An exploration of the effects of roads and traffic on mental health in Auckland, New Zealand

A thesis submitted in fulfilment of the requirement for the Degree of

Masters of Science in Geography

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August 2016

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Acknowledgements

I would like to acknowledge and thank the following people who gave their time, advice and support through this research. I am extremely grateful for their invaluable contribution throughout my studies.

I would firstly like to thank the team of supervisors, Professor Simon Kingham, Dr Paul Beere and Dr Andrea Menclova, for their support and guidance. Thank you Simon for your enthusiasm, energy and big ideas, they have been a constant source of inspiration throughout my time at the University of Canterbury; Paul for your invaluable advice throughout, your GIS knowledge and general wizardry offered a path through what were at times daunting barriers; and Andrea for your kindness, patience and expert knowledge to guide me through the intricacies of the analysis.

I would like to thank Dr John McCarthy for all the time effort that went into collecting and creating the data that has made this research possible. Also to the Ministry of Health for their support of the GeoHealth Laboratory and this thesis.

Finally, I would like to thank my family and friends, for their endless support and healthy distractions.

Abstract

Mental illness is the third highest cause of poor health in New Zealand, accounting for 11% of the total burden of disease. Like many other chronic illnesses, associations between mental health outcomes and the built and social environment have been found. Roads and traffic have been associated with reduced mental wellbeing as they are a source of stress for individuals and are disruptive to daily activities; partially a result of the air and noise pollution produced.

The primary aim of this research was to investigate the relationship between exposure to traffic and mental health treatment in Auckland, New Zealand.

Measures of distance to motorways, road class metrics, traffic volume and traffic density were produced for all households in Auckland. Poor mental health for individuals was measured by cases of issued prescriptions for mood and anxiety disorders or use of addiction related services in a 12-month period, sourced from the Ministry of Health Programme for the Integration of Mental Health Data (PRIMHD). A random sample of Auckland address points were selected for comparison. Logistic regression was used to investigate possible associations. The social composition of neighbourhoods were considered as confounders, including income, deprivation and social capital indicators. The effect of green space was also investigated.

No detectable effect of traffic volume or traffic density on mental health was found. However, the volume of heavy commercial vehicles was associated with poor mental health, with a 3% increase in treatment for every 1000 vehicles on motorways within 100 metres of home address points. The neighbourhood has an important influence on mental health outcomes; deprivation and indicators of social capital are among the strongest predictors, but they also predicted exposure to traffic. Controlling for these confounders, the effect of heavy commercial vehicles on motorways decreased to 1% increase in treatment per 1000 vehicles.

This research provides a useful contribution to the literature investigating traffic and mental health due to the geographic scale at which it is performed, and the use of individual exposure and health measures.

Abbreviations

HCV	Heavy commercial vehicles
MoH	Ministry of Health
NZTA	New Zealand Transport Association
PRIMHD	Programme for the Integration of Mental Health Data
RC1	Road Class 1
RC2	Road Class 2
RC3	Road Class 3
VPD	Vehicles per day
WHO	World Health Organisation

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1. Introduction

1.1 Burden of disease

Mental illness refers to a range of chronic, subjectively unpleasant psychological conditions that range from mild symptoms to severe outcomes (Halpern, 1995). Currently, depression accounts for 4.3% of global burden of disease and one of the leading causes of disability worldwide (World Health Organization, 2013), while in New Zealand, depression is the third leading cause of health loss (Ministry of Health, 2013). 16.3% of the population have been diagnosed with common mental disorders such as depression, bipolar or anxiety disorders, and a further 6.1% are psychologically distressed (Ministry of Health, 2014a).

The incidence of mental illness treatment is increasing. Previous New Zealand research has found a 30% increase in prescription rates for medication of mental illnesses over a 3 year period from 2004, largely a result of better access to treatment (Exeter, Robinson, & Wheeler, 2009). Like many chronic illnesses, some groups are over-represented in the statistics. In New Zealand, those living in high deprivation areas, women, Māori and Pacific Islanders have high rates of mental distress (Ministry of Health, 2014a, 2014b). Although, treatment rates may not always reflect this pattern (Exeter et al., 2009).

1.2 Environment and health

An individual's environment and how they interact with it influences their health and well-being. With the increasing urbanisation of populations, understanding how the complex urban environment affects health, both negatively and positively is important. The environment can be understood to consider both the built physical components and the social, economic and cultural environment. Each of these elements has a variety of direct and indirect influences on health.

Transportation is a critical component of the urban environment; it dictates form and function of the city, and for residents, it influences their decisions of how to move through their environment and their ability to access resources such as employment, services and social networks. Some forms of transportation, such as motor vehicles, can have serious negative impacts on health through the production of physical and noise pollution, and disrupt daily activities.

The production and distribution of negative environmental externalities are not constant across an urban area. This spatial variation in environmental quality frequently corresponds with socio-economic patterns, resulting in compounded stress and risk where low socio-economic status and poor environmental quality intersect. For example, socio-economic position has been found to correspond with higher exposure to hazardous wastes and toxins, air pollution, noise pollution and have poorer water quality, housing quality, and neighbourhood conditions (G.Evans & Kantrowitz, 2002).

Understanding how the environment affects health, and where the groups at greatest risk are likely to be located, offers public health professionals and urban designers opportunities to target high-risk areas and develop healthier environments in the future.

1.3 Environment and mental health

As mental health diagnosis and treatment has developed, there has been increasing recognition of the effect that the social and built environment has on health and wellbeing. The key pathways in which mental health is affected by the environment is through stress, feelings of control and the influence that it has on individuals' social networks and support, each of which may be a result of direct or indirect characteristics of the environment (Halpern, 1995). For the most part, the environment is a source of chronic stress, opposed to discrete life events that are more commonly associated with individual mental health (Downey & Van Willigen, 2005).

With mental health, exposure may not always correspond directly to outcomes, as a substantial component of stress associated with the environment is mediated by the individual's perceptions and cognitive assessment of the exposure (Kruger, Reischl, & Gee, 2007). Perceptions of the environment vary by gender, age, ethnicity and socio-economic status. While this is difficult to account for in research design, it poses interesting design challenges and opportunities for interventions, as the reduction of the stressor may not be the most effective solution available.

