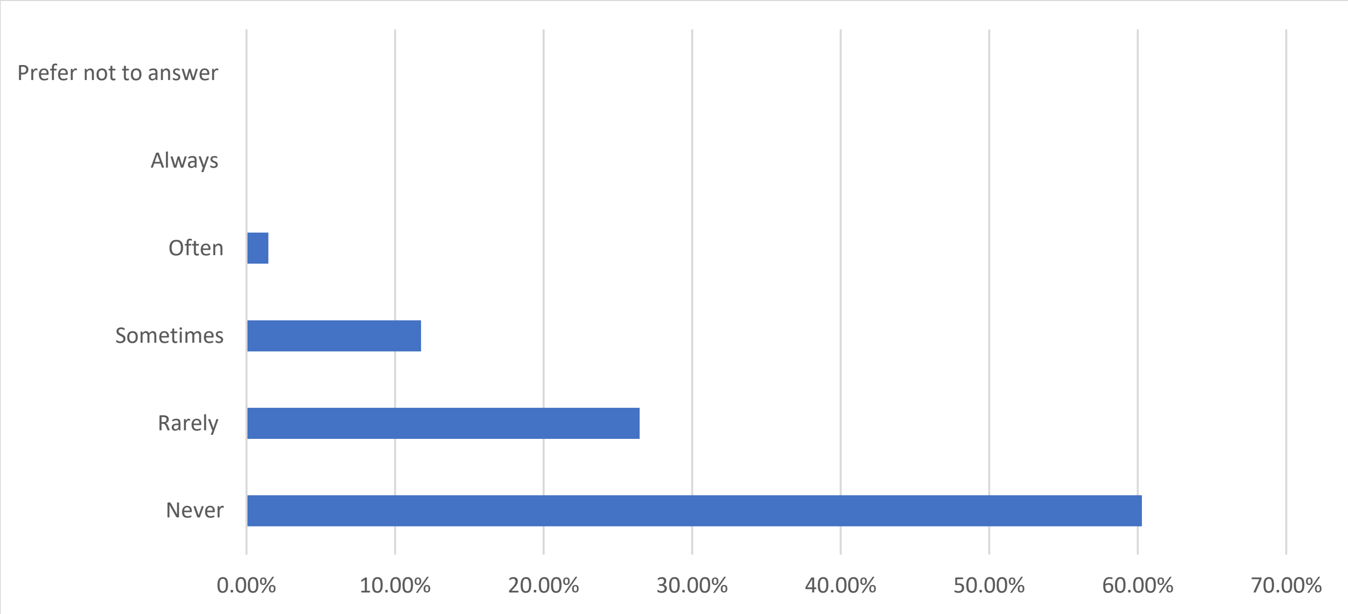

Figure 13: How frequently does respondents financial situation keep them from making a trip they needed or wanted to make.

60.29% of respondents selected that their financial situation never stops them from making a trip they need or want to make while 13.23% selected sometimes/often their financial situation keeps them from making a trip they need or want to make (figure 13). 28.57% of respondents selected that if they have more money available, they would choose to change their travel method. Of these respondents, 25% would use an electric car. 37.50% chose 'other' as their reason for this. 'Other' included distance from work, exercise benefits, timing, and ease.

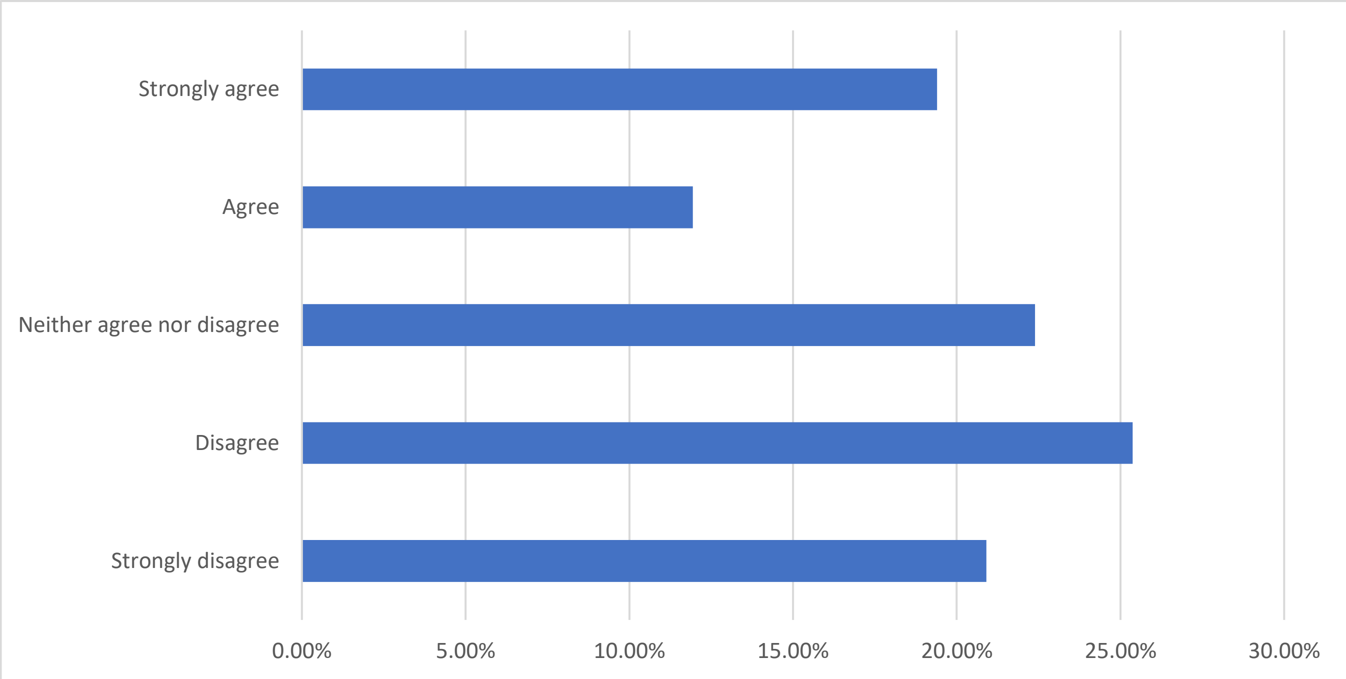

Figure 14: Respondents level of agreement with the following statement: *I'd be more likely to cycle, walk or use public transport if I had to pay a direct fee for driving in certain areas (i.e. congestion charge or road toll).*

To gain an insight into whether road pricing would likely cause a mode shift in Christchurch, respondents were asked if they agreed or disagreed that they would change how they travel if they had to pay a fee. 46.27% of respondents disagreed/strongly disagreed that they would cycle, walk, or use public transport more if they had to pay a direct fee for driving in certain areas while 31.14% agreed/strongly agreed that they would switch to more sustainable modes if they had to pay a fee as shown in figure 14.

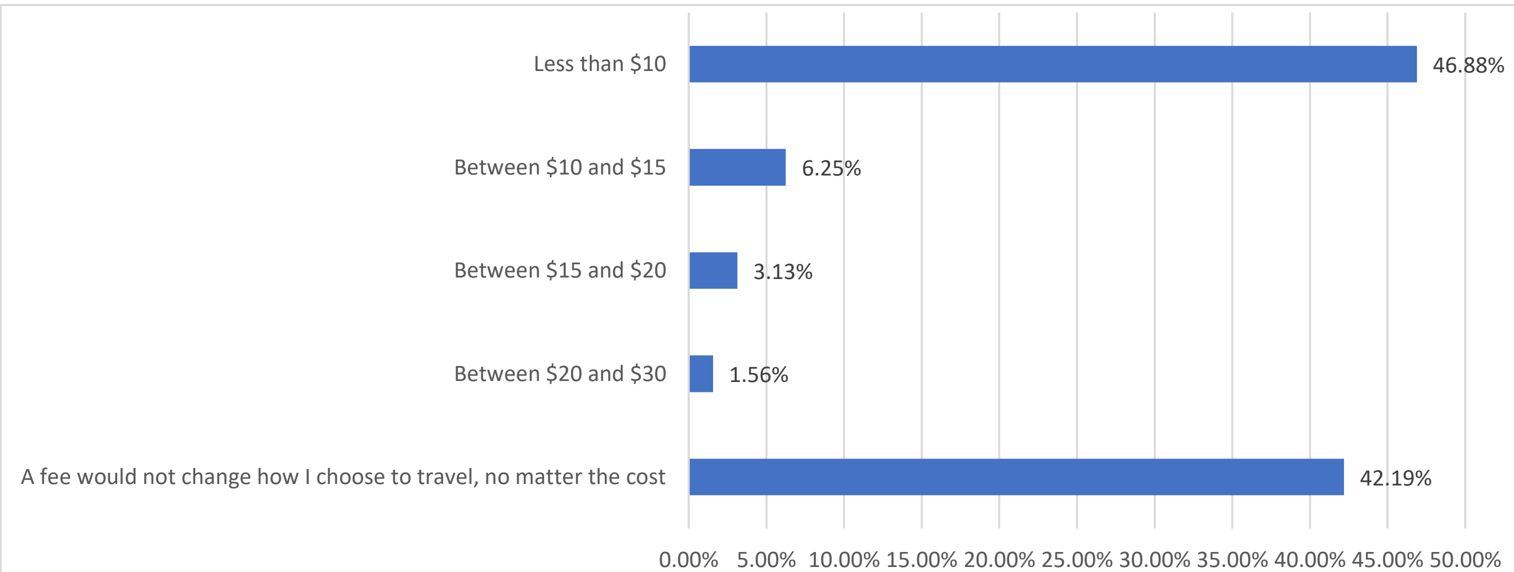

Figure 15: The cost of which respondents would be willing to pay for driving in a congestion charging zone before switching to another transportation mode.

Figure 15 shows that 46.88% of respondents would be willing to pay less than $10 a day before switching to another mode of transportation. On the other hand, 42.19% would not change how they choose to travel no matter the cost. Of those who selected a fee would not change how they choose to travel, the majority were those who earn $150,001 or more per annum (27.78%).

Table 6: Level of respondents' satisfaction with their lives

Satisfaction level	Percentage of respondents
1= extremely dissatisfied	1.39%
2= dissatisfied	6.94%
3 = neither dissatisfied or satisfied	12.50%
4 = satisfied	68.06%
5= extremely satisfied	11.11%

Table 7: How happy respondents were the day prior to taking the survey

Happiness level	Percentage of respondents
1= extremely unhappy	0.00%
2= unhappy	12.50%
3 = neutral	26.39%
4 = happy	56.94%
5 =extremely happy	4.17%

Table 8: How anxious respondents felt the day prior to taking the survey

Level of anxiety	Percentage of respondents
1= not at all anxious	34.29%
2= slightly anxious	31.43%
3= neutral	15.71%
4= anxious	15.71%

5= extremely anxious	2.86%

Table 9: Extent to which respondents feel the things they do in their life are worthwhile

Extent to which respondents feel the things they do in their life are worthwhile	Percentage of respondents
1= not at all worthwhile	1.43%
2= mostly worthwhile	22.86%
3= neutral	11.43%
4= worthwhile	51.43%
5= extremely worthwhile	12.86%

One section of the survey focused on people's subjective wellbeing. A majority of respondents gave positive indications about their wellbeing. 68.1% reported being satisfied with their life (table 6) and 56.9% said they were happy on the day prior to taking the survey (table 7). 34.29% of respondents did not feel anxious at all the day prior to taking the survey (table 8) and 51.43% of respondents felt the things they do in their life are worthwhile (table 9).

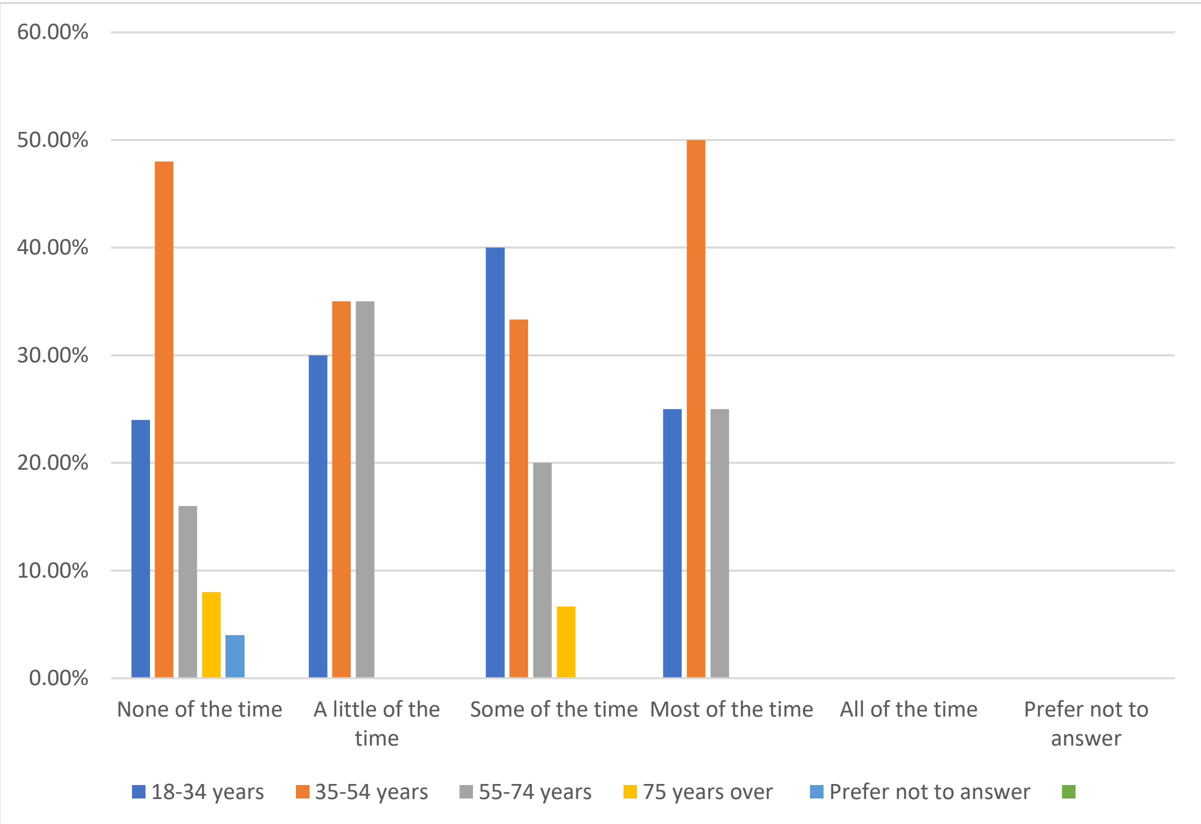

Figure 16: Frequency respondents feel lonely.

Figure 16 reveals that 50% of respondents who feel lonely most of the time are aged between 35-54 years, on the other hand, 48% of those who never feel lonely are also aged between 35-54 years. 40% of those who feel lonely some of the time are aged between 18-34 years.