1.4 Rationale for thesis

This study was influenced by recent research into resident's perceptions of air quality and experiences of living close to motorways in Auckland. Pattinson, Longley, & Kingham, (2015) found an inverse relationship between the distance of residence from motorways and their perceptions of the ill health effects of exposure. Interviews with residents recorded mostly negative attitudes towards the motorways, with strong responses heard from those with at-risk individuals in their households. Other research from Auckland supports these findings; quality of life has been found to be significantly lower for those living within 50 metres of motorways in Auckland compared to people living on a quiet streets (Welch, Shepherd, Dirks, McBride, & Marsh, 2013). At present, there is no New Zealand research which investigates whether there is a more serious mental health outcome of living in proximity to traffic.

There is a large body of international research that has documented negative psychosocial outcomes of living near busy roads, including annoyance, sub-optimal sleep, disrupted activity, reduced cognitive functioning and affected mood (Belojević, Jakovljević, & Aleksić, 1997; Dratva, Zemp, & Dietrich, 2010; Öhrström, 2004; Passchier-Vermeer & Passchier, 2000). Evidence of stronger effects such as prescriptions and diagnosis have been mixed (Belojević et al., 1997; Stansfeld, Gallacher, Babisch, & Shipley, 1996). This research has generally focussed on one component of traffic such as noise or physical pollution. Furthermore, it is often performed at a small spatial scale.

From a public health perspective, there is benefit in investigating the relationship between mental health and traffic in the New Zealand context. The different urban patterns, cultural attitudes to the environment, and mental health may result in a unique pattern of mental health compared to previous studies. Secondly, the literature review identified a lack of ecological level studies into the effects of traffic on mental health. This research will seek to address these two deficiencies.

1.5 Aims and objectives

The primary aim of this research is to investigate whether there is an association between exposure to traffic and treatment of mental health. As the research is novel in its approach, a secondary aim is to develop a large-scale traffic exposure methodology with the publicly available data.

The investigation into the relationship between traffic and mental health were guided by the following research questions:

I. Does proximity to motorways affect mental health treatment?
II. Does accessibility as a result of living near motorways affect mental health treatment?
III. Does traffic volume affect mental health treatment?

1.6 Outline of thesis

This thesis is organised into seven chapters. Chapter One has provided a broad overview of the topic, the rationale for this research, and outlines the aims and objectives.

Chapter Two contains a review of the literature on the effects associated with roads and traffic on mental health, while the literature review in Chapter Three outlines other common features of the neighbourhood, including green space, deprivation and social fragmentation that have been found to be influential to mental health.

Chapter Four is the methodology chapter. It provides information on the data used in this research, the development of exposure variables and confounders, and the analytical methods.

The outcomes of the analysis are presented in Chapter Five and critically discussed in relation to previous research in Chapter Six. Chapter Six also discusses the limitations of the research, the exposure methodology and implications of the research.

Chapter Seven will provide a conclusion to the thesis, outlining the key findings and implications of the research.

2. Literature review – Effect of roads on mental health

This chapter provides a framework and discussion of the pathways that the environment affects mental health, followed by an in-depth review of previous research into the relationship between roads, traffic and mental health.

2.1 A socio-ecological framework of health

With the realisation that directly treating each affected individual would not solve population-wide health problems, medical geography has increasingly broadened its focus to incorporate the socioecological framework of the determinants of health (Andrews, 1985). The socio-ecological framework considers not only the individual compositional characteristics of a person but also the contextual micro and macro social, cultural, economic and political environment that the individual is situated within (Stokols, 1996). It recognises that individuals are simultaneously affected by different levels of environment (Gifford, 2014). For example, an individual may have a low income and live in a poorly insulated house in a deprived neighbourhood. Each of these components have the potential to directly and indirectly affect the health outcomes of that individual.

The socio-ecological model provides a useful structure to understand and identify the complex relationships and interactions in which the environment influences mental health. Within the scope of the framework, academics have developed models to explain how particular facets of place and the neighbourhood affect mental health. In this case, the focus will primarily be roads and the relevant interactions and associations with health that are discussed in the literature. The Environmental Stress Model (Figure 1), developed by Wandersman and Nation (1998) provides a foundation to guide the literature review and research to understand the pathways that environmental stressor such as roads have on mental health. This model is not exhaustive; the socioecological model provides scope to seek and explain other facets of the environment that affect mental health, in particular, possible confounders.

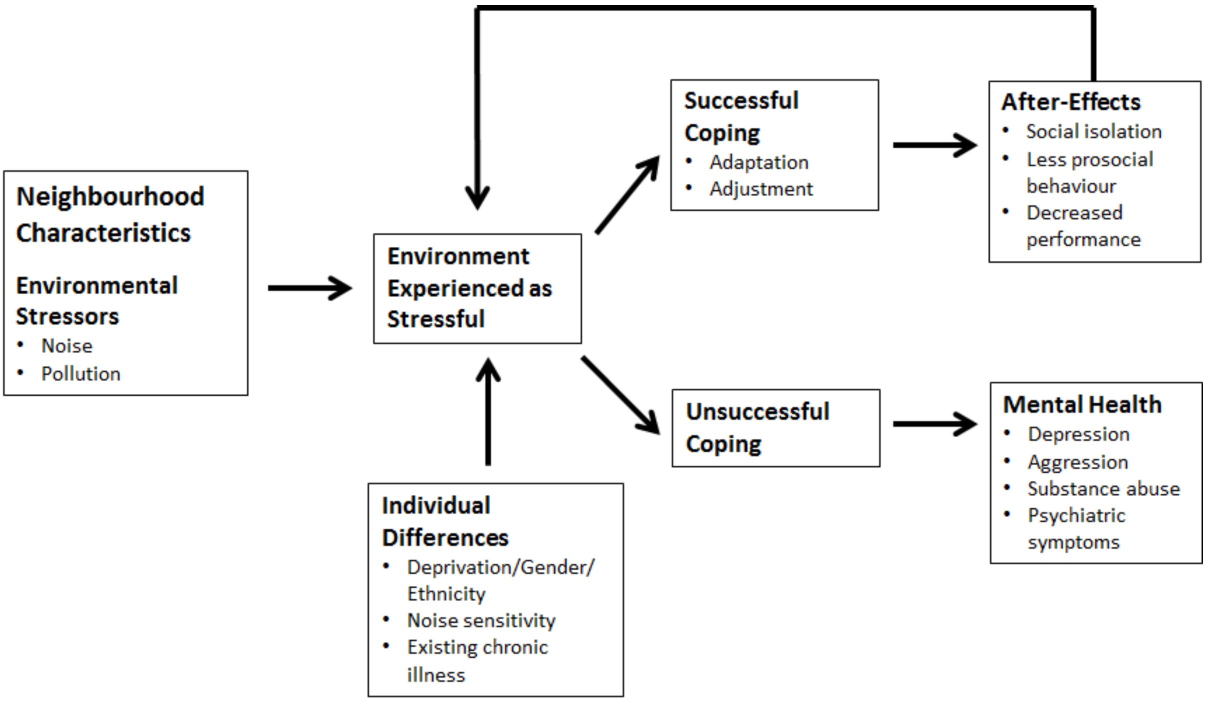

Figure 1 Environmental Stressors and Mental Health. Adapted from Wandersman & Nation (1998)

2.2 Pathways for how the environment can affect mental health

2.2.1 Stress

Traffic and the associated air and noise pollution may result in a 'stress' response from the individual. Stress is defined as a psychological or biological response to an environmental stimulus, which exceeds the normal adaptive capacity of the individual (Cohen, Kessler & Gordon, cited by Contrada & Baum, 2011). The environmental stimulus may include unwanted noise, perceived danger in the environment in the form of pollution or social disorder.

The effects of stress on the human body are extensive and varied (for an overview of stress, see Contrada & Baum, 2011). Extended periods of stress can lead to the exhaustion of compensatory mechanisms and decrease the body's regulatory capacity which may cause severe negative health outcomes in the medium term (Kaltenbach, Maschke, & Klinke, 2008). Furthermore, stress is known to exacerbate some forms of mental illness, in particular, affective disorders including depression and problems associated with substance abuse (Almog, Curtis, Copeland, & Congdon, 2004).

Stress is mediated and managed by individuals coping mechanisms, which impact behavioural and health responses (Lazarus, 1993). Coping mechanisms are influenced by perceptions of control, which are affected by a genetic and individual factors, in particular, socio-economic status (Taylor & Stanton, 2007). However, coping capacity can be reduced by exposure to chronic stressors, as they create a 'continuous overload condition' (G. Evans, Jacobs, Dooley, & Catalano, 1987).

2.2.2 Control and learned helplessness

A sense of powerlessness and/or lack of control of an individual's immediate environment is a major factor in adverse mental outcomes in a range of settings (Halpern, 1995). The perception of control is critical to mental well-being. People who have more subjective control in their lives report higher levels of happiness than those with less control (Larson 1989); however, it is not necessarily actual control, but the ability to distort reality into a sense of control (Taylor & Brown, 1988).

Control can reduce the effects of stress because control improves the predictability of the outcome and allows the individual to prepare for the situation and achieve better results overall. An individual in control will be confident that the situation will not become intolerable (Thompson & Spacapan, 1991). Feelings of control are particularly important for those groups who already have limited control over their environment, or are at special risk for negative outcomes from stressful experiences, such as the young, the old, individuals with low levels of income or education and the already ill (Thompson & Spacapan, 1991)

Control is relevant at a range of scales. For example, in response to traffic noise heard at home, an individual may feel in control if they have the resources to provide extra sound proofing to their home (Makri & Stilianakis, 2008). Lack of control can extend to the wider community, especially in the case of unsafe or socially undesirable neighbourhoods (Downey & Van Willigen, 2005). The feeling of the possibility of affecting decision making regarding local policy contributes as well, and a sense of powerlessness will be exacerbated if there are no results from efforts to make a change (Ross, Reynolds, & Geis, 2000).

2.2.3 Social capital

The leading scholar on social capital, Robert Putnam defines social capital as the 'networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit' (Putnam, 1995, p. 67). In particular, it is critical for the creation of community-level networks and organisations which produce benefits for the wider community (Putnam, Leonardi, & Nanetti, 1994). In this respect, social capital is a contextual feature of the neighbourhood rather than a quality associated with individuals. It is this contextual social capital has been found to be more important to health (Subramanian, Lochner, & Kawachi, 2003). There is an extensive range of literature exploring the types and nuances of social capital, for this thesis, Putnam's definition is used as it highlights the social trust and support facets which are beneficial to wellbeing.

Low levels of social support have been widely linked to poor mental health outcomes (P. Barnett & Gotlib, 1988; Kawachi & Berkman, 2001; Linden & Gunther, 2003). Social capital provides a sense of purpose, belonging and security, and promotes the spread of information and health promoting behaviours (Kawachi, 1999; Veenstra et al., 2005). During stressful situations, the perceived availability of functional social support offers a buffer from the effects of stress and enhances individuals coping abilities, just as realised social support during a stressful time can provide support that alleviates and individuals stress (Cohen & Wills, 1985).

Social capital may be affected by the presence of roads because people alter their behaviour and subsequently reduce contact with neighbours. Appleyard (1981) showed how a busy road acts as a barrier, limiting contact between two sides of the street reducing friendships in the street. Research has found that people prefer to exercise in pleasant environments, and the presence of possible pollution may result in people choosing to exercise elsewhere, reducing opportunities to develop social connections (Bresnahan, Dickie, & Gerking, 1997; Pattinson et al., 2015). Some also perceive traffic as a visible sign of disorder and an undesirable neighbourhood in which they do not wish to engage with (Ross & Mirowsky, 2001).