When asked “*in up to five words or phrases, how would you describe your neighbourhood (physical environment and/or intrinsic values/community)”,* there were varied responses including both positive and negative descriptions. Some of the most common words respondents stated were ‘busy’, ‘friendly’, ‘green’, ‘safe’, ‘quiet’, and ‘traffic’. Some comments made by respondents are listed in verbatim below:

Quiet, green, nice, pleasant, private

Noisy, traffic, walking, river

Green, cycle ways, safe, traffic

Unsociable, busy, older, high amount of traffic

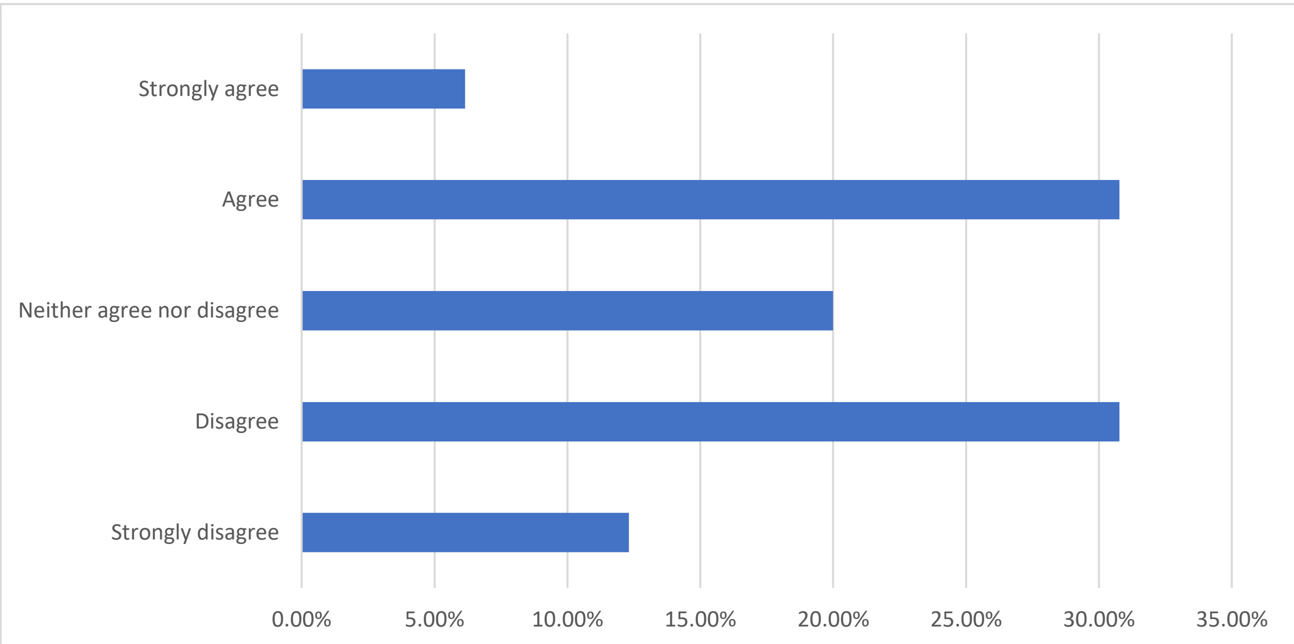

Figure 17: Respondents level of agreement with the following statement: *My neighbourhood has been designed to prioritise walking and cycling.*

As neighbourhood environments and the quality and quantity of pedestrian and cycling infrastructure impact how people choose to travel, respondents were asked about whether they felt their neighbourhood had been designed to prioritise walking and cycling (figure 17). The same percent of respondents agreed and disagreed with this statement (30.77%). Additionally, respondents were asked whether they have access to most of the amenities they need within a 5–10-minute walk or bike. A large proportion of respondents agreed/strongly agreed that they have access to most of the amenities they need within a 5–10-minute walk or bike (60%) compared to 35.39% who disagree/strongly disagree. Furthermore, most respondents agree/strongly agree they feel safe (both from harassment/physical harm and from traffic-related injuries) walking or biking in their neighbourhood (62.5%).

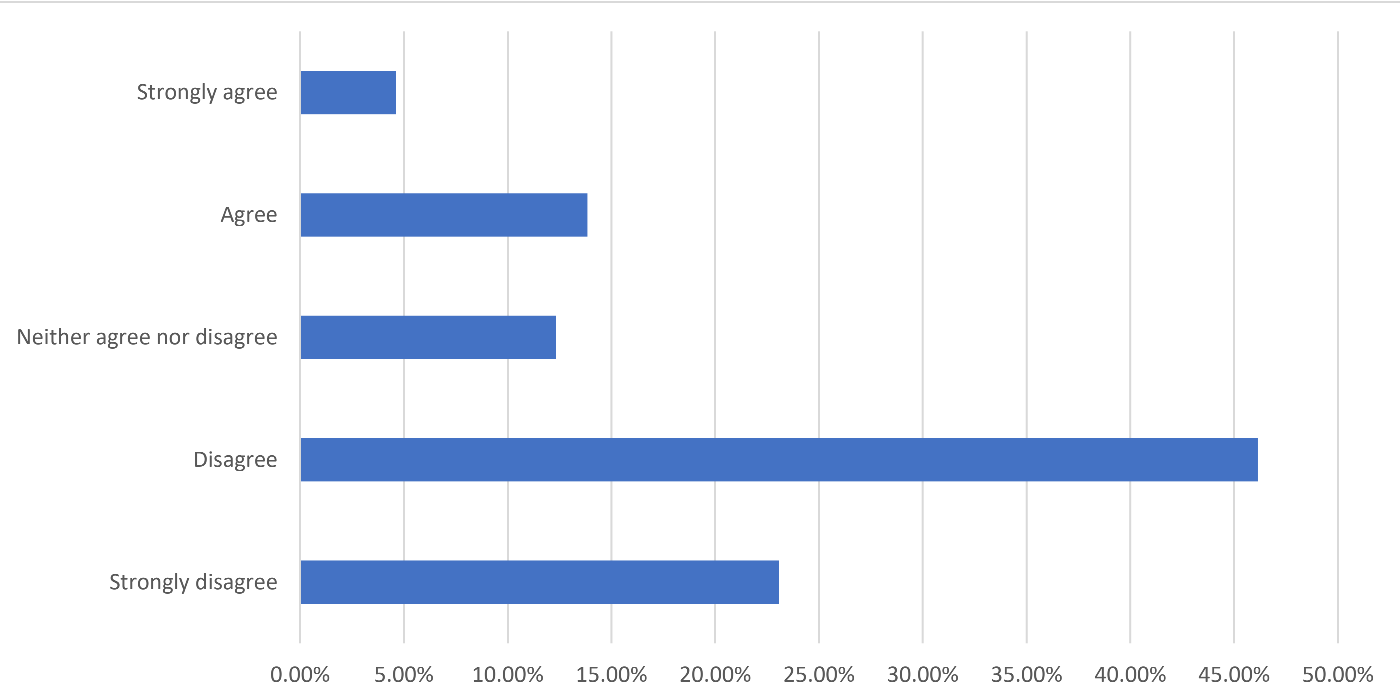

Figure 18: Respondents level of agreement with the following statement: *The amount of traffic in my neighbourhood keeps me from walking, biking, or playing in my neighbourhood.*

The amount of traffic in a neighbourhood has been found to impact the level of social connectedness in a neighbourhood and how people choose to travel. To gain an understanding of how traffic impacts neighbourhood environments in the Greater Christchurch area, respondents were asked about the amount of traffic in their neighbourhood and whether they felt this affected if they interacted with their neighbours and how they use their neighbourhood space. 49.2% of respondents stated they had moderate amounts of traffic in their neighbourhood during peak hours and 30.8% selected having a great deal of traffic in their neighbourhood. A small proportion selected having very little traffic in their neighbourhood (18.5%). 84.38% of respondents disagree/strongly disagree that the amount of traffic in their neighbourhood keeps them from interacting with their neighbours while only 9.38% agree/strongly agree. Figure 18 shows that 69.23% of respondents disagree/strongly disagree that the amount of traffic in their neighbourhood keeps them walking, biking, or playing in their neighbourhood.

Neighbourhood social connectedness can play a key role in improving one's wellbeing and level of resilience. To understand how socially connected people feel to their neighbours in the Greater Christchurch area, respondents were asked if they felt close to their neighbours. 46.88% of respondents agree/strongly agree that they feel close to their neighbours while 20.26% disagree/strongly disagree.

69.23% of respondents' main way of staying in contact with their neighbours is by talking in person while 24.62% don't stay in contact with their neighbours. 38.71% of respondents have been in contact (i.e., quick chat to a long catch up) with their neighbours at least once a week in the last four weeks while 24.19% have only been in contact at least once in the last four weeks. A very small proportion have been in contact with their neighbours every day in the last four weeks (3.23%) while 19.35% have not been in contact with their neighbours at all in the last four weeks. Despite this, 75.81% of respondents stated having about the right amount of contact with their neighbours.

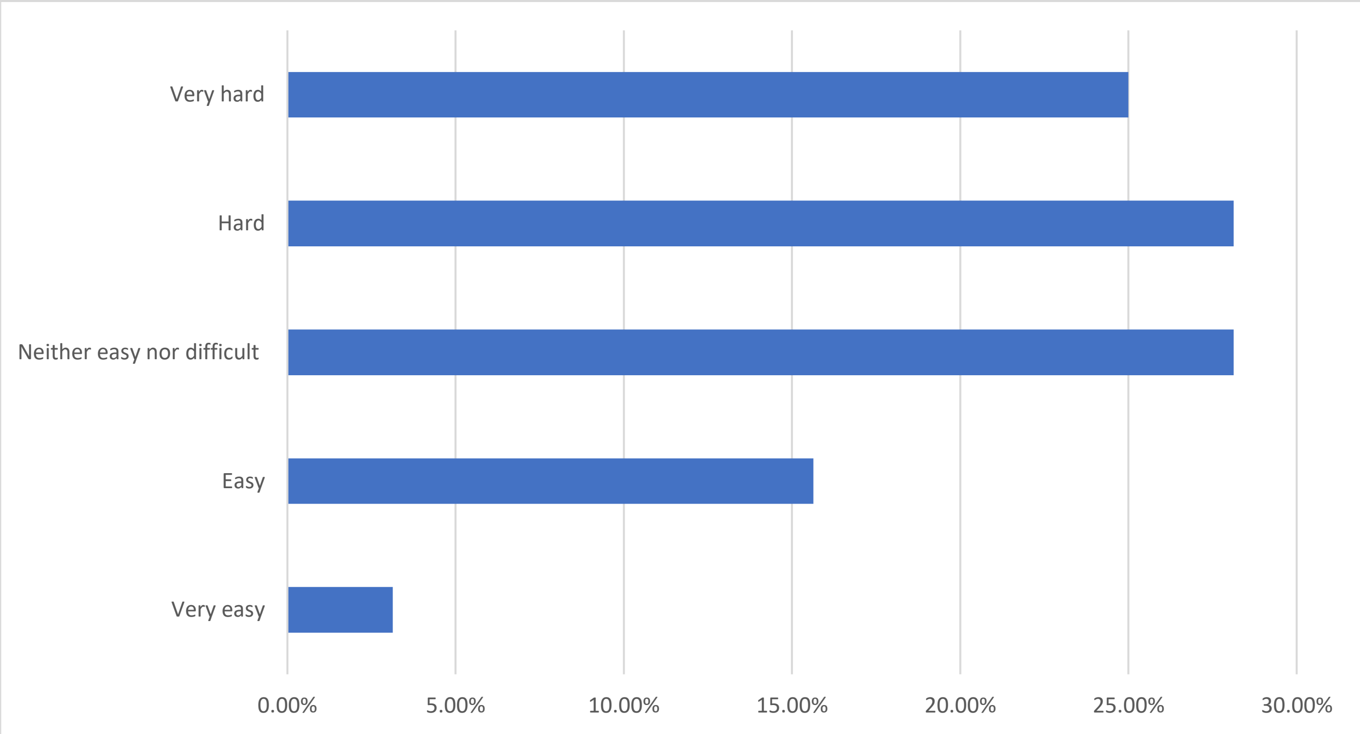

Figure 19: Respondents level of ease in talking to someone in their neighbourhood if they felt down or a bit depressed.

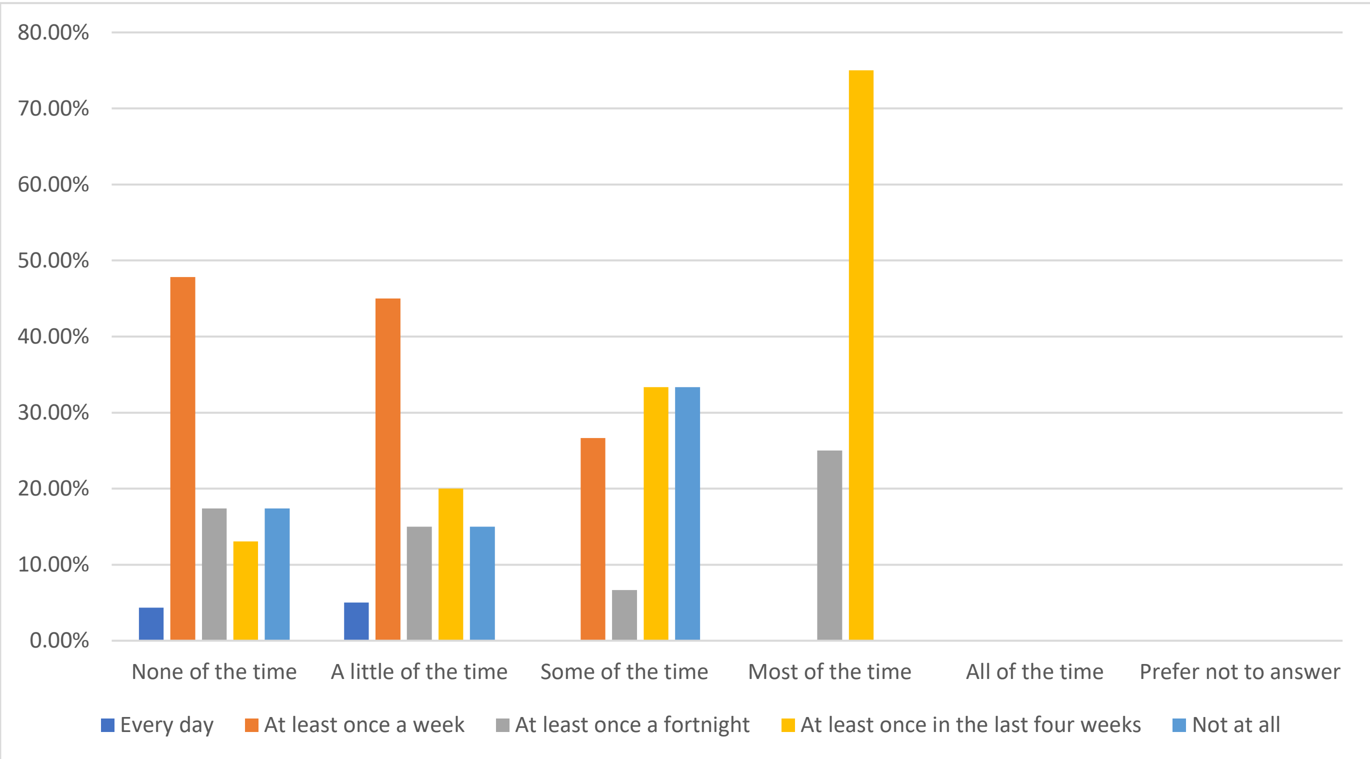

Figure 20: Respondents level of loneliness with level of contact with their neighbours

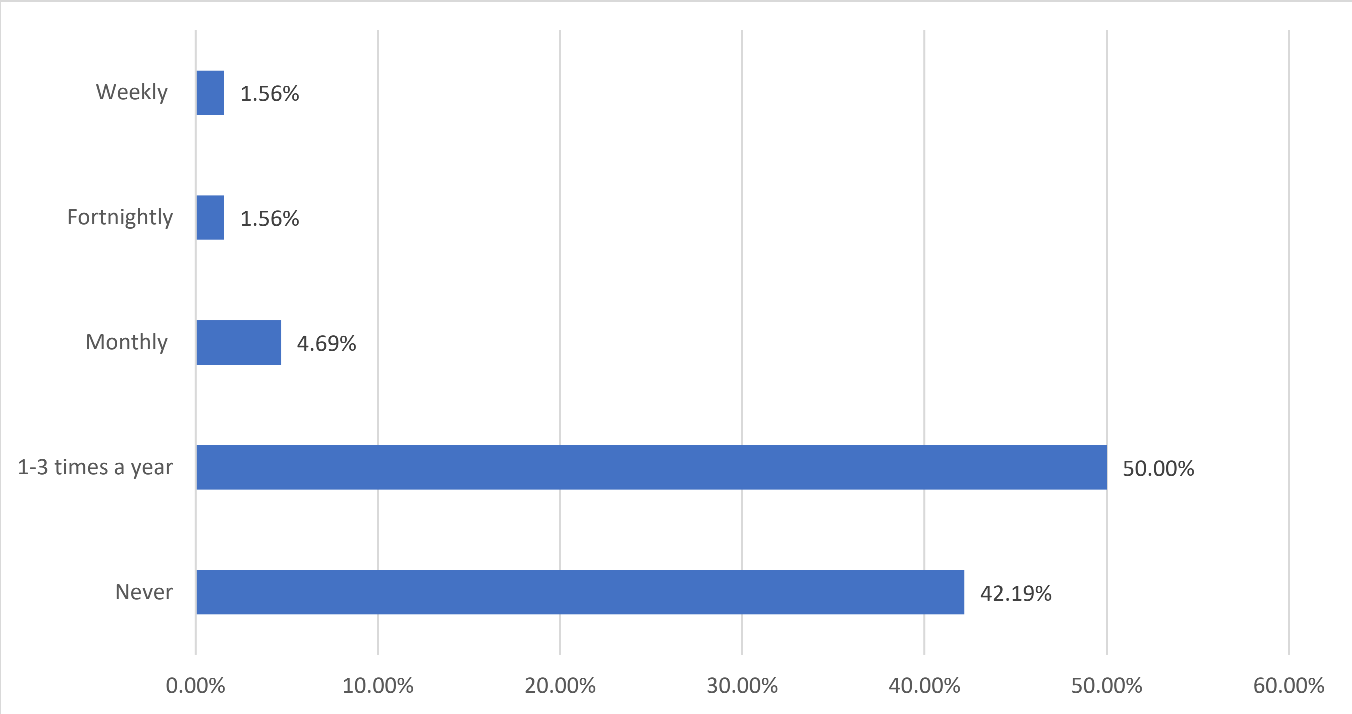

Figure 21: Frequency of neighbourhood events

Neighbourhood social connections and being involved in community groups can provide support and reduce feelings of loneliness. Respondents were asked if they felt they can talk to their neighbours if they felt down or a bit depressed. Figure 19 shows that 53.13% would find it hard/very hard to talk to someone in their neighbourhood if they felt down or a bit depressed while only 18.76% would find it easy/very easy. Of those who feel lonely most of the time, 75% are those who have only been in contact with their neighbours at least once in the last four weeks (figure 20). 47.83% of those who do not feel lonely, have been in contact with their neighbours at least once a week. Additionally, only 31.25% of respondents are involved in a neighbourhood/community association or group and 50% of respondents selected that their neighbourhood holds events 1-3 times a year (figure 21).