2.2.4 Double burden – Socioeconomic inequality and environmental inequality

The uneven distribution of the individual, community and environmental risks across society, often results in a double burden of personal situation risk such as low income, and environmental risk (Kingham, Pearce, & Zawar-Reza, 2007; Perlin, Wong, & Sexton, 2001). This double burden has been found across a range of negative environmental qualities (G. Evans & Kantrowitz, 2002), and a number of settings (O'Neill, Jerrett, Kawachi, & Levy, 2003).

Further compounding the risk for these groups ability to deal with stresses, are personal perceptions towards the environmental stimulus. Research has found that those with higher individual risks that have greater concern towards hazards, contributing further to inequalities. G. Evans (2003) found that individuals with poor mental health are more likely to rate their environment and abilities more negatively than others. An inverse relationship has been found between concern about air quality and socio-economic status, with the poorest having the greatest concern about pollution (Bickerstaff & Walker, 2001). This could be a result of the focus of public health research into factors that affect minority groups such as those with chronic illnesses (Bickerstaff & Walker, 2001), cultural attitudes towards the environment (Flynn, Slovic, & Mertz, 1994; Johnson, 2002), or lack of control (Thompson & Spacapan, 1991).

In conclusion, the literature indicates that the effects of environmental risk of living close to roads may differ across society, regardless of the quantity of direct exposure.

2.3 Features of roads that affect mental health

The increase in the use of the personal motor vehicle and the use of vehicles for the distribution of goods has resulted in increased road building. Auckland has been particularly prolific, following in the footsteps of US urban design principles (Mees & Dodson, 2006). The increase in roads and traffic have resulted in increased physical, visual and noise pollution which has a range of direct and indirect effects on well-being.

The anecdotal evidence from Auckland that has influenced this thesis suggests that residents who live beside busy motorways view it as a source of stress, while for others it provides benefits from the accessibility it offers (Pattinson et al., 2015). This supports earlier research by Welch et al. (2013), who found that living near motorways in Auckland reduced health-related quality of life across all four WHO domains (physical, psychological, social and environmental). People are more likely to be alerted to hazards in their environment when it is visible and tangible, and find the closest source of a hazard the most concerning (Bickerstaff & Walker, 2001). Therefore, roads, which are a central feature of the Auckland landscape, and the associated visible pollution cues of dust, noise, odour and irritation may be a substantial source of environmental stress for residents of Auckland. The actions taken to reduce exposure to noise or air pollution may indirectly affect physical and mental health, as they may aggravate existing conditions or incite new issues. For example reducing outdoor activities may reduce physical activity or social interactions, and sealing the home reduces ventilation and may increase the spread of airborne infections or the incidence of asthma (Morrell, Taylor, & Lyle, 1997).

2.3.1 Air pollution

Vehicle pollution, or mobile source pollution, is believed to be responsible for 70-80% of Auckland region's air pollution emissions (Auckland Council, 2012a). Traffic is responsible for the production of a number of pollutants, including particulate matter (PM10 and PM2.5), nitrous oxides (NO_x), benzene, carbon monoxide, and ozone. The harmful physical effects of these pollutants has been widely researched, and associations found to cancer, asthma and other respiratory illnesses, low birth weight and shorter gestation periods, coronary heart disease, stroke and autism (A. Barnett, Plonka, Seow, Wilson, & Hansen, 2011; Becerra, Wilhelm, Olsen, Cockburn, & Ritz, 2012; Carlsen et al., 2015; Hansell et al., 2014; Janssen et al., 2003; R. Pearson, Wachtel, & Ebi, 2000; Rose, Cowie, Gillett, & Marks, 2009).

The effects of physical pollution on psychosocial wellbeing are not as distinct as the effects on physical well-being. Concern about pollution is the most common pathway by which living in proximity to roadways affects mental health. There is substantial evidence to suggest that people are unhappy with poor air quality; people have rated air pollution as their biggest environmental concern (Paunović, Jakovljević, & Belojević, 2009), while good air quality has found to be a factor in residential satisfaction (Buys & Miller, 2012; Williams & Bird, 2003). Furthermore, surveys have linked air quality to annoyance. Over half of the respondents across 24 western European centres indicated that air pollution was an annoyance, and those exposed to high levels of traffic reported higher annoyance. Annoyance was further aggravated by heavy vehicle traffic (Jacquemin et al., 2007). These results have been replicated in a variety of locations and with a range of exposure measures (Forsber, Stjemberg, & Wall, 1997; Klæboe, Kolbenstvedt, Clench-Aas, & Bartonova, 2000; Llop et al., 2008).

Pattinson et al. (2015) found that all participants in an Auckland study believed that air pollution from the nearby motorway had an effect on health, with 14% of respondents reflecting on the adverse effects on a daily basis. In particular, studies find that there is a high level of concern if there are vulnerable family members in the household such as children with asthma or elderly people (Gallina & Williams, 2014; Klæboe et al., 2000; Pattinson et al., 2015). Perceptions and actual risks are often misaligned (Bickerstaff, 2004; Slovic, Fischhoff, & Lichenstein, 1979), people underestimate the effects of chronic hazards opposed to rare events that individuals 'dread' (Slovic et al., 1979). Whether or not the general public has an accurate understanding of the risk associated with air pollution is unclear. The general population have been found to have a good understanding of the effects and possible mechanisms which pollution affects physical well-being (Day, 2006; Pattinson et al., 2015), but they may not correctly estimate the magnitude of the risk.

The actual physical ill effects of pollution will also affect psychosocial well-being as there is high comorbidity between physical and mental health outcomes (Egede, 2007; Noël et al., 2004). Therefore, if living next to motorways results in, or exacerbates chronic ill health, such as asthma, this in turn, will affect psycho-social wellbeing (Öhrström, 1991). The evidence indicates living in proximity to busy roads has a greater impact on the already chronically ill (Bickerstaff & Walker, 2001). In a Dutch qualitative study, one participant recounted their change in perception following their development of a chronic respiratory illness, and acknowledged that their level of concern about their local environment had increased with their diagnosis (Hamersma, Arts, Tillema, & Heinen, 2015). The chronically ill are also more likely to alter their behaviour in response to environmental hazards (Lissåker, Talboot, Kan, & Xu, 2015), which may have further indirect consequences for mental health.

Effect of traffic pollution may not be proportional to exposure. Williams and Bird (2003) found that the public's perception of air quality was not a reliable indicator of actual levels. A study of annoyance found that the degree of annoyance was more closely linked to pollution levels at the municipality level rather than at the individual level (Llop et al., 2008). Research has found people are often unwilling to accept that their particular locality has poor environmental quality compared to other areas (Brody, Peck, & Wesley, 2004). Individual characteristics matter too; women are more likely to express annoyance than men (Jacquemin et al., 2007); older respondents are likely to perceive pollution to be worse (Brody et al., 2004), and cultural and ethnic groups may also respond differently. Ethnic minorities have been found to express more concern about the effects of pollution on health (Johnson, 2002; Macias, 2015), which is hypothesised to be a result of differing political and cultural values (Macias, 2015).

A literature review of the effect of industrial areas on mental health was performed as well, as many of the annoyances that are highlighted in the traffic literature are a feature of exposure to industrial activity. Dust, smell, noise and air pollution were common complaints and concerns (Howel, Moffatt, Prince, Bush, & Dunn, 2002). Several studies in a variety of locations have found evidence of the negative relationship between industry and mental health (Boardman et al., 2008; Chattopadhyay, Som, & Mukhopadhyay, 1995; Downey & Van Willigen, 2005; Marques & Lima, 2011). Many similar underlying pathways were identified, including stress, dissatisfaction with their neighbourhood and feelings of ineffectiveness regarding controlling their personal environments.

Air pollution and perceived air pollution may result in changes to human behaviours that may have flow on effects for mental health (G.Evans & Jacobs, 1981). Common behaviour changes that are reported include rearranging or limiting outdoor leisure activities, staying indoors, closing windows and using air conditioning (Bresnahan et al., 1997; Johnson, 2002; Lercher, Schnitzberger, & Kofler, 1995; Pattinson et al., 2015; Wells, Dearborn, & Jackson, 2012). These actions may limit social interactions with their neighbours thus reducing social capital and networks, or lessens the likelihood of exercise as there is increased financial and time costs required to avoid the hazard (Reichert, Barros, Domingues, & Hallal, 2007). However, behavioural changes do not appear to be common, or consistent, across the exposed population. A US study found that 10-15% of respondents reported changing activities as a result of air quality warnings, but individuals were more likely to change their behaviour if they perceived air quality to be poor, regardless of whether there was an alert or not (Semenza et al., 2008), similar results were reported by Wells et al. (2012). Some groups are more likely to change their activities than others, including individuals with hay fever, respiratory illnesses, those with higher educations (Bresnahan et al., 1997; Wells et al., 2012), and non-white groups in the US (Johnson, 2002).

2.3.2 Noise pollution

Noise, and particularly traffic noise, is becoming of increasing concern to policy makers. It is the primary cause of environmental nuisance in the World Health Organisation European zone (World Health Organisation, 2011). Noise is considered a nonspecific stressor that causes adverse health effects in the long term. Conservative estimates indicate that there is a loss of 1 - 1.6 million disability-adjusted life years (DALY) per year in western Europe from traffic in urban areas with populations greater than 50,000 (World Health Organisation, 2011). Noise has repeatedly been shown tobe detrimental to physical and mental health, with associations found in hypertension, ischemic heart disease, diabetes, reduced sleep quality, weight , annoyance, and cognitive functioning (Belojević et al., 1997; Dzhambov, 2015; Griefahn, Marks, & Robens, 2006; Kaltenbach et al., 2008; Öhrström, Hadzibajramovic, Holmes, & Svensson, 2006; Passchier-Vermeer & Passchier, 2000; Pirrera, Valck, & Cluydts, 2010). In a review of the literature Chu, Thorne, and Guite (2004) identified stimulus overload, sleep disruption, annoyance, stress and anxiety and a potential reduction in social interactions as the most significant psychosocial outcomes of exposure to noise.

Transportation is one of the primary sources of environmental noise in urban areas. Traffic noise is the product of the vibration of the vehicles mechanical system, the tire-road surface contact and aerodynamic noise, all of which are affected by the vehicle type and speed of travel, and the type and quality of road that they are travelling on (Shu, Yang, & Zhu, 2014). Noise is objectively and subjectively quantifiable. The objective measure of noise is decibels (dB), however as humans are not able to hear sound across the frequency, the sound level which humans can hear is weighted (dB(A)) (Passchier-Vermeer & Passchier, 2000). Noise may also be expressed as an average over time, often as day-night level, annual or over the work day (Passchier-Vermeer & Passchier, 2000). A literature review by Kaltenbach et al. (2008) determined an appropriate outdoor noise limit for air traffic to be 60dB(A) during the day and 50db(A) at night based on the effect of health, but recommend levels of 55db(A) during the day and 45db(A) at night in order to protect the more sensitive groups in an areas such as children, older people and the chronically ill.

Noise level is reflected in residential satisfaction; people living in high traffic volume areas (34 000 vehicles per day, 10% of which were heavy vehicles) had lived in the area on average 7.6 years fewer than their counterparts in a quiet area and 23% indicated that they wanted to move away (Öhrström, 1991). This is also reflected in house prices; a Dutch study found that traffic noise above 65 dB has an effect on house prices, whereas house prices with a noise level of less than 40 dB will receive a premium price (Theebe, 2004).However, this may underestimate the effect of noise, as (Hamersma, Heinen, Tillema, & Arts, 2015) found that people did not anticipate the effect that noise would have on them before moving to a noisy area. Noise levels also affect individuals perceptions to other aspects of traffic; people in higher noise areas find pollution from traffic more annoying (Klæboe et al., 2000).