Trust is one factor used to measure the level of social capital in a community. To gain an insight into the level of social capital in neighbourhoods in the Greater Christchurch area, respondents were asked to give a number from 1 to 10 (with 10 meaning they trust their neighbours) whether they think that most people in their neighbourhood can be trusted. The average level of trust was 7.21. This means that most respondents felt their neighbours can be trusted and indicates respondents’ neighbourhoods have relatively high levels of social capital.

Neighbourhoods should be a place where it is safe for children to play outside. This helps to create a more socially connected neighbourhood. Respondents who had children living in their home or regularly look after children in their home (38.46%) were asked if they felt their neighbourhood was safe for children (over the age of 10) to play outside without supervision. 52% felt it was safe for children while 12% felt it was unsafe. Additionally, respondents were asked what would make their neighbourhood safer for children to play outside in which they were able to select up to two options. 58.33% selected their neighbourhood would be safer for children to play outside if there were fewer vehicles on the road while 45.83% selected it would be safer if other children played in the street.

4.3 Spatial analysis using ArcGIS Pro

The impacts of implementing a LTN, road diet, congestion charge, and MRT system in the Greater Christchurch area were examined to understand how each of these actions would impact accessibility for commuting traffic in Christchurch and how this may impact different socio-economic groups. In particular, are these actions likely to reduce or worsen transport poverty and transport disadvantage?

4.3.1 Locations of the four emission reduction actions

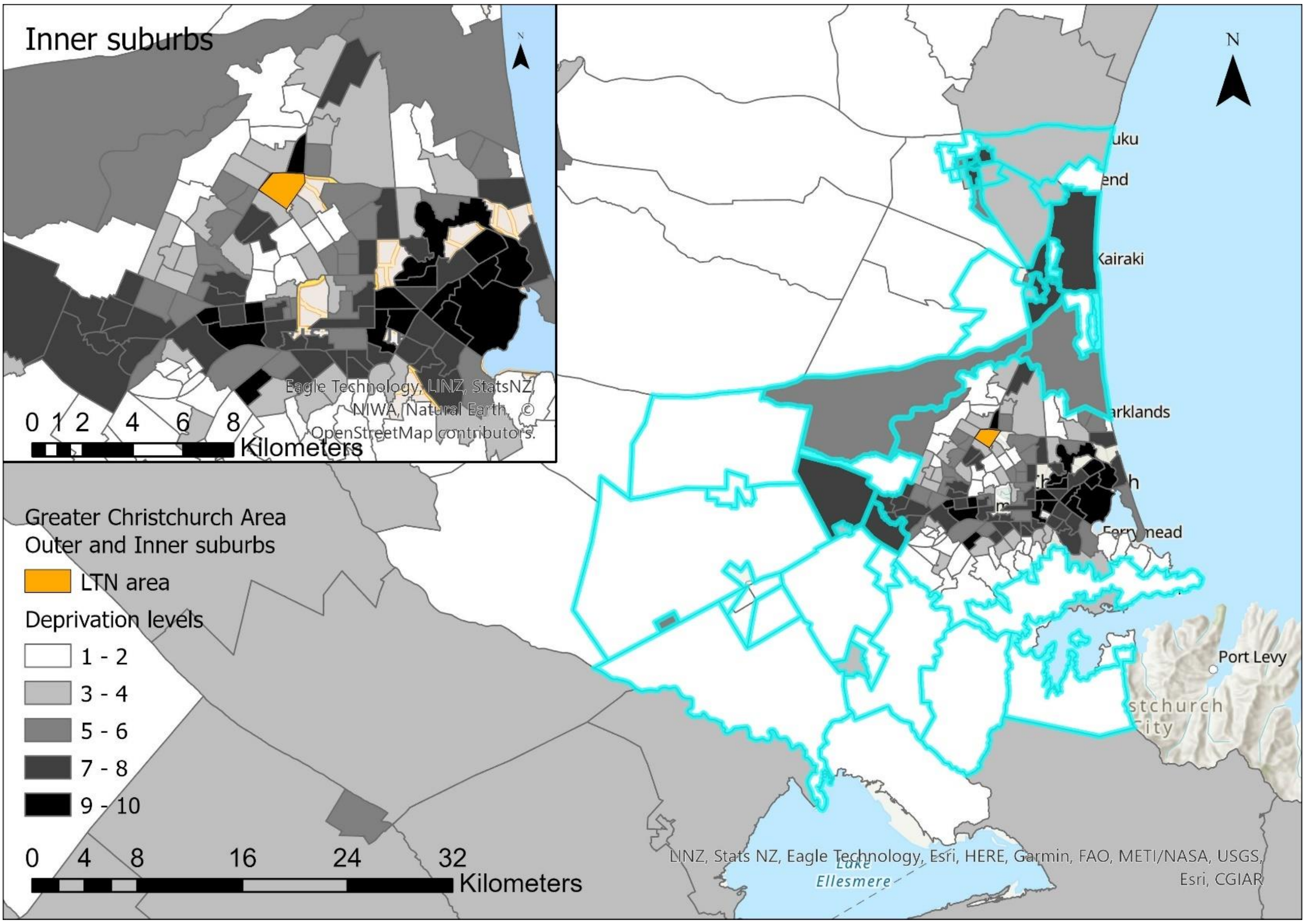

Figure 22: Location of the LTN in the Greater Christchurch area and average deprivation levels

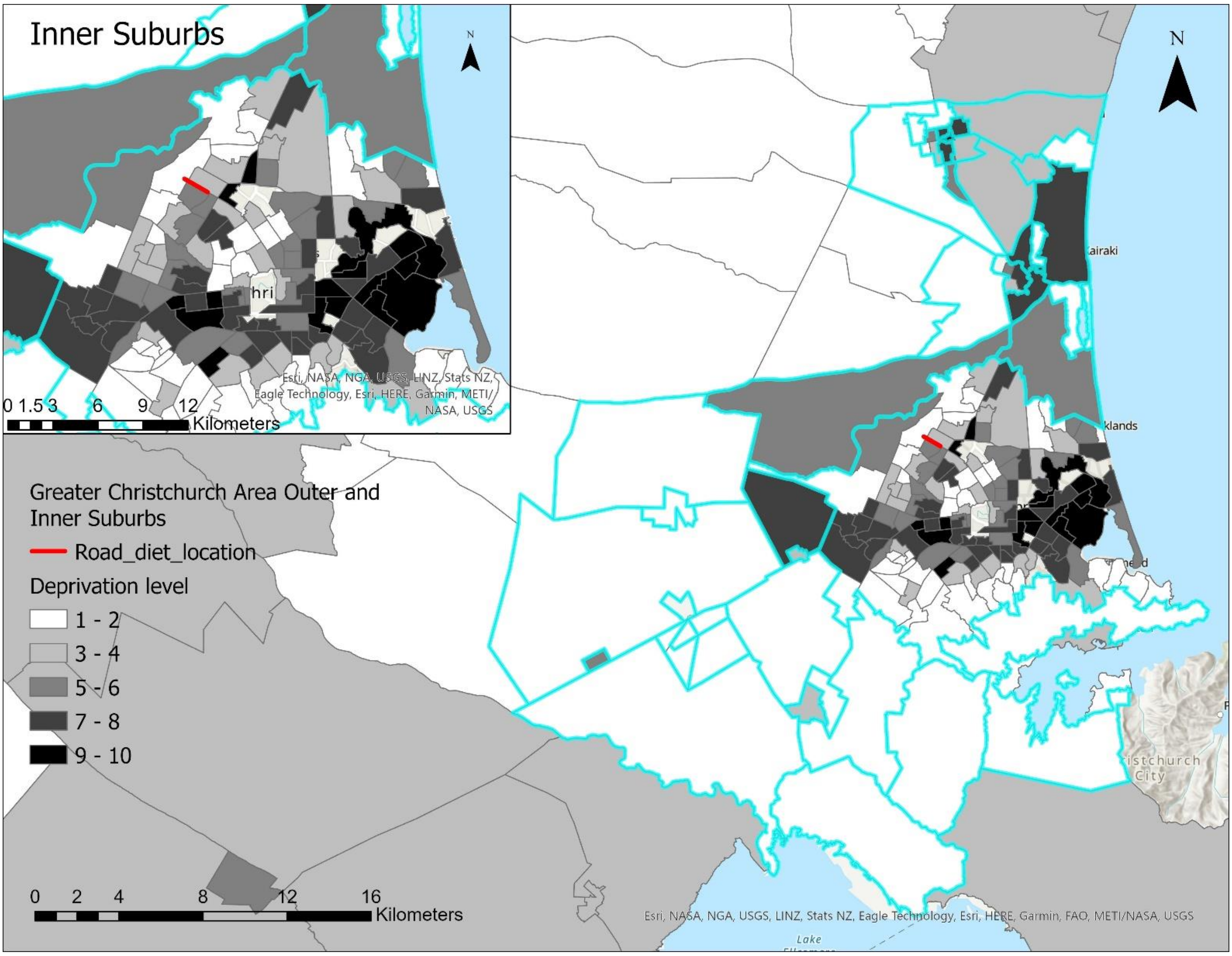

Figure 23: Location of this project's road diet in the Greater Christchurch area with average deprivation levels

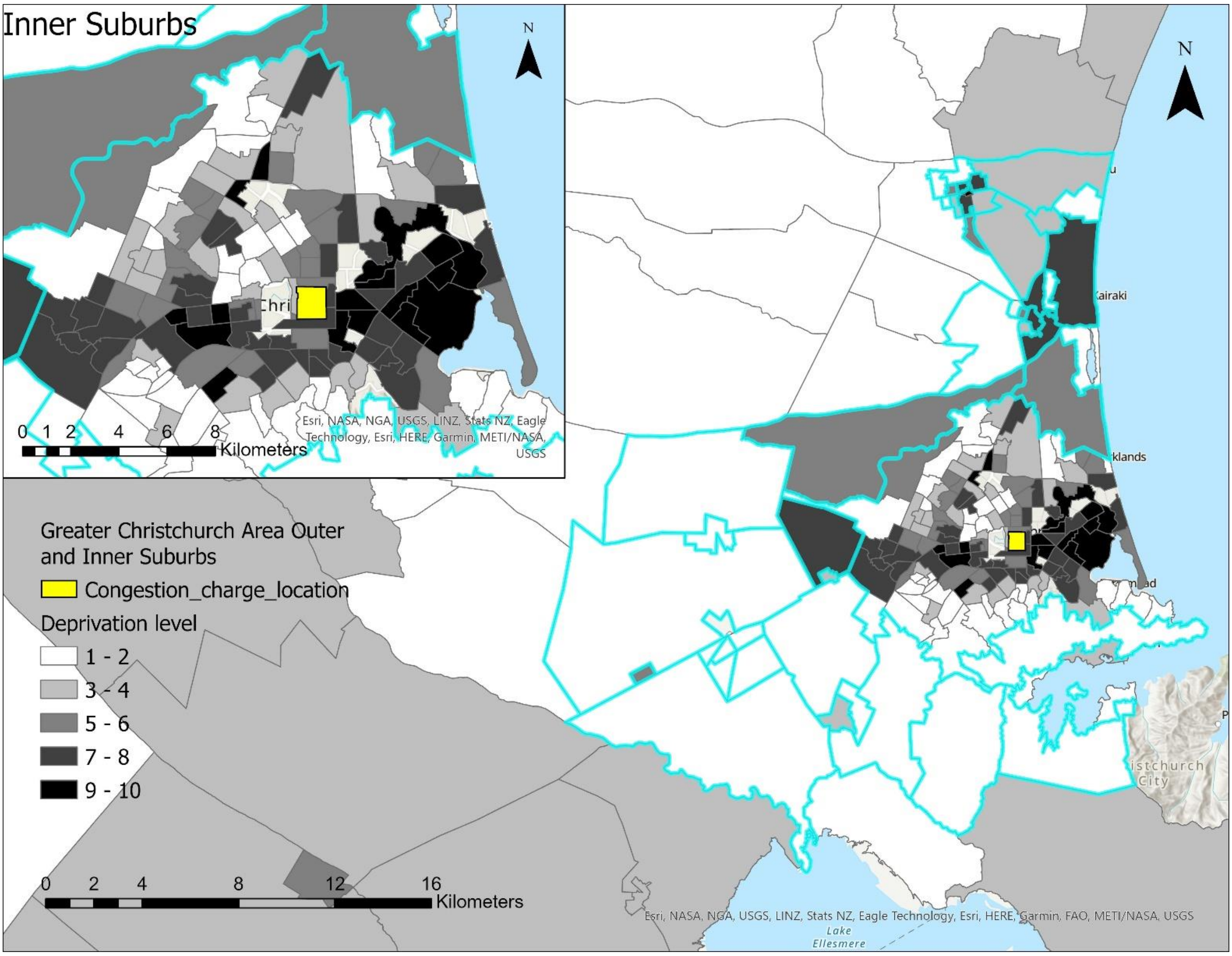

Figure 24: Location of this project's congestion charge in the Greater Christchurch area with average deprivation levels