The effect of noise on psychosocial wellbeing is more ambiguous than that of the physical effects. Interest in the impact of noise on mental health gathered momentum with the finding that psychiatric admissions increased in areas that were exposed to noise from Heathrow Airport (Abbey-Wickrama et al., 1969 cited by (Öhrström, 1991).The results from the Heathrow study were not able to be replicated, however, Gattony and Tarnopolsky (1973 cited by Öhrström, 1991) found a relationship between annoyance caused by noise and psychiatric symptoms. Aircraft noise has since been the focus of a number of studies, as it is rated as the most annoying source of noise (Miedema & Vos, 1999). Aircraft noise has been linked to an increase in admittances to psychiatric care and increased prescription of medication relating to anxiety and depression, although results have not been consistent (Morrell et al., 1997).

Similarly, uncertain results have been found in association with noise from roads. Dratva et al. (2010) found a weak association between traffic noise exposure and mental health. A five-year follow-up of Welsh men compared to traffic noise maps found no dose-response relationship between noise and psychiatric outcomes, although some differences between anxiety and depression were recorded between areas with varying levels of sound (Stansfeld et al., 1996). Öhrström (2004) found those living closer to high concentrations of road traffic had increased symptoms such as tiredness, headaches, and affected mood. Similarly, individuals in noisy areas were more likely to report fatigue, depression, nervousness and headaches, and worse interpersonal relationships, but there were no significant difference in use of sedatives, intensity of headaches or seeking of psychiatrists help (Belojević et al., 1997). These findings have been replicated in a number of international contexts (Basner et al., 2014; Ouis, 1999; Yoshida et al., 1997).

Annoyance is a common outcome investigated in the literature. Noise annoyance is described as a feeling of resentment, displeasure, discomfort, dissatisfaction or offence when noise interferes with one's thoughts, feelings or activities (Dratva et al., 2010; Passchier-Vermeer & Passchier, 2000). Noise annoyance is a result of the individual's negative feelings towards the noise source, or if the noise is disruptive or interfering with intended activities (Hoeger, Schreckenberg, Felscher-Suhr, & Griefahn, 2002). Annoyance may be linked to mental health outcomes if annoyance is a result of sleep disturbance as it affects the body's ability to recover, or contributes to general stress (Rylander & Dunt, 1991). As noise annoyance is related to physiological symptoms of stress and arousal, objective technical measures of noise may not be an applicable measure (Lima & Marques, 2005), although a dose-response relationship between sound level and general annoyance has been found (Öhrström, Skånberg, Svensson, & Gidlöf-Gunnarsson, 2006). Research investigating the effect of noise annoyance, opposed to noise level has found significant relationships to physical and psychosocial outcomes (Öhrström, 2004). Noise annoyance has been found to be related to more time spent at home during the day, which may be due to unemployment or retirement. In turn, this may indicate a decrease in the ability to control their surroundings and, therefore, provoke negative emotions and perceptions towards their environment (Paunović et al., 2009). The level of noise annoyance is related to the source of the noise, Hoeger et al. (2002). found that the level of noise annoyance was high when the source was heavy vehicles and public transport at night, this was replicated by Paunović et al. (2009)

Noise sensitivity is the strongest predictor of noise annoyance (Paunović et al., 2009). Noise sensitivity is defined as a factor involving underlying attitudes towards noise in general and is an inherent personality trait (Belojević et al., 1997). It is not related to living in areas of high noise but it does affect the rate of noise annoyance (Paunović et al., 2009; Welch et al., 2013). Noise sensitive individuals are more likely to "attend to sound" and view it negatively and are more likely to have stronger emotional reactions to the noise and, therefore, find it harder to habituate (Stansfeld, 1992 cited by (Welch et al., 2013).

There have been suggestions that the sensitivity to noise does not moderate the effects of noise annoyance, but it is linked to the susceptibility to health problems and annoyance in general, as correlations have been found between neuroticism, subjective noise sensitivity and sleep disorders and psychological disturbances (Belojević et al., 1997). However, an Auckland study that sampled two populations, one beside a motorway and a second in a quiet area concluded that noise sensitivity was a moderating factor on the effect that noise had on quality of life (Welch et al., 2013).

Environmental characteristics can influence actual and perceived levels of noise. Housing features can make a difference in moderate noise areas. Wei et al. (2012) found that having a quiet side of the house was important, as is the location and orientation of living areas and bedrooms (Bluhm, Nordling, & Berglind, 2004; Paunović et al., 2009), while the presence of greenery has been found to reduce the effect of noise annoyance (Dzhambov & Dimitrova, 2015a; Gidlöf-Gunnarsson & Öhrström, 2007; Li, Chau, & Tang, 2010). However, regarding green space, the accessibility of it has been debated, as Li et al. (2010) found that accessibility is not important, while Gidlöf-Gunnarsson & Öhrström, (2007) found it to be significant. If an individual can physically see the source of the noise pollution, it has a significant effect on the degree of noise annoyance (Bangjun, Lili, & Guoqing, 2003). Therefore barriers which are made of solid materials such as concrete and timber have a greater perceived effect (Joynt & Kang, 2010). Although these barriers in turn may cause dissatisfaction due to poor aesthetics or loss of sunlight (Arenas, 2008).

A longstanding critique of the noise and mental health literature has been the lack of dose-response relationship between exposure and poor health outcomes (Stansfeld et al., 1996). In a laboratory study of sleep, Rylander and Dunt (1991) found the number of noise events had a better dose-response relationship than the noise level, although laboratory studies are difficult to draw conclusions from due to the lack of habituation. Some studies have found evidence of a ‘break point’ at certain noise level or number of vehicles per day which result in a ‘peak’ in outcomes (Dratva et al., 2010; Rylander & Dunt, 1991). Although in the case of noise level in Dratva et al's (2010) study, the breakpoint differed for different health outcomes and by gender. The strong role that individual perceptions and the differences in the wider noise environment have may be effective at masking, or be responsible for the lack of dose-response relationships.