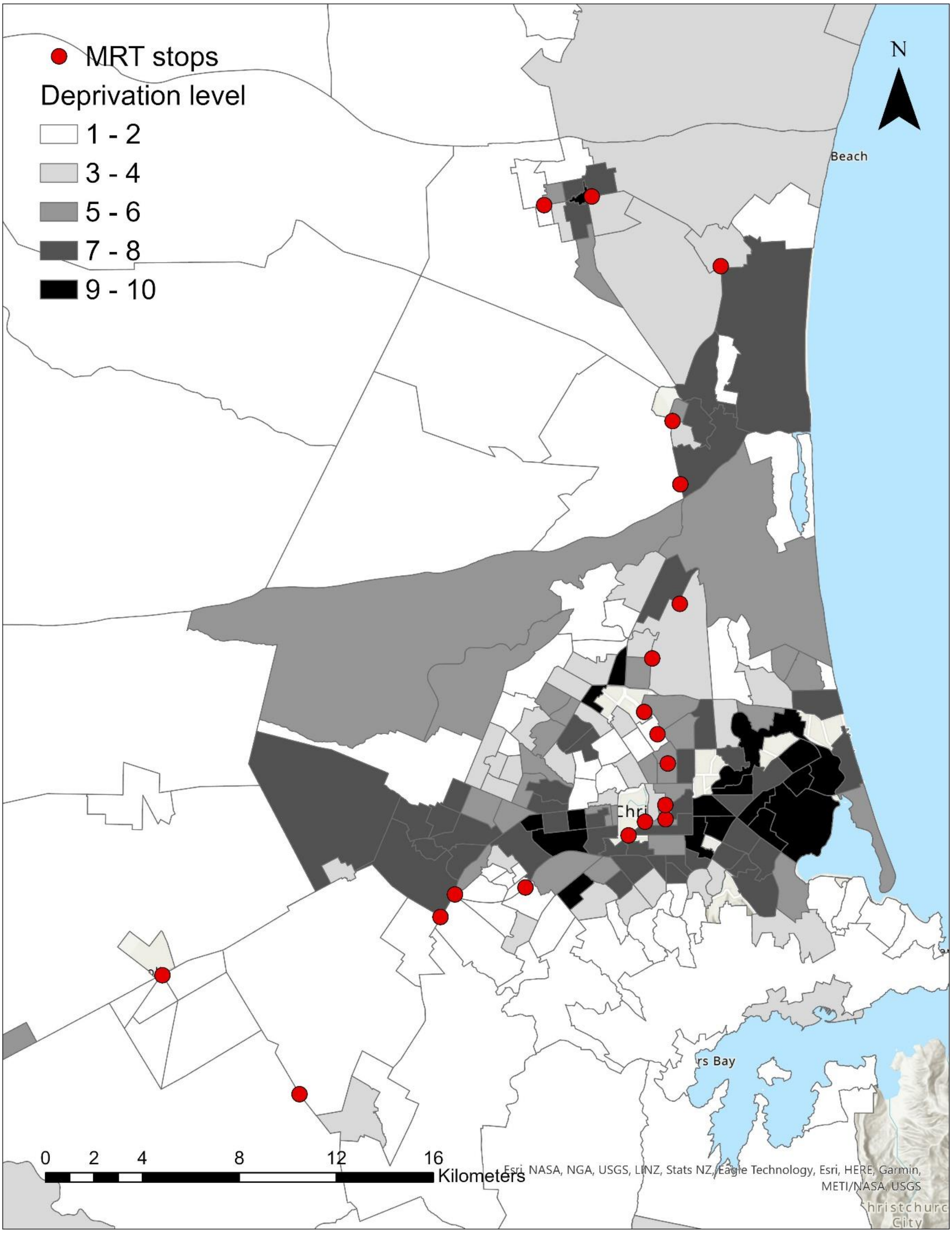

Figure 25: Location of the bus stops of the MRT street running limited stops scenario in the Greater Christchurch area with average deprivation levels (Public Transport Futures Business Case for Greater Christchurch – Mass Rapid Transit Interim Report).

Figures 22, 23, 24, and 25 show the 2018 average deprivation levels by SA2 in the Greater Christchurch Area as a base choropleth map. The lighter shades represent the least deprived areas while the darker shades represent the most deprived areas. Furthermore, a deprivation score of 1 represents areas with the least deprivation and 10 represents areas with the most deprivation. The most deprived areas are largely clustered in eastern Christchurch and further north into the outer suburbs. The least deprived areas are located in western Christchurch and the outer suburbs in the south. South-west is also highly deprived. The main map on each figure shows the outer and inner suburbs of Greater Christchurch with the outer suburbs outlined in florescent blue. On figure 22, 23, and 24, the map inset shows a closer look at the inner suburbs and the location of each action. The location of each action is highlighted on the maps.

4.3.2 Analysing accessibility of the four actions

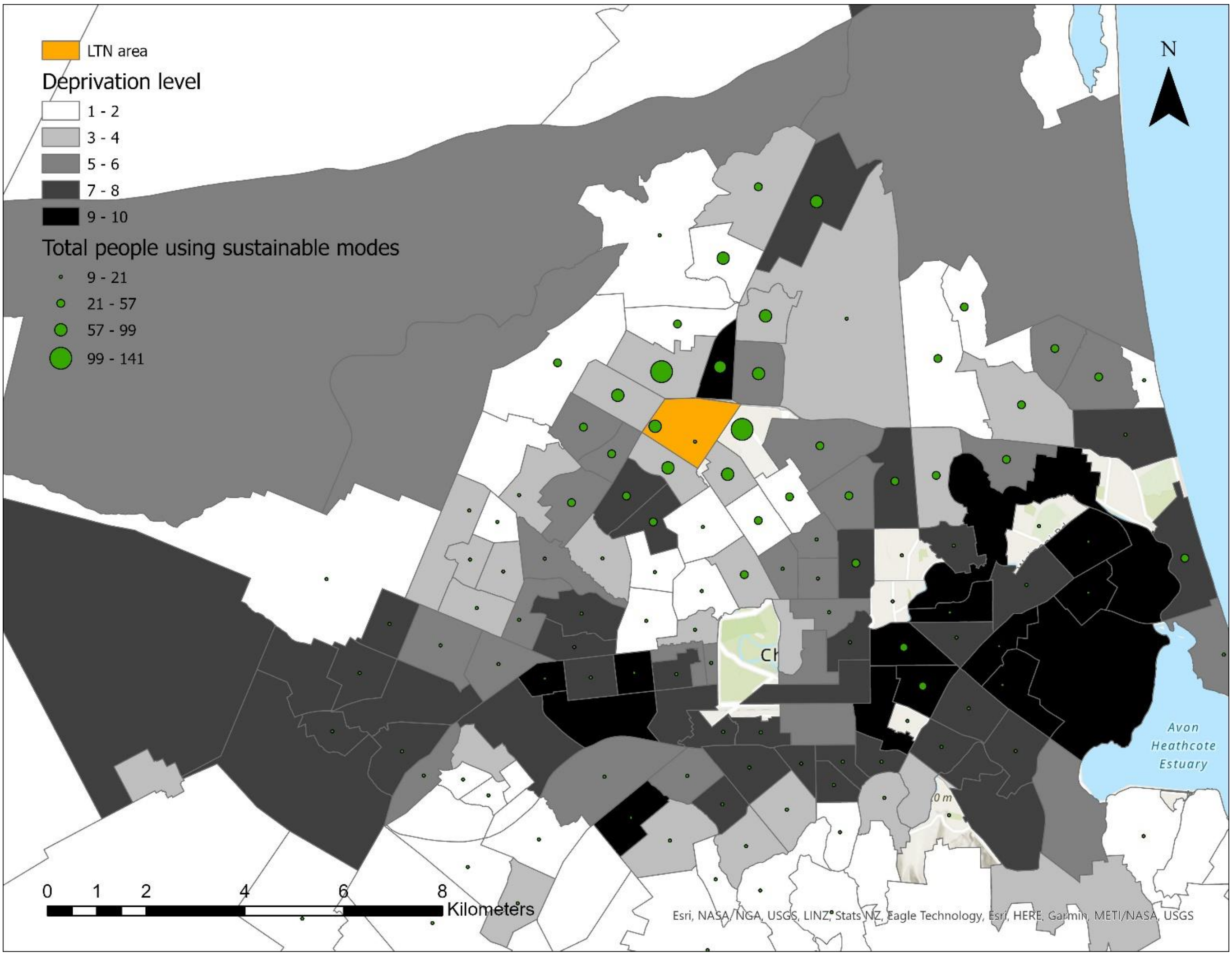

Figure 26: Total number of people using sustainable modes to commute to the LTN for work or education with deprivation levels.

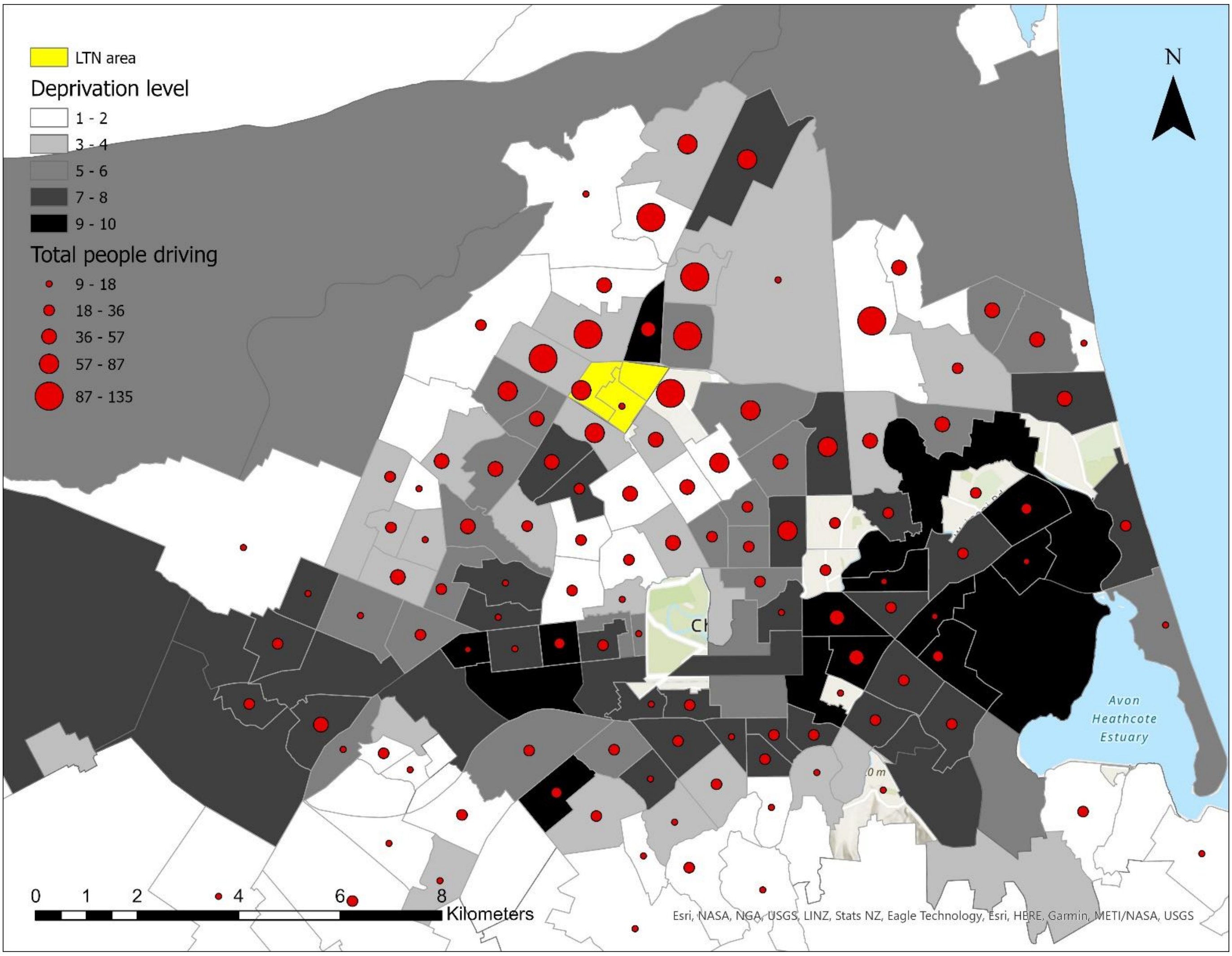

Figure 27: Total number of people driving to the LTN for work or education with deprivation levels.

The LTN located in north Christchurch is surrounded by primarily low to moderately deprived areas. Figure 26 shows the total number of people commuting by sustainable modes (public bus, walking, and cycling) to the LTN for work or education purposes from their usual residence address while figure 27 shows the total number of people driving to the LTN for work or education from their usual residence address. The proportional dots represent the total number of people commuting by sustainable modes (green dots). The larger the dot, the greater the number of people commuting from that SA2 by sustainable modes to the LTN. Any areas without a proportional dot means there are zero people commuting from those areas to the LTN. Deprivation scores by SA2 are also shown on both maps with the darker shades representing areas with the most deprivation and the lighter shades representing areas with the least deprivation. Most people commuting by sustainable modes were from the neighbouring areas of the LTN, all of which have a relatively low deprivation score. A very small proportion of people were using sustainable modes or driving to get to the LTN from the outer suburbs. Of the people commuting by sustainable modes to the LTN, 71% are from low to moderately deprived areas (an average deprivation score of less than 7). Similarly, 71.9% of people driving to the LTN are from low to moderately deprived areas. The largest proportion of people driving to the LTN are commuting from northern Christchurch.

Figure 28: Total number of people using sustainable modes to commute to the road diet area for work or education from their residential address with deprivation levels.

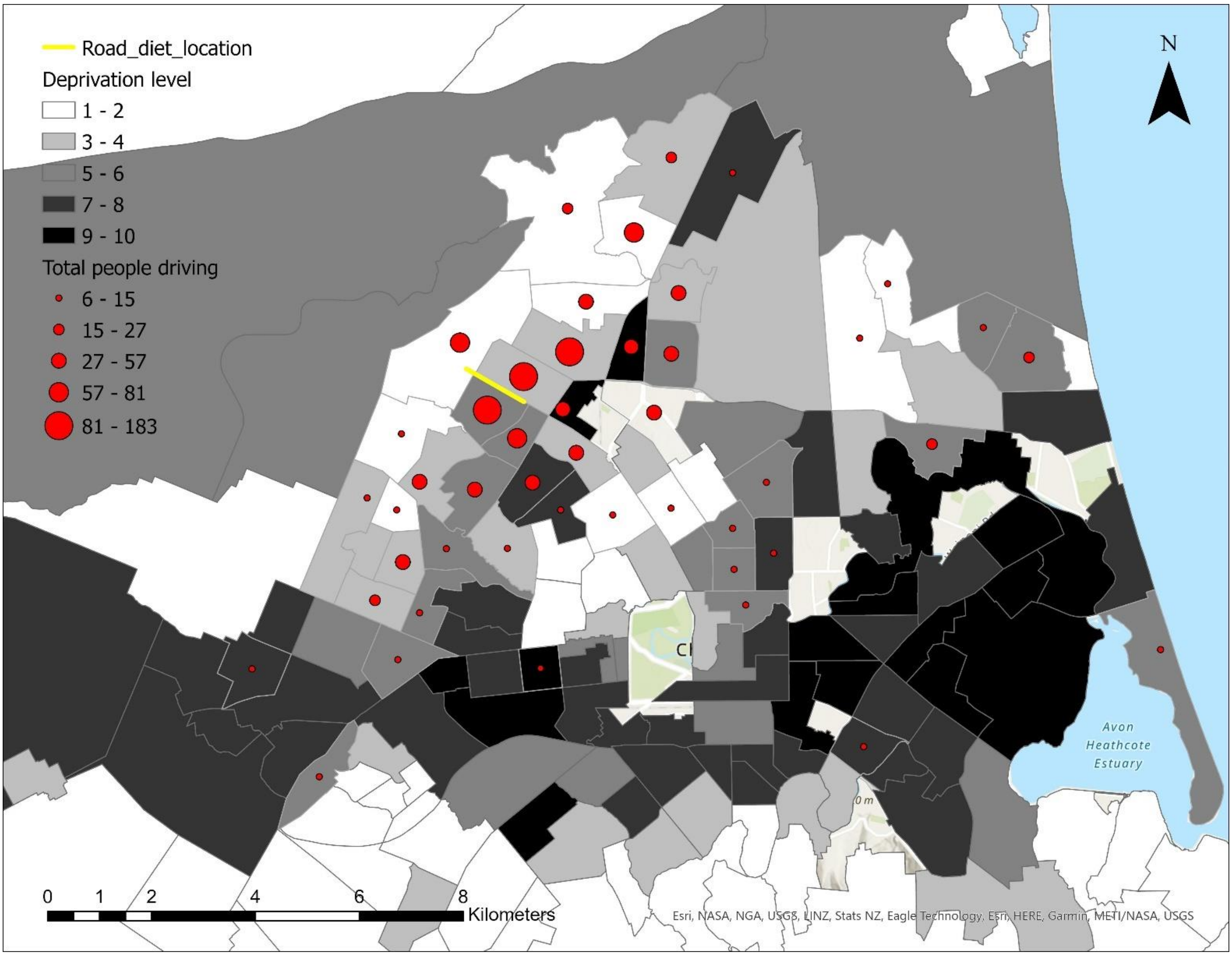

Figure 29: Total number of people driving to the road diet area for work or education from their residential address with deprivation levels.