2.3.3 Other factors

A small number of studies considered traffic density, or traffic stress, as a standalone stressor rather than investigating the effects of a specific stressor such as noise. Gundersen, Magerøy, Moen, & Bråtveit, (2013) used traffic volume to assign classifications of densities to areas and investigated the association to physical and mental health-related quality of life (HRQoL), finding significant differences between physical HRQoL for women, but no associations for men or mental HRQoL. Song, Gee, Fan, & Takeuchi (2007) found that individuals who rated traffic stress in their environment higher showed greater depressive symptoms when they were in a neighbourhood with greater traffic burden or in a neighbourhood with major streets. Having more green space, however, dampened this relationship. This was similar to earlier findings between higher traffic stress, low health status and high depressive symptoms (Gee & Takeuchi, 2004). Finally, using both objectively measured noise and air pollution levels and subjective sensitivity, von Lindern, Hartig, &

Lercher (2016) suggest that higher exposure limited the restorative qualities of a residential area which contributed to the negative effects on self-perceived health and satisfaction.

The accessibility that roads offer individuals was not found to have much focus linking them to mental health in the literature; although there are several indirect components that are worth mentioning. In their investigation of residents perceptions of motorways in Auckland, Pattinson, et al. (2015) noted that some respondents viewed the motorways in a positive light, as it reduced commute times. Similar feelings were expressed in a study of neighbourhood social cohesion in Massey, Auckland. Respondents viewed the motorway positively, as it reduced commuting time, therefore, it allowed individuals to live in a neighbourhood that met their desires without compromising their ability to work (Witten, McCreanor, & Kearns, 2003). Hamersma, Tillema, Sussman & Arts (2013) found that residential satisfaction from living near highways in the Netherlands was for the most part high, but satisfaction was reduced if the individual did not report using it regularly. In a city such as Auckland where personal vehicles are the predominant transport method (Mees & Dodson, 2006), the value of accessibility due to roads may not be equally available across the population, a possible cause of future disparities.

Similarly, the disruptive effect that roads have on the use of public space and the possible relationship to health is limited. Roads are a public space, and the area alongside the vehicle throughway can provide a space for social and recreational activity which is important for well-being. Jane Jacobs (1961) work, *The Death and Life of Great American Cities*, initiated the interest in the area with her observations of the importance of the social networks to the functioning and safety of a community. A busy road acts as a barrier between two sides of the street, limiting contact between neighbours. Appleyard (1981) found this to be the case in an observational study of three San Francisco streets, where those living on quiet streets had more close friends and more acquaintances than those living on roads with moderate and high traffic levels. Previous research cited here suggests that people are likely to spend less time outdoors, or alter intended behaviours (Bresnahan et al., 1997; Semenza et al., 2008; Wells et al., 2012). If people spend less time outdoors and exercise outside of their neighbourhood, they will not form the networks within their area which promote healthy communities. This is particularly relevant to exercise, as people prefer to exercise in nice environments and safety is a significant consideration (G.Evans, 2009). Traffic volume is a significant component of this, for example (Tranter & Pawson, 2001) found that higher traffic volumes were associated with low levels of childhood freedom, including play opportunities and the ability to travel alone.

2.4 Conclusion

Roads and traffic are disruptive to daily life, interrupting or reducing the quality of sleep, social interactions and exercise, among other activities. However, in contrast to the more direct dose-response type exposure outcomes of the effects of exposure to pollutants on physical health, an individual's response to environmental factors is influenced by genetics, family influences, peer group, community and the wider economic and political environment (Rutter, 2005).

3. Other impacts of the urban environment on mental health

This chapter discusses a range of neighbourhood factors that have been found to affect mental health and individual level factors that are associated with the prevalence of mental illness and likelihood to seek treatment.

3.1 The neighbourhood

The social processes within, and collective character of neighbourhoods has a major role on many desirable influences and effects for health (Sampson, 2003). The factors that affect mental health are varied, and there are numerous interactions and pathways between them (Sugiyama, Leslie, Giles-Corti, & Owen, 2008).

3.1.1 Income effects

The levels of income in a neighbourhood are believed to have independent effects on health over and above the absolute level of income of an individual or household. Table 1 shows a brief summary of the variety of effects that have been considered in the literature. Individual income is more proximal, and therefore has greater impact than the community level income hypothesis, but there is evidence linking the other mechanisms described to poor health outcomes (Subramanian, Delgado, Jadue, Vega, & Kawachi, 2003).

The community income hypothesis is more commonly described as areas of deprivation. Deprivation is the relative disadvantage of an individual, family or community compared to the wider society (Townsend, 1987 cited by J. Atkinson, Salmond, & Crampton, 2014). Living in deprived areas can be bad for personal health outcomes as populations in poor areas are affected by the harmful conditions in their wider community (Almog et al., 2004; R. Atkinson & Kintrea, 2001; Sloggett & Joshi, 1994; Stafford & Marmot, 2003). High deprivation areas face greater problems in their neighbourhood such as crime, traffic safety, pollution and litter and exacerbates the effects of other life stressors (Stafford & Marmot, 2003). Epidemiology and health research has widely accepted the influence of neighbourhood deprivation.

Table 1 Income effects on health

Hypothesis	Outcomes
Absolute income hypothesis	Self-rated health improves with increase in household incomes
Community contingent individual absolute income hypothesis	The relation between household income and self-rated health varies across communities
Community absolute income hypothesis	Self-rated health improves as the community in which the individual lives becomes richer
Community income inequality hypothesis	Self-rated health deteriorates as the community in which the individual lives becomes more unequal
Individual community interaction hypothesis	Cross-level integration between community income inequality and household income, the most adverse effect of income inequality is on poor individuals while it may not have any impact on rich individuals

(Subramanian, Delgado, et al., 2003)

Income inequality has been of interest since the late 1990s. Income inequality refers to how the distribution of income in society over and above individual or household income has a further detrimental effect on the physical and mental wellbeing of individuals within a society (Subramanian, Delgado, et al., 2003). It is believed to reduce social cohesion which in turn leads to social isolation and stress which have been linked to poor health outcomes (Kawachi & Kennedy, 1997a). Wider structural factors such as reduced investment in human and social capital through welfare and health care expenditure have also been identified (Kaplan, Pamuk, Lynch, Cohen, & Balfour, 1996). There is some evidence that income inequality has a detrimental effect on mental health, although findings are mixed. (Subramanian, Delgado, et al., 2003) found a negative effect on health of living in a community with high income inequality, over and above the effect of individual incomes. Kahn, Wise, Kennedy, and Kawachi (2000) found that low-income women in high-income inequality US states had a higher risk of depressive symptoms than their counterparts in low income inequality states. In contrast Stockdale et al. (2007), also in the US, did not find any contextual evidence of deprivation over and above the individual effect. In an alternative spatial approach to the relative income hypothesis, A. Pearson, Griffin, Davies, and Kingham (2013) looked at isolation by relative income in New Zealand. They found that living in a low socio-economic meshblock surrounded by high socio-economic meshblocks was associated with higher rates of anxiety and mood disorders. Research from the UK has found similar, but the effect of being poor and living in an area of concentrated poverty is worse than being poor and living in a socially mixed environment (R. Atkinson & Kintrea, 2001).