Figure 28 and figure 29 show that the road diet is surrounded by mostly low to moderately deprived areas. Figure 28 shows the total number of people commuting by sustainable modes (public bus, walking, and cycling) to the road diet for work or education from their usual residence address with the larger dots indicating a greater number of people commuting. Figure 29 shows the total number of people driving to the road diet area for work or education. The largest proportion of people commuting by sustainable modes and by driving were from the areas closest to the road diet, all of which have a relatively low deprivation score. The vast majority of those driving to or commuting by sustainable modes to the road diet areas are from western Christchurch with very few people driving from eastern Christchurch. Of the people commuting by sustainable modes to the road diet, 88.8% are from low to moderately deprived areas (an average deprivation score of less than 7). Likewise, of all those driving to the road diet area, 87.3% are from the least deprived areas.

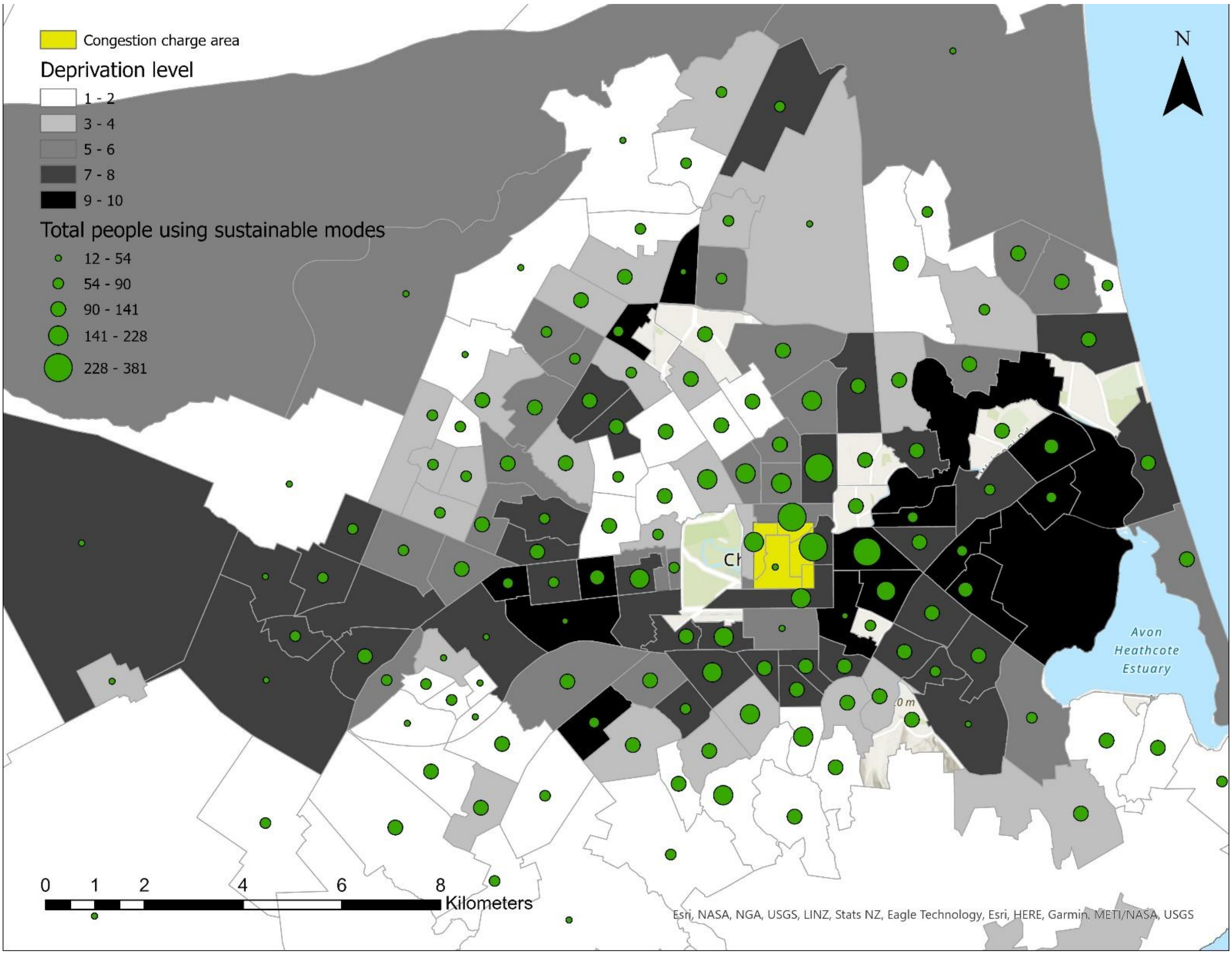

Figure 30: Total number of people using sustainable modes to commute to the congestion charge area for work or education from their residential address with deprivation levels.

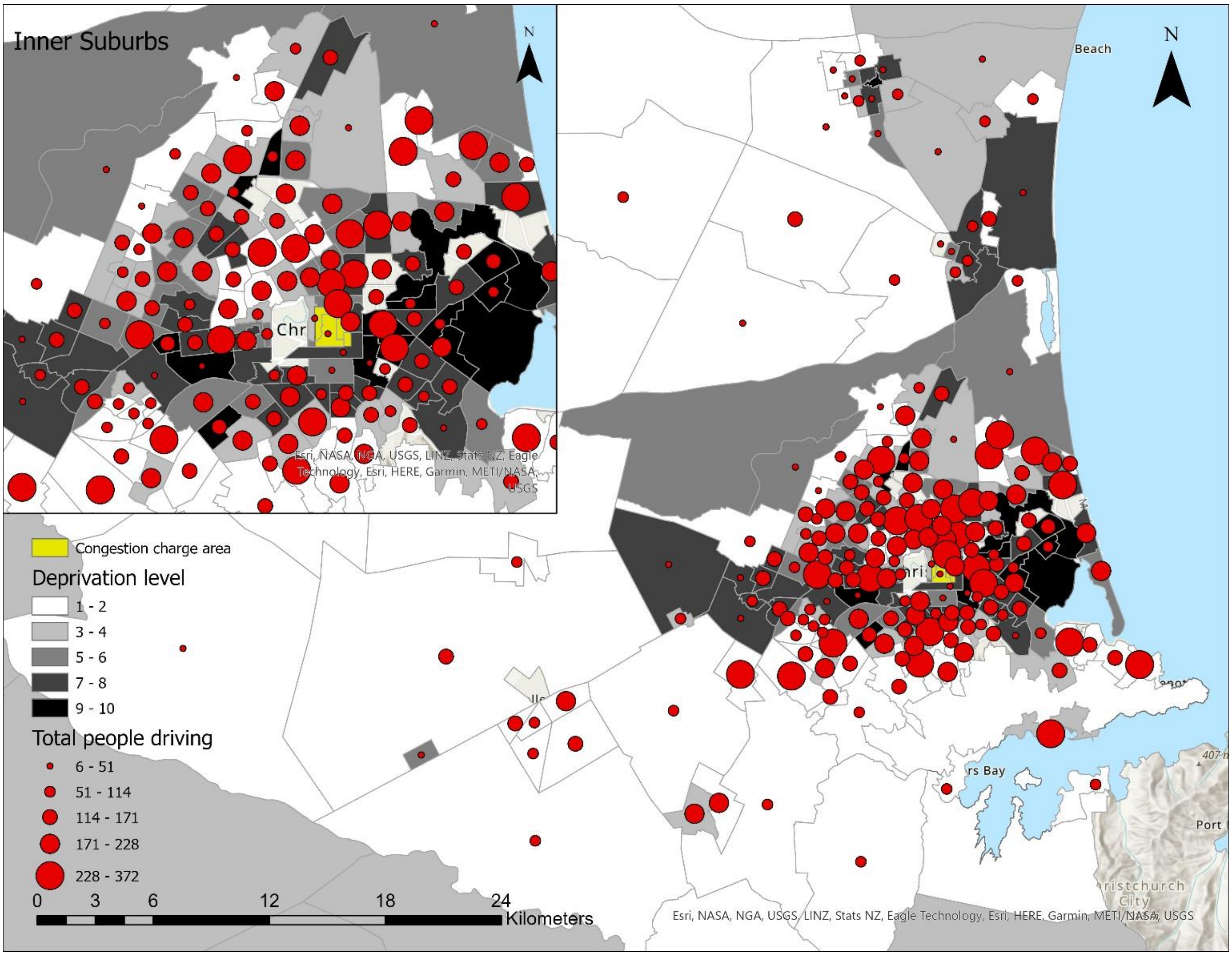

Figure 31: Total number of people driving to the congestion charge area for work or education from their residential address with deprivation levels.

Figures 30 and 31 show the location of the congestion charge highlighted in yellow. Figure 30 shows the total number of people commuting by sustainable modes to centre from their usual residential address while figure 31 shows the total number of people driving to centre city.

Figure 30 shows that the majority of people commuting to centre city for work or education by sustainable modes (cycling, walking, or busing) reside in central city. Of those commuting by sustainable modes, 68.4% are from the least deprived areas. The inset map in figure 31 gives a closer look at the number of people driving to the congestion charging area from the inner suburbs in Christchurch while the main map gives a full view of the proportion of people driving to the zone from both inner and outer suburbs in the Greater Christchurch area. A large proportion of people drive from all areas of Christchurch, particularly the south-east and north-west. 73.23% of those driving to centre city are from the least deprived areas.

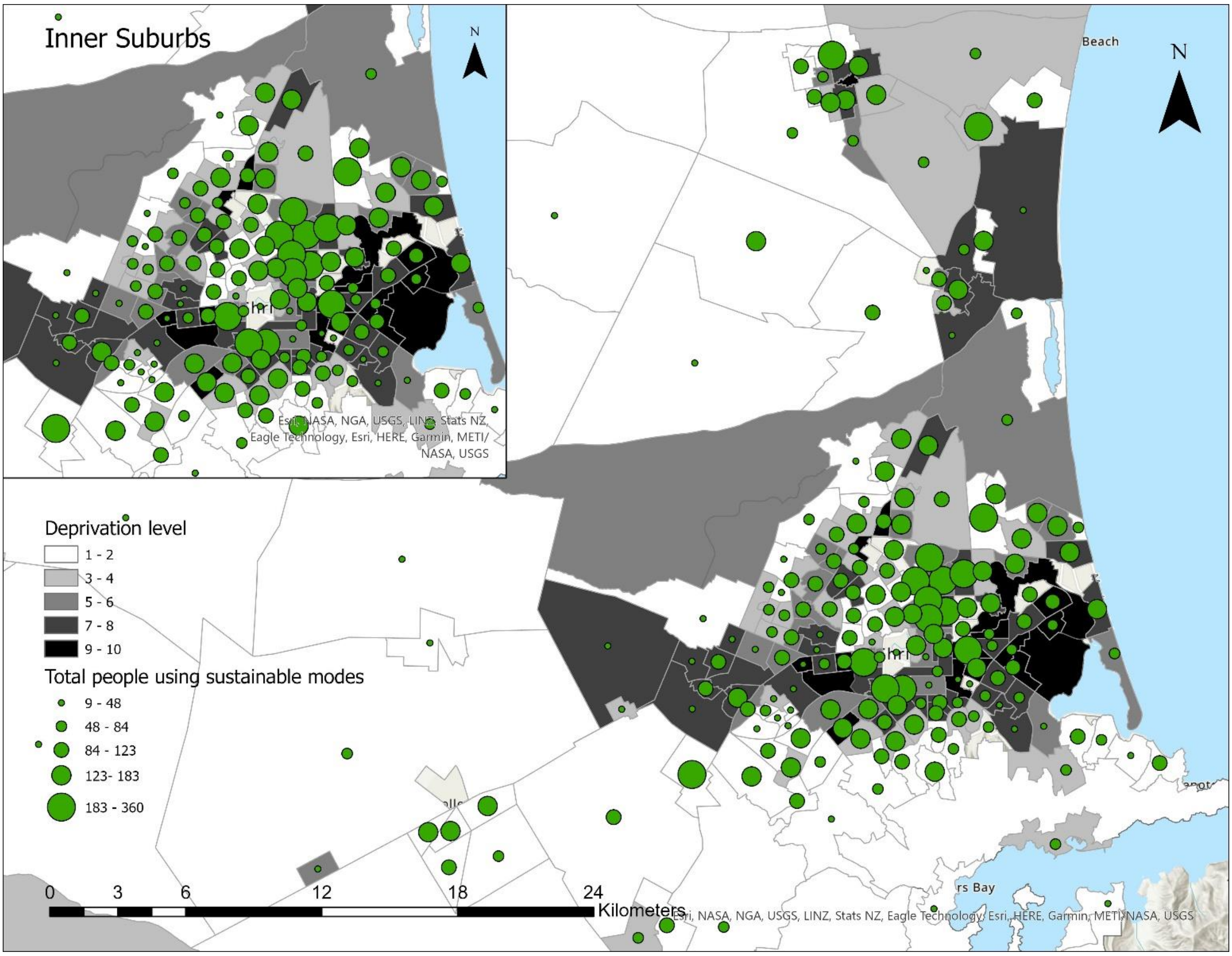

Figure 32: Total number of people using sustainable modes to commute to MRT areas with deprivation levels

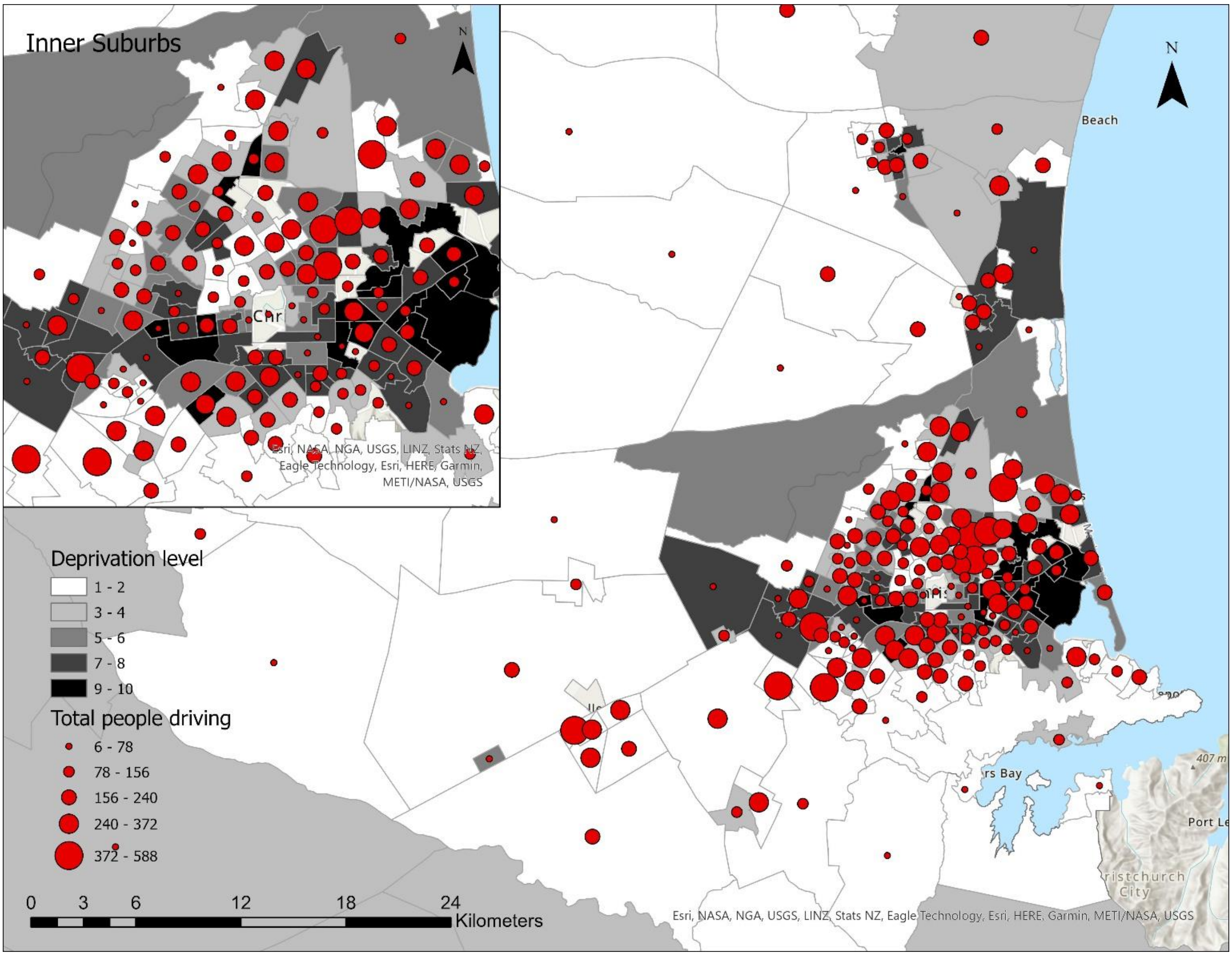

Figure 33: Total number of people driving to MRT areas with deprivation levels

The impacts of implementing a MRT system running from Rolleston through centre city to Rangiora were examined to understand how a MRT would impact accessibility for commuting traffic in the Greater Christchurch area.

Figure 32 shows the total number of people commuting to the MRT areas for work or education by sustainable modes (cycling, walking, or busing) from their usual residence address and figure 33 shows the total number of people driving to these areas. A relatively large proportion are using sustainable modes and driving to the areas where the MRT system would reach are from the outer suburbs. The largest proportion of those using sustainable modes are clustered in central Christchurch while the largest proportion of those driving tend to be from the north-east and south-west. Of those commuting by sustainable modes, 72.4%

are from the least deprived areas. Similarly, of those who drive to these areas, 73.9% are from the least deprived areas.

5.0 Discussion

5.1 What are the impacts of these actions on wellbeing and resilience?

This study examined the extent to which LTNs, road diets, congestion charging, and MRT impact a range of social and environmental factors while also investigating travel choices and neighbourhood environments in the Greater Christchurch area. Furthermore, this study investigated where these actions could be implemented in Christchurch and the impacts this may have on accessibility and mode shift. The results from the co-benefits framework showed that LTNs have the greatest impact overall, particularly on the social aspects. This suggests that LTNs will have the largest impact on wellbeing and resilience. However, all of the four transport emission reduction actions contribute in some way to wellbeing and resilience, but the extent to which these impact wellbeing and resilience varies.

This study's co-benefit's framework included both environmental and social dimensions. The environmental dimensions included emission reduction, decreased congestion, mode shift, reduced conventional car use, and reduction in traffic accidents. These environmental and safety aspects are often the primary focus of current literature; therefore, they were not given a higher weighting, as the social aspects are the focus of this research.

Reducing emissions is the primary focus of all four of the transport emission reduction actions. MRT scored the highest on reducing emissions because it showed the greatest reduction in emissions (10 - 89%). In comparison, LTN's and road diets scored the lowest on the framework because neither had evidence supporting a reduction in emissions. However, it is expected that both would reduce emissions because of significant evidence in support of mode shift and reductions in traffic volumes and reduced conventional car use. A congestion charge showed relatively high levels of emission reduction (10-16%) but was not given the highest score because of the framework's scoring system (3 = over 20%). Poor air quality has significant negative effects on health such as respiratory issues, lung cancer and heart problems (World Health Organisation, 2013). It affects groups of people unequally with low socio-economic groups facing the worst air pollution. This is because low socio-economic groups are more likely to live near main roads and transport corridors. As a result of this, they are exposed to higher concentrations of vehicle pollutants. This significantly reduces peoples' quality of life and wellbeing. LTNs, congestion charging and MRT have been found to reduce emissions, thereby, helping to reduce environmental injustice and protect people from health problems caused by air pollution. In comparison, road diets have less impact on reducing conventional car use and therefore, are less effective at improving air quality. MRT is found to have a localised effect on emission reduction. This means if the MRT system is located in the most deprived areas, environmental injustice can be reduced. The MRT street running limited stop scenario is located close to areas that are deprived, while connecting people to the centre city. However, areas that are highly deprived such as Bromley and Ōtākaro-Avon River corridor are not well serviced by this MRT option, as shown in figure 25.

Another aspect of the framework in which the actions were assessed against was decreased congestion. LTN's and congestion charge scored the highest on the framework for this aspect because both showed strong evidence in support of this. Congestion charging showed a 12-44% reduction in congestion while LTN's did not specifically show evidence supporting a reduction in congestion, the large reduction in conventional car use inside and along the boundary roads of the LTN imply there would most definitely be a reduction in congestion, particularly as through traffic is restricted from entering the LTN. Like LTN's, MRT did not specifically have statistics supporting a decrease in congestion, however, the 12-23% reduction in conventional car use indicates it would reduce congestion in the areas near the MRT. Road diet scored the lowest because it showed little evidence in support of reduced traffic volumes and one study showed a slight increase in traffic levels.

Mode shift was another factor used in the co-benefits framework to assess the actions. LTN's and road diets scored the highest for this co-benefit. Both showed strong evidence in support of a mode shift with LTN's showing a 31-68% increase in active travel modes. Similarly, road diets showed a 23-73% shift towards active travel. Congestion charging showed a 6-66% mode shift. MRT showed a mode shift towards public transport (4-14%). However, the evidence showed less of an impact in comparison to the other actions.

Reduced conventional car use is another important aspect in the framework as fewer people relying on their cars to get places will ultimately reduce emissions and create a safer and healthier environment for all types of transport users. Congestion charge and MRT both scored the highest for this co-benefit because congestion charging showed a 49% reduction in car use and MRT showed a 12-23% reduction in car use. LTN was given an average score as the evidence showed a 11-75% reduction in conventional car use despite this there was some evidence showing a small increase in traffic levels on some roads surrounding the LTN. Road diets scored the lowest possible score for this co-benefit because the evidence showed little reduction in traffic volumes and one study even showed an increase in traffic levels.

Another important aspect in the framework is reduction in traffic accidents. Road diets and MRT scored the highest on this co-benefit, followed by LTN's. Congestion charging was given the lowest possible score for this co-benefit. LTN's showed a 70% reduction in traffic accidents. Road diets showed significant reductions in traffic related accidents (19-70%). Likewise, MRT showed significant evidence in support of a reduction in traffic accidents (26-92%). Conversely, Congestion charging showed no evidence supporting a reduction in traffic accidents.

Public support of the action is another dimension of the co-benefit's framework. Although it is a social aspect, it was not given a higher weighting as it does not significantly affect wellbeing and resilience. LTN's, MRT, and congestion charging all scored the same with a relatively high score while road diets scored the lowest for this co-benefit. LTN's showed varied levels of support but most public perceptions were positive. Likewise, MRT had varied levels of public support depending on the survey and place. However, the evidence showed relatively high levels of support for the action (56-82%). Congestion charging showed low levels of support prior to implementation. Nevertheless, after the congestion charge was implemented, public support increased with relatively high levels of support (41-67%). Road diets showed no evidence on public support of the action, but the studies showed that both pedestrians and cyclists felt safer, implying they support the action.

For this study's co-benefit's framework, the social dimensions which include improved access, improved mobility options for those who experience transport poverty and transport disadvantage, improved neighbourhood social connectedness, improved physical fitness and health, and transport resilience, were all given a higher weighting as these dimensions are directly associated with improved wellbeing and resilience.

Accessibility is a significant factor in wellbeing as it effects people's participation in society and their ability to access resources needed to flourish. LTNs improve access for active transport modes. However, LTNs do reduce access for people who live outside the area and commute by driving. Although this is the purpose of the LTN (to reduce through motor traffic), it does limit the level of access for those driving which is a problem for those who depend on private vehicles to get around, such as the elderly and people with disabilities. Yet, this can be counteracted by improved safety for all transport modes. In comparison, road diets improve accessibility for all transport modes. This is, however, dependent on the quality of the cycle and pedestrian infrastructure put in place. Congestion charging will improve access for pedestrian and cyclists but as it does not include the implementation of active travel infrastructure, it may not have the same access benefits as a road diet. MRT will improve access for all people, particularly if the buses include bike holders and are accessible for people with disabilities. Those who live in the areas closest to where the MRT runs will gain the greatest benefits. Raerino et al (2013) found that Māori participants identified that car use was the only way to access sites important to their identity such as a marae and that public transport did not connect them to these places. It is, therefore, important in the Greater Christchurch area to connect Māori with places important for their cultural identity both through public transport (such as MRT) and by active transport modes, as this is not only important for their culture but also their wellbeing and resilience. The MRT street running limited stops option is within walking and cycling distance to Rehua Marae which is 1.9km away from the bus stop at Christchurch convention centre. Additionally, the Tokona Te Raki Marae is only approximately 1km away from the Lincoln Road bus stop. However, Nga Hau E Wha National Marae is over 5km from the nearest MRT bus stop and Wheke Rapaki Marae is approximately 17km away from the nearest MRT bus stop. Overall, LTN's and road diets scored the highest on the co-benefit's framework for improved access because of their significant improvements to road safety for all modes and improvements to active travel infrastructure. MRT scored relatively high on the co-benefits framework as it greatly reduces traffic related accidents and provides a low-cost and efficient public transport option.

Conversely, a congestion charge scored the lowest as there is little evidence on improvements of road safety and without implementing pedestrian and cycling infrastructure alongside the charge, there is little impact on improved safety for active travel modes.

Physical activity plays an important role in the wellbeing of individuals and communities. It results in lower stress levels, greater life satisfaction, greater self-efficacy, and higher levels of happiness and excitement (Hyde et al., 2013). Several studies show how active travel can increase physical activity in individuals creating a more physically active society (Hamer & Chider, 2008; Sahlqvist et al., 2012). LTNs create a safer and more inclusive environment for walking and cycling resulting in a modal shift, thereby, increasing physical activity (Aldred & Goodman, 2020; Lambeth Council, 2022). Likewise, road diets increase physical activity by causing a shift to active travel modes and encouraging those who already partake in walking and cycling to engage in these more frequently (Huang et al., 2019; Tan, 2011). Road diets reallocate road space to active travel infrastructure while also reducing the number of lanes needed to cross for both pedestrians and cyclists, creating a safer environment. Congestion charging can result in increased physical activity by causing a shift to sustainable forms of transportation, particularly public transport (FHWA, 2021; OECD et al., 2017; Pike 2010). Public transport usage has been found to increase physical activity as users have to walk to and from bus stops and their destinations (Lemoine et al., 2016). Furthermore, congestion charging can result in people changing to active travel modes because of increased travel costs, thus, increasing physical activity among individuals resulting in better health outcomes (Transport for London, 2009). However, there is less evidence of a congestion charge causing a modal shift to active travel compared to road diets and low traffic neighbourhoods, indicating there may be a lower increase in physical activity. Therefore, unless congestion charging is done alongside improvements in active travel infrastructure, it is less likely to result in a switch to active travel. Similar to congestion charging, MRT increases physical activity among users as those who use MRT are more likely to do moderate to vigorous physical activity than those who do not use MRT (Lemoine et al., 2016). Overall, LTN's, road diets, and MRT have strong evidence that they increase physical activity and, therefore, they all scored highly on this dimension. Conversely, congestion charging had little evidence on improving physical fitness and health and, thus, scored low on this dimension.

Transport poverty and transport disadvantage significantly reduce one's ability to participate in society which, in turn, impacts their wellbeing and resilience (Currie & Delbosc, 2010; Social Exclusion Unit, 2003). It is, therefore, of vital importance that the transport system supports a range of transport modes, particularly low-cost options such as active travel and public transport. LTNs, road diets, and MRT all scored the highest possible score for this co-benefit as all facilitate the uptake of active travel and public transport. This will improve wellbeing and resilience among individuals as they will not be excluded from society and the stress associated with travel costs can be reduced. In contrast, congestion charging scored the lowest possible score for this co-benefit because it increases travel costs for those who rely on motor vehicles to get places. This will negatively impact those on low-incomes, those who are not well-serviced by public transport and those who are unable to partake in active travel due to physical and/or mental disabilities and will, therefore, feel the effects of the congestion charge more than others.

Those who are more socially connected typically have better wellbeing and are more resilient as they have support, enjoyment of others, access to more resources and opportunities, sense of belonging and purpose, greater life satisfaction, and a better self-reported mental health (Brown et al., 2012; Satici et al., 2016). Conversely, those who are less socially connected are more likely to experience feelings of loneliness. Loneliness has been associated with increased depression, poorer physical health and has been found to have a negative relationship with resilience and wellbeing (Chen & Feeley, 2013; Cornwell & Waite, 2009; Golden et al., 2009; Satici et al., 2016). Frieling et al. (2018) state that older adults and young people are more at risk of feelings of loneliness and social isolation. Results from the survey conducted as part of this research support this conclusion with 28% of those who never feel lonely aged between 35-44 years while 33.33% of those who feel lonely some of the time were aged between 18-24 years. However, 50% of those who feel lonely most of the time are aged between 35-44 years which varies from Frieling's et al. (2018) conclusion. Of those who feel lonely most of the time, 75% have only been in contact with their neighbours at least once in the last four weeks. In comparison, 47.83% of those who do not feel lonely have been in contact with their neighbours at least once a week. The present findings align with prior evidence that neighbourhood social connectedness is associated with reduced feelings of loneliness and act as a protective factor against loneliness (Jose & Lim, 2014; Satici et al., 2016).

The built environment can either foster social connections and the development of community or act as a barrier to this (Canterbury District Health Board, 2006). One way to enhance neighbourhood social connectedness is to ensure neighbourhoods are close to or include key amenities such as a medical centre, schools, and greenspace. Additionally, low traffic volumes and speeds can enhance neighbourhood social connectedness. Conversely, other characteristics, such as busy roads, can segregate a community (Canterbury District Health Board, 2006). Therefore, how a neighbourhood is designed, as well as the transport infrastructure in place will dictate how people choose to travel and how socially connected people are. Walkable and low traffic neighbourhoods create opportunities for social interactions (Boniface et al., 2011; Kingham et al., 2020; Panter et al., 2008). For example, Leyden (2003) found that those living in walkable and mixed-use neighbourhoods are more likely to know their neighbours. LTNs, road diets and congestion charging help create more active neighbourhoods. MRT can increase one's social network by providing a low-cost and more reliable public transport option, increasing one's accessibility. This is particularly important for those who face transport poverty and are, as a result, more at risk of social exclusion. Numerous studies have found that social exclusion is associated with negative health and wellbeing outcomes (Bernstein, 2016; Bailey & McLaren, 2005; Russel et al., 1984; Litman, 2003). Congestion charging can increase the number of people who car share. This means there will be fewer solo motorists and allow for more social interaction. Being socially connected is important for dealing with adversity and life's daily stressors by providing emotional, instrumental, and/or informational support (Frieling et al., 2018). Moreover, there is a negative relationship between social support and a sense of belonging with depression and poor psychological health (Frieling et al., 2018). The survey results revealed that slightly over 50% of respondents would find it hard or very hard to talk to someone in their neighbourhood if they felt down or a bit depressed. This emphasises the importance of creating neighbourhood environments that prioritise active travel and reduce car use in the Greater Christchurch area to improve wellbeing and resilience among individuals and communities. Overall, LTN's scored the highest on increased social connectedness, followed by a road diet. Congestion charge and MRT both were given a relatively low score as neither had strong evidence supporting increased social connectedness.

Transport resilience plays a key role in urban resilience as well as individual resilience. A key aspect of transport resilience is ensuring there are alternative routes and transport infrastructure in place for all transport modes (Litman, 2021: Victoria Transport Policy Institute, 2019; Xu et al. 2018). By doing so, people will have greater options to access resources, people, and services needed to participate in society. Road diets and MRT directly improve transport resilience by providing alternate transport mode infrastructure. Therefore, road diets scored the highest on this co-benefit, followed by LTN's and MRT. Congestion charging scored the lowest for this co-benefit.

The four transport emission reduction actions impact wellbeing and resilience to different extents. LTNs, road diets, and MRT are effective at improving wellbeing and resilience through increased physical activity, strengthening social connectedness, reducing environmental injustice, improving accessibility, and enhancing transport resilience, whereas congestion charging has less of a positive impact on these factors.

5.2 How do these actions affect accessibility for commuting traffic, particularly those who face transport poverty and transport disadvantage?

A lack of access to good transport can lead to or exacerbate social exclusion and contribute to or worsen transport poverty and transport disadvantage (Bonsall & Kelly, 2005). The English accessibility planning framework includes six categories of standard indicators used to measure and compare accessibility across local transport agencies (LTSs). These core indicators have been identified as having the most impact on life chances (Chapman & Weir, 2008). Three of these indicators are accessibility to school education, accessibility to further education, and accessibility to work. Ensuring access to work and education is, therefore, important for individuals' wellbeing and quality of life. Where these four transport emission reduction actions are implemented in the Greater Christchurch area will affect people's accessibility to work and education and will either worsen or reduce transport poverty and transport disadvantage.

This study implemented a LTN in the area covering Papanui North, Northlands (Christchurch City), and Northcote (Christchurch City). Approximately 2,292 people walk or cycle to these areas for work or education while 4,689 people drive. A LTN would help improve accessibility for those already walking or cycling in these areas. Papanui North is highly deprived with an average deprivation score of 9. By encouraging residents in this area to use active travel modes, the cost of travel can be reduced, thereby, reducing transport poverty. Of those driving to the LTN, 71.9% are from the least deprived areas. This indicates that people from the least deprived areas, are more inclined to own and use a private vehicle than those from the more deprived areas. By limiting through traffic in the LTN, access for private vehicles will be reduced and this will encourage a switch to more sustainable modes of transport.

This study examined implementing a road diet on Harewood Road which includes the statistical areas of Bishopdale West, Bishopdale North and Harewood. Approximately 972 people walk or cycle to these areas for work or education while 1587 drive. 88.8% of people commuting by sustainable modes to this area are from low to moderately deprived areas. The road diet is located in north-western Christchurch, which is largely low to moderately deprived areas. Very few people are travelling from eastern Christchurch to this area which is unsurprising as it is significant distance away. A road diet will help enhance accessibility to these areas for those walking and cycling as a result of implementing pedestrian and cycle infrastructure. However, there will be fewer benefits to those who face transport poverty as the LTN is located in western Christchurch.

The MRT street running limited stops scenario includes 35 statistical areas throughout the Greater Christchurch area. A notable proportion of people who drive (26.1%) are from the most deprived areas. This suggests that MRT has the potential to reduce transport poverty by providing an efficient and low-cost transport alternative, thereby, enabling a mode shift for those who currently rely on driving.

For this study, a congestion charge was implemented in Christchurch Central with Salisbury St, Barbadoes St, St Asaph St, and Montreal St as the boundary roads. With a large number of people (approximately 14,547) already commuting by sustainable modes to central city, it shows there is potential for a further shift towards these modes. Approximately 27,309 people drive to central city for work/education. A relatively high proportion of people who drive to the city centre (26.7%) are from highly deprived areas (an average deprivation score between 7-10). This can result in negative distributional effects, with those on lower incomes being faced with additional travel costs, worsening transport poverty and transport disadvantage. It is, therefore, important to ensure alternative modes of transportation are available, so people have the choice to either pay the fee or use alternative modes. This will counteract the uneven economic effects of the congestion charge. Furthermore, many places have exemptions or discounts for certain groups, such as those on lower incomes, those who live in the area in which the congestion charge is placed, low emission vehicles and delivery vehicles (Hamilton, 2006). For example, residents in the London congestion charging scheme only pay 10% of the fee. If a congestion charge is implemented in Christchurch, the revenue should be used to implement new active travel and public transport infrastructure as well as to improve existing infrastructure for these modes (Auckland Council et al, 2020). If these mitigation measures are not taken, congestion charging can increase social exclusion for particular groups such as people with disabilities and those on lower incomes. However, if these measures are put in place, congestion charging can reduce environmental injustice and create a better environment for all road users (FHWA, 2021).

5.3 How likely are these actions to change how we travel in Christchurch?

The survey conducted as part of this research found that just over 50% of respondents use private diesel/petrol vehicles to commute to their place of work, study or main daily destination, and just over 30% use private vehicles for most short trips (under 3km). This emphasises the large dependence on private vehicles in the Greater Christchurch area, even for short trips and the need for invterventions to change the way people travel. Results from this study's survey showed that the main reason people choose their current mode of transportation is because it is quicker and to visit shops etc., on the way to/from work/university. This indicates that people's main priorities when it comes to deciding how to travel is commute time and being able to make multiple stops along their journey.

This study's survey found that the main reasons respondents do not cycle at least once a week (66.7%) is because they need to carry shopping, other goods, and equipment. Better footpath and road conditions was the top option that might encourage them to use active transport more frequently. This was closely followed by increased safety features such as pedestrian crossings, traffic calming and dedicated lanes. Appropriate cycling infrastructure is, therefore, important in encouraging people to switch to active travel modes. Road diets can help encourage people to make this switch because one aspect of a road diet is to reallocate road space to cycle and pedestrian infrastructure. LTNs can also encourage people to cycle more frequently by calming traffic and, thereby, creating a safer environment for people to cycle. Slower traffic was also a key improvement respondents would like to see. A significant benefit of road diets is their ability to reduce traffic speeds, while a disadvantage of congestion charging is it has been found to increase traffic speeds (FHWA, 2021; NZTA, 2014; Pike, 2010). Ultimately, road diets and LTNs are more effective at encouraging people to use active travel modes.

89.86% of respondents do not take the bus to their place of work, study or main daily destination at least once a week. Overall journey time was the main improvement respondents selected that might encourage them to use the bus more frequently. MRT can help encourage people to use public transport as it is found to improve travel time for users (Inter-America Development Bank, 2015).

The most important practical aspect of commuting for respondents was speed/travel time, followed by cost. MRT is a low-cost travel option that can reduce travel times in comparison to other public transport options and even private vehicles which are often held up by congestion. With cost being an important practical aspect of commuting, a congestion charge has the potential to cause a modal shift to more sustainable modes, especially if the charge is relatively high and with few exemptions. LTNs will likely increase travel time for those commuting by private vehicles as they will not be able to cut through the low traffic neighbourhood. Likewise, road diets may result in an increase in travel time for private vehicles. However, both a LTN and road diet will improve travel time for active travel modes. Transport costs may decrease for residents in LTNs if they choose to use alternative modes while travelling in their neighbourhood. Similarly, by implementing and improving pedestrian and cycle infrastructure in road diets, people may switch to active travel modes which are far cheaper than owning and running a car.

A low proportion of respondents felt their neighbourhood had been designed to prioritise walking and cycling. However, more than half of the respondents agree/strongly agree that they have access to most of the amenities they need within a 5–10-minute walk or bike. Traffic volume and speeds can reduce the overall appeal of a neighbourhood as a place to walk and cycle, even with amenities close by. A LTN creates a neighbourhood environment that prioritises walking and cycling by restricting through traffic. Road diets can also create an environment that fosters active travel by providing appropriate infrastructure for these modes, reducing the number of lanes to cross, and reducing traffic speeds. Congestion charging can create a walking and cycling neighbourhood by discouraging private vehicle use and, in turn, encouraging people to switch modes. MRT is found to increase physical activity among users. By more people walking or cycling to the bus stops, others will be encouraged to participate in these transport modes.

A notable percentage (31.14%) greed/strongly agreed that they would change to more sustainable modes if they had to pay a direct fee for driving in a certain area. This shows a congestion charge is likely to result in a modal shift. However, 46.27% of respondents disagreed/strongly disagreed that they would change how they choose to travel, no matter how much they would have to pay to drive in a particular area. This is more likely to be those on higher incomes. Many of the studies overseas showed a lack of support for road pricing prior to its implementation. After it had been established for a period of time, there were obvious modal shifts and reductions in congestion showing that people did change how they travelled (Eliasson, 2014; FHWA, 2021; Pike, 2010). Additionally, in all cases, the public's level of support for congestion charging improved after they were able to see the benefits it provided (Auckland Council et al. 2020). This would likely be the case in Christchurch.

LTNs, road diets (reallocation of road space), congestion charging and MRT are all likely to cause a modal shift to more sustainable transport modes in the Greater Christchurch area. However, the level of modal shift will vary. Ultimately, the combination of all four of these transport emission reduction actions in Christchurch will produce the greatest benefits and will have a greater impact on how people choose to travel in Christchurch.

6.0 Limitations and future research

As with any research project, there were limitations to this study. Firstly, the survey sample was unrepresentative of the Christchurch population which means that the findings of this study may not be able to be generalised. Most of the participants in this study identified as

European/Pakeha and earned over $100,000 a year. If a larger number of respondents were those on lower incomes, it is likely that the results about road pricing and travel behaviour would differ. To make the results more representative of the Greater Christchurch population, a larger sample would be advantageous. Another limitation of the study was the accuracy of the scoring on the co-benefit framework. Although, the scoring was based on evidence from academic literature, there is a degree of individual interpretation.

It would be of interest to conduct further research into alternate locations for these actions in the Greater Christchurch area and then compare the different impacts these locations would produce in terms of the co-benefits. In addition, if these actions are implemented in Christchurch, it would be beneficial to conduct a before and after study of the effects these actions have. This would give a more in-depth, context-specific and precise overall score for each action on the co-benefit's framework. Furthermore, the survey could be done again to get a sample that is more representative of the Christchurch population. It would be interesting to use this study's co-benefit's framework to assess different transport emission reduction actions or a larger range of transport emission reduction actions.

7.0 Conclusion

Automobile dependency is a key issue worldwide. It has significant negative impacts on the environment and on people's wellbeing and level of resilience. In Christchurch, the transport sector accounts for over 50% of total emissions. If this trend continues, people's quality of life will be reduced as well as the quality of the environment. Transport emission reduction actions are one way to reduce emissions from transport and to create a healthier environment for all. The current literature on transport emission reduction actions focuses primarily on the environmental benefits these actions provide with little attention to how these actions impact the social connectedness, accessibility, wellbeing, and resilience. To fill this knowledge gap, a co-benefits framework was proposed as a way to assess transport emission reduction actions against a range of benefits, with a stronger focus on the social aspects.

This research aims to provide an in-depth review of the co-benefits of the four transport emission reduction actions (LTN's, road diets, congestion charging and MRT) that are being considered to be implemented in the Christchurch. A co-benefits framework was created as a way to assess the actions against a range of benefits to see which one produces the greatest benefits and, ultimately, which one has the largest positive influence on wellbeing and resilience. Three research questions underpinned this research: Firstly, *what are the co-benefits of these actions? In particular, how do these actions impact wellbeing and resilience?* Secondly, *how do these actions impact accessibility for commuting traffic where these actions could be implemented?* Lastly, w*hat are the public's perceptions of transport and neighbourhood in environments in Christchurch, and would these actions impact how people choose to travel in the Greater Christchurch area?*

All four transport emission reduction actions provide a range of benefits; however, LTNs were found to produce the greatest co-benefits and, therefore, have the greatest impact on wellbeing and resilience. Congestion charging scored the lowest overall on the co-benefit's framework. Although, it produced a range of environmental benefits such as emission reduction and reduced congestion, it scored low on the social aspects such as improved social connectedness. The actions are all likely to improve accessibility for sustainable modes of transportation and will likely result in a shift towards these modes.

All four emission reduction actions will help to create a healthier and more resilient city, especially if done in conjunction with each other. The co-benefits framework is an effective way to assess different transport emission reduction actions against key benefits, particularly the more social aspects. It is important to consider how transport emission reduction schemes will impact wellbeing and resilience as both are vital to creating healthy and functional individuals and communities.

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9.0 Appendices

Appendix one

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE
Secretary, Rebecca Robinson
Telephone: +64 03 369 4588, Extn 94588
Email: human-ethics@canterbury.ac.nz

Ref: HEC 2021/94/LR Amendment 1

30 November 2021

Rebecca Adolph
School of Earth and Environment
UNIVERSITY OF CANTERBURY

Dear Rebecca

Thank you for your request for an amendment to your research proposal "Co-benefits of Implementing Transport Emission Reduction Actions in Christchurch" as outlined in your email dated 29th November 2021.

I am pleased to advise that this request has been considered and approved by the Human Ethics Committee.

Yours sincerely

Dr Dean Sutherland
Chair, Human Ethics Committee

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

F E S

Appendix two

Co-benefits of implementing transport emission reduction actions in Christchurch

Start of Block: Information sheet

School of Earth and Environment
Phone: +64 3 3692026
Email: rja167@uclive.ac.nz
06/10/2021
HREC Ref: HEC 2021/94/LR

Co-benefits of implementing transport emission reduction actions in Christchurch

Kia ora,

You are invited to participate in a research study on the co-benefits of implementing transport emission reduction actions in Christchurch. This study is being conducted by Rebecca Adolph from the University of Canterbury | Te Whare Wānanga o Waitaha and is supervised by Dr Lindsey Conrow. The study is being carried out as a requirement for Master of Urban Resilience and Renewal.

What is the purpose of this research?
This research aims to investigate the co-benefits of implementing transport emission reduction actions in Christchurch, with a particular focus on the impacts these actions have on social connectedness and wellbeing. The information from this study will help to show general individual wellbeing, people's current travel mode choices and their reasons for these, neighbourhood environments, and social connectedness within neighbourhoods in the Greater Christchurch area.

Why have you received this invitation?
You are invited to participate in this research because you live and travel in the Greater Christchurch area. Your participation is voluntary (your choice). If you decide not to participate, there are no consequences. Your decision will not affect your relationship with me, the University of Canterbury or any member of the research team.

What is involved in participating?
If you choose to take part in this research, please complete the online survey that follows this information page. The survey involves answering questions about your general individual wellbeing, how you choose to travel to and from your main daily destinations, your neighbourhood environment and how connected you feel to your neighbours. Completing the survey should take around 10 to 15 minutes.

Are there any potential benefits from taking part in this research?
We do not expect any direct benefits to you personally from completing this survey. However, the information gathered will potentially impact transport outcomes in Christchurch.

Are there any potential risks involved in this research?
Some questions ask you to consider sensitive or personal information about your general wellbeing. This may cause some participants to become upset or distressed. If you become upset or distressed we recommend you consider stopping the survey. You may also want to consider contacting the support agency listed below.
Support Agency: Lifeline Helpline
Contact Information: 0800 543 354 or text HELP to 4357

What if you change your mind during or after the study?
You are free to withdraw at any time. To do this, simply close your browser window or the application (App) the survey is presented on. Any information you have entered up to that point will be deleted from the data set. As this is an anonymous survey it will not be possible to withdraw your information after you have completed the survey.

What will happen to the information you provide?
All data will be anonymous. All data will be stored on the University of Canterbury's computer network in password-protected files. All data will be destroyed five years after completion of the study/publication of study findings. I will be responsible for making sure that only members of the research team use your data for the purposes mentioned in this information sheet.

Will the results of the study be published?
The results of this research will be published in a Master's dissertation. This dissertation will be available to the general public through the UC library. Results may be published in peer-reviewed, academic journals and conferences and/or in Council reports. You will not be identifiable in any publication. I will send a summary of the research to you at the end of the study, if you request this. If you provide an email address for this purpose, it will not be linked with your survey responses.

Who can I contact if I have any questions or concerns?
If you have any questions about the research, please contact: Rebecca Adolph: rja167@uclive.ac.nz or Dr Lindsey Conrow: lindsey.conrow@canterbury.ac.nz This study has been reviewed and approved by the University of Canterbury Human Research Ethics Committee (HREC).

If you have concerns or complaints about this research, please contact the Chair of the HREC at human-ethics@canterbury.ac.nz .

What happens next?
If you would like a PDF version of this information sheet, please email Rebecca Adolph at the email address above.

Please read the following statement of consent and start the survey below.

Statement of consent:
I have read the study information and understand what is involved in participating. By completing the survey and submitting my responses, I consent to participate.

End of Block: Information sheet

Start of Block: General wellbeing

To begin this survey, there will be four short questions about your general wellbeing. You do not have to answer these questions if you feel uncomfortable, just click 'next' to move on to the next question.

Overall, how satisfied are you with your life nowadays? (You do not have to answer if you feel uncomfortable).

○ 1 = extremely dissatisfied (1)

○ 2 = dissatisfied (2)

○ 3 = neither dissatisfied nor satisfied (3)

○ 4 = satisfied (4)

○ 5 = extremely satisfied (5)

Overall, how happy did you feel yesterday? (You do not have to answer if you feel uncomfortable).

○ 1 = extremely unhappy (1)

○ 2 = unhappy (2)

○ 3 = Neutral (3)

○ 4 = happy (4)

○ 5 = extremely happy (5)

Overall, how anxious did you feel yesterday? (You do not have to answer if you feel uncomfortable).

- 1 = not at all anxious (1)
- 2 = slightly anxious (2)
- 3 = neutral (3)
- 4 = anxious (4)
- 5 = extremely anxious (5)

Overall, to what extent do you feel the things you do in your life are worthwhile? (You do not have to answer if you feel uncomfortable).

- 1 = not at all worthwhile (1)
- 2 = mostly worthwhile (2)
- 3 = neutral (3)
- 4 = worthwhile (4)
- 5 = extremely worthwhile (5)

This next section asks about your usual mode of transport, your reason for this choice, and your commute experience.

What is your usual (i.e. most commonly used) mode of transport to your place of work or study or your main daily destination? If you take more than one mode, select the one you use to cover the most distance.

- ○ Private diesel/petrol car/truck (1)
- ○ Electric vehicle (2)
- ○ Company car/truck (3)
- ○ Bus (4)
- ○ Walk (5)
- ○ Bicycle (including electric bike) (6)
- ○ Scooter or electric scooter (7)
- ○ Motorcycle/moped (8)
- ○ Rideshare (9)
- ○ I usually work or study from home (10)
- ○ Other (please specify) (11) ____

What are your main reasons for using your chosen travel method? (Select all that apply)

- ▢ To visit shops etc. on the way to/from work/university (1)
- ▢ Use during the day to perform job (2)
- ▢ Use during day for non-work purposes (i.e. to visit doctor) (3)
- ▢ Personal security during journey (4)
- ▢ Because it is quicker (5)
- ▢ Because it is healthier (6)
- ▢ Dropping off and collecting children (7)
- ▢ Lack of viable alternative form of transport (8)
- ▢ Because it is cheaper (9)
- ▢ For environmental reasons (10)
- ▢ Because it is more comfortable (11)
- ▢ I travel in the same way as other people like me (12)
- ▢ Other (please specify) (13) ____

How long (in minutes) does it take, using usual mode of transport, to travel to/from your usual place of work, study or your main daily destination?

____

Page Break

Please list up to five key words or phrases that best describe your usual commute experience.

____

For short trips (under 2km), what is your main mode of transportation?

- ○ Private car/truck (non-electric) (1)
- ○ Electric vehicle (2)
- ○ Company car/truck (3)
- ○ Bus (4)
- ○ Walk (5)
- ○ Cycle (including e-bike) (6)
- ○ Scooter or e-scooter (7)
- ○ Motocycle/moped (8)
- ○ Rideshare (9)
- ○ Other (please specify) (10) ____

End of Block: Modal choice

Start of Block: Cycle to work

On average, do you cycle to your place of work, study, or main daily destination at least once a week?

- ○ Yes (1)
- ○ No (2)

What are some of the reasons you do not cycle to work/study/main daily destination at least once a week? Please tick all that apply:

- ☐ Absence of parking charges (ie I have a private car park or can easily get a car park without having to pay) (1)
- ☐ Insufficient bike storage facilities (2)
- ☐ Insufficient showering/changing facilities (3)
- ☐ Distance from work (i.e. too far to cycle) (4)
- ☐ I need a car/truck/van to do my job (i.e. tradesperson, professional driver, etc.) (5)
- ☐ I need to carry passengers (i.e. children or other dependents) (6)
- ☐ I need to carry shopping/other goods or equiptment (7)
- ☐ I need to make multiple stops along my commute (trip-chaining) (8)
- ☐ Insufficient cycle infrastructure for safety (i.e. lack of cycle lanes, separated cyleways) (9)
- ☐ Other safety concerns (e.g crime, harassment, lighting/visibility) (10)
- ☐ I view cycling as a fitness/sport activity and want to keep it seperate from my professional/day-to-day life (11)
- ☐ I don't feel like I'd enjoy recreational road cycling as much if I cycled every day (12)
- ☐ Other (please specify) (13) ____________________

What improvements to active transport modes (like walking and cycling) might encourage you to use it more frequently? (Select up to three)

- ☐ Security features (e.g. lighting, emergency call boxes, greater campus security presence, etc.) (1)
- ☐ Increased safety features (e.g. infrastructure such as pedestrian crossings, traffic calming, dedicated lanes, etc). (2)
- ☐ Subsidy to purchase a bicycle, skateboard, etc. (3)
- ☐ Better footpath and road conditions (4)
- ☐ Easier access to parking and storage facilities (5)
- ☐ More direct route (6)
- ☐ More destinations along the route (e.g. shops, cafes, dairies, parks, etc.) (7)
- ☐ Walking or cycling as part of a group (8)
- ☐ Less road lanes (i.e. two compared to three of four) (9)
- ☐ Slower traffic where I walk or cycle (10)
- ☐ Other (please specify) (11) ____

End of Block: Cycle to work

Start of Block: Public transport

On average, do you take the bus to your place of work, study or main daily destination at least once a week?

- ○ Yes (1)
- ○ No (2)

What are some of the reasons you do not take the bus more frequently? Please tick all that apply:

- ☐ Absence of parking charges (ie I have a private car park or can easily get a car park without having to pay) (1)
- ☐ I need a car/truck/van to do my job (i.e. tradesperson, professional driver, etc.) (2)
- ☐ I need to make multiple stops along my commute (trip-chaining) (3)
- ☐ Insufficient bus infrastructure (i.e. lack of bus shelters) (4)
- ☐ Other safety concerns (e.g crime, harassment) (5)
- ☐ Bus stops are too far to get to/from (6)
- ☐ Bus is too expensive (7)
- ☐ Bus is unreliable (8)
- ☐ Bus route is not direct/does not get me where I need to go (9)
- ☐ Buses are not frequent enough (10)
- ☐ Bus is too slow (11)
- ☐ Other (please specify) (12) ____

What improvements to public transport might encourage you to use it more frequently? (Select up to three)

- ☐ Fewer interchanges/more direct routes (1)
- ☐ Lower fares (2)
- ☐ Greater reliability (3)
- ☐ More frequent services (4)
- ☐ Overall journey time (5)
- ☐ Cleanliness (6)
- ☐ Comfort (7)
- ☐ Safety (at stops) (8)
- ☐ Luggage services (including animals) (9)
- ☐ Clean, dry, and safe bus shelters (10)
- ☐ Other (please specify) (11) ____

Which of the following PRACTICAL aspects of commuting are important to you? (Please tick up to three)

- ☐ Cost (1)
- ☐ Speed/travel time (2)
- ☐ Safety (3)
- ☐ Punctuality/timing (4)
- ☐ Being able to make multiple stops along a trip (trip chaining) (5)
- ☐ Freedom of movement (6)
- ☐ Physical activity (7)
- ☐ Other (please specify) (8) ____

Which of the following PERSONAL aspects of commuting are important to you? (Please tick up to three)

- [ ] Concerns about sustainability/environmental issues (1)
- [ ] Reflecting my identity (2)
- [ ] Time for exercise/physical activity (3)
- [ ] Engaging with technology/devices (4)
- [ ] Challenge or adventure/risk (5)
- [ ] Other (please specify) (6) ____

How often does your financial situation keep you from making a trip you need or want to make? (you do not need to answer this question if you feel uncomfortable).

- ○ Never (1)
- ○ Rarely (2)
- ○ Sometimes (3)
- ○ Often (4)
- ○ Always (5)
- ○ Prefer not to answer (6)

If you had more money available to you would your travel method change (you do not need to answer this question if you feel uncomfortable)

- ○ Yes (1)
- ○ No (2)
- ○ Prefer not to answer (3)

(If yes) What method would you use? (within reason)

- ◯ Car/ Van (driver) (non-electric) (1)
- ◯ Car/ Van (passenger) (non-electric) (2)
- ◯ Electric car (driver) (3)
- ◯ Electric car (passenger) (4)
- ◯ Bus (5)
- ◯ Cycle (non-electric) (6)
- ◯ E-bike (7)
- ◯ Walk (8)
- ◯ Motorbike/moped (9)
- ◯ Skateboard/blades/scooter (non-electric) (10)
- ◯ E-scooter/e-skateboard (11)
- ◯ At home/telecommute (12)
- ◯ Other (please specify) (13) ____

Why would you choose this travel mode?

- ◯ To visit shops etc. on the way to/from University/work (1)
- ◯ Use during day to preform job (2)
- ◯ Use during day for non-work purposes (i.e to visit doctor) (3)
- ◯ Personal security during journey (4)
- ◯ Because it is more luxurious (5)
- ◯ For environmental reasons (6)
- ◯ Because it is more comfortable (7)

◯ Other (please specify) (8)

____

This next section is about road pricing.

How much do you agree with the following statement:

I'd be more likely to cycle, walk or use public transport if I had to pay a direct fee for driving in certain areas (i.e., congestion charge or road toll).

◯ Strongly agree (1)

◯ Agree (2)

◯ Neither agree nor disagree (3)

◯ Disagree (4)

◯ Strongly disagree (5)

How much would you be willing to pay daily for driving in a congestion charging zone, before switching to another mode of transportation (i.e., cycling, walking, or public transport)?

◯ Less than $10 (1)

◯ Between $10 and $15 (2)

◯ Between $15 and $20 (3)

◯ Between $20 and $30 (4)

◯ A fee would not change how I choose to travel, no matter the cost (5)

This next section asks about your neighbourhood environment.

How much do you agree/disagree with the following statements:

My neighbourhood has been designed to prioritise walking and cycling.

- ◯ Strongly agree (1)
- ◯ Agree (2)
- ◯ Neither agree nor disagree (3)
- ◯ Disagree (4)
- ◯ Strongly disagree (5)

I have access to most of the amenities I need (i.e., supermarket, park, pharmacy) within a 5–10-minute walk or bike.

- ◯ Strongly agree (1)
- ◯ Agree (2)
- ◯ Neither disagree or agree (3)
- ◯ Disagree (4)
- ◯ Strongly disagree (5)

The amount of traffic in my neighbourhood keeps me from interacting with my neighbours.

- ◯ Strongly agree (1)
- ◯ Agree (2)
- ◯ Neither agree nor disagree (3)
- ◯ Disagree (4)
- ◯ Strongly disagree (5)

I feel safe (both from harassment/physical harm and from traffic-related injuries) walking or biking in my neighbourhood.

- Strongly agree (1)
- Agree (2)
- Neither agree nor disagree (3)
- Disagree (4)
- Strongly disagree (5)

The amount of traffic in my neighbourhood keeps me from walking, biking, or playing in my neighbourhood.

- Strongly agree (1)
- Agree (2)
- Neither agree nor disagree (3)
- Disagree (4)
- Strongly disagree (5)

How close is the nearest bus stop to your residence?

- Less than 0.5km (1)
- 0.5 to 1km (2)
- 1km to 1.5km (3)
- 1.5 to 2km (4)
- More than 2km (5)
- Unsure (6)

During peak hours, how much traffic is in your neighbourhood?

○ Very little (1)

○ Moderate amount (2)

○ A great deal (3)

Page Break

In up to five words or phrases, how would you describe your neighbourhood (physical environment and/or intrinsic values/community).

____

This next section is about your neighbourhood environment and children. If you do not have children living at home with you or that you look after regularly at your house, select 'no' and you will move onto the next set of questions.

Do you have children living in your home or do you regularly look after children in your home?

- ○ Yes (1)
- ○ No (2)
- ○ Prefer not to answer (3)

How safe is your neighbourhood for children (over the age of 10) to play without supervision?

- ○ very safe (1)
- ○ Safe (2)
- ○ Neither safe nor unsafe (3)
- ○ Unsafe (4)
- ○ Very unsafe (5)

Page Break

My neighbourhood would be safer for children to play outside if... (Select up to 2).

☐ There were fewer vehicles on the road (1)

☐ I trusted my neighbours more (2)

☐ Other children played in the street (3)

☐ Other (please specify) (4) ____

This next section is about neighbourhood social connectedness.

How much do you agree with the following statement? I feel close to my neighbours.

○ Strongly agree (1)

○ Somewhat agree (2)

○ Neither agree nor disagree (3)

○ Somewhat disagree (4)

○ Strongly disagree (5)

Page Break

Generally speaking, would you say that most people in your neighbourhood can be trusted. Please use the slider below to indicate from 0 to 10 your level of trust, where 0 means neighbours can not be trusted and 10 means neighbours can be trusted.

	0	1	2	3	4	5	6	7	8	9	10
Level of trust ()											

How frequently does your neighbourhood hold neighbourhood events?

- ◯ Weekly (1)
- ◯ Fortnightly (2)
- ◯ Monthly (3)
- ◯ 1-3 times a year (4)
- ◯ Never (5)

Suppose you felt down or a bit depressed and wanted to talk with someone about it. How easy or hard would it be to talk to someone in your neighbourhood?

- ◯ Very hard (1)
- ◯ Hard (2)
- ◯ Neither easy nor difficult (3)
- ◯ Easy (4)
- ◯ Very easy (5)

How often do you feel lonely?

- None of the time (1)
- A little of the time (2)
- Some of the time (3)
- Most of the time (4)
- All of the time (5)
- Prefer not to answer (6)

What is your main way of staying in contact with neighbours?

- I don't stay in contact with my neighbours (1)
- Talking in person (2)
- Video conversations (3)
- Telephone (4)
- Written communication (5)

In the last four weeks, how often have you been in contact (i.e., quick chat to a long catch up) with your neighbours?

- ◯ Every day (1)
- ◯ At least once a week (2)
- ◯ At least once a fortnight (3)
- ◯ At least once in the last four weeks (4)
- ◯ Not at all (5)

How satisfied are you with the amount of contact you have with your neighbours?

- ◯ Too much contact (1)
- ◯ About the right amount of contact (2)
- ◯ Not enough contact (3)

Are you involved in a neighbourhood/community association or group?

- ◯ Yes (1)
- ◯ No (2)

This last section is about demographics.

What gender do you identify with?

- ◯ Male (1)
- ◯ Female (2)
- ◯ Gender diverse (3)
- ◯ Unsure (4)
- ◯ Prefer not to say (5)
- ◯ Other (please specify) (6) ____

What ethnicity do you identify with?

- ◯ European/ Pākehā (1)
- ◯ Māori (2)
- ◯ Pacific peoples (3)
- ◯ Asian (4)
- ◯ MELAA (Middle Eastern/Latin American/African) (5)
- ◯ Prefer not to say (6)
- ◯ Other (please specify) (7) ____

What age are you?

- ◯ 18-24 years old (1)
- ◯ 25-34 years old (2)
- ◯ 35-44 years old (3)
- ◯ 45-54 years old (4)
- ◯ 55-64 years old (5)
- ◯ 65-74 years old (6)
- ◯ 75 years or older (7)
- ◯ Prefer not to answer (8)

What is your postcode?

____

What is your income per annum?

- ◯ Loss (1)
- ◯ Zero income (2)
- ◯ $1-$10,000 (3)
- ◯ $10,001-$20,000 (4)
- ◯ $20,001-$30,000 (5)
- ◯ $30,001-$40,000 (6)
- ◯ $40,001-$50,000 (7)
- ◯ $50,001-$70,000 (8)
- ◯ $70,001-$100,000 (9)
- ◯ $100,001-$150,000 (10)
- ◯ $150,001 or more (11)
- ◯ Don't know (12)
- ◯ Prefer not to anser (13)

What do you do at the moment?

- ◯ Full time education (student) (1)
- ◯ Part time education (less than 16 hours) (2)
- ◯ Apprenticeship (3)
- ◯ Working full time (4)
- ◯ Working part time (less than 16 hours) (5)
- ◯ Internship (6)
- ◯ Stay at home parent (7)
- ◯ Volunteering (8)
- ◯ Retired (9)
- ◯ Other (please specify) (10) ____