3.1.2 Social capital and fragmentation

As described in Section 2.2.3, social capital within the neighbourhood has an important effect on mental wellbeing, through the sense of purpose it provides, the sharing of resources and information and the perceived and functional support it offers (Cohen & Wills, 1985, Kawachi, 1999, Veenstra et al., 2005). Sampson (2012, cited by Barton & Gibbons, 2015) describes neighbourhoods as 'containers of social mobility', as the social resources of the neighbourhood affect the outcomes of individuals within the neighbourhood.

Social capital requires individuals in a neighbourhood to form strong connections with their neighbours, therefore is influenced by their ability to connect and their motivations to connect. Education has the strongest correlation with trust in society and civic engagement (Putnam, 1995). Education provides individuals with common knowledge which facilitates interactions, and teaches cooperation and social norms (Newton, 1997). The proportion of home ownership is also highly correlated with social capital measures, as homeowners have a greater incentive to invest in a community, as better neighbourhoods increase the value of their home, and they have much higher relocation costs relative to non-homeowners (Glaeser & DiPasquale, 1998). Residential stability is another strong predictor, as time is required for residents to form strong connections with neighbours, while residential instability is disruptive to the wider social network (McCullock, 2003). Ethnic fragmentation is believed to reduce social capital as individuals in areas of high ethnic diversity retreat socially (Putnam, 2007). Ethnic fragmentation is particularly important to minorities, as high levels of dispersion may lead to isolation from cultural specific resources and networks (Whitley, Prince, McKenzie, & Stewart, 2006)

Social capital is believed to be a central mechanism for the effects of that income inequality has on health, over and above the effects of absolute income differences, as it may increase social isolation (Kahn et al., 2000; Kaplan et al., 1996). This theory has empirical support; (Kawachi, Kennedy, Lochner, & Prothrow-Stith, 1997) have found that inequality correlated with reduced social trust and, group membership, which also correlated with mortality.

An alternative approach to considering the social fabric of a neighbourhood is through the lens of social fragmentation. Social fragmentation is described as the 'social organisation or structure of a neighbourhood' that influences the social connections in a neighbourhood, measured through the use of composite indexes (Ivory, 2008). Areas with high fragmentation are characterised by low levels of volunteering, socialising and trust in others (Attwood, Singh, Prime, & Creasey, 2003). Similar to social capital, factors that are believed to describe a socially fragmented neighbourhood include high population turnover, low home ownership, non-family households and high levels of native language speakers (Congdon, 1996; Ivory, 2008). Social fragmentation research has found association with suicide, psychosis, and psychiatric admissions (Allardyce et al., 2005; Almog et al., 2004; Congdon, 1996; J. Evans, Middleton, & Gunnell, 2004; Middleton et al., 2004). In New Zealand, social fragmentation has been associated with depression (A. Pearson, Ivory, Breetzke, & Lovasi, 2014) and poorer self-rated mental health (Ivory, Collings, Blakely, & Dew, 2011).

3.1.3 Neighbourhood disorder

Neighbourhood disorder has been found to have an adverse impact on physical and psychological health. Neighbourhood disorder has been described as inappropriate standards and behaviours that would be expected in public space (Skogan 1990 cited by Wandersman & Nation, 1998). Neighbourhood disorder is commonly categorised as a chronic stressor (Hill, Ross, & Angel, 2005; Ross & Mirowsky, 2001; Stockdale et al., 2007). There have been some suggestions that it has a role in reducing health promoting behaviours (Stockdale et al., 2007), although, this has not been found in all studies (Ross & Mirowsky, 2001). In general, neighbourhood disorder greatly affects residential satisfaction (Cook, 1988; Howley, Scott, & Redmond, 2009; Parkes, Kearns, & Atkinson, 2002). Components of neighbourhood disorder that have been commonly investigated include crime, litter, vandalism, and vacant buildings (Hill et al., 2005; Latkin & Curry, 2003; Ross & Mirowsky, 2001; Ross, 2000; Stafford, Chandola, & Marmot, 2007; Stockdale et al., 2007).

Neighbourhood disorder is strongly linked to social capital and deprivation (Kawachi, Kennedy, & Wilkinson, 1999; Ross, 2000). Neighbourhood disorder also limits support from those outside the neighbourhood, as friends and family may be reluctant to visit those in areas that are perceived to be unsafe (Cattell, 2001). Once again, those more socially deprived are faced with a double burden, as crime is perceived to be more of a threat for those in lower socio-economic areas compared to those with similar crime levels in higher socio-economic areas (Parkes et al., 2002). There is a reciprocal relationship between neighbourhood disorder and social capital; social capital promotes organisations and networks which deter antisocial behaviour, while the presence of neighbourhood disorder results in reduced participation in these activities by residents (Kawachi et al., 1999; Saegert & Winkel, 2004).

3.2 Green space

In addition to affecting the perception of noise (see Section 2.3.2 Noise pollution), green space, has been found to affect mental health outcomes. Green space is defined as any areas of natural, semi-natural, or artificial ecological systems in urban environment (Tzoulas et al., 2007). Green spaces are locations that provide an aesthetic place for social and recreational opportunities, that facilitate and encourages physical activity, enhances social ties and promotes mental and physical recuperation (X. Zhou & Parves Rana, 2012).

Research into the effects of green space on mental health outcomes has found evidence of an association. In a US study, mental health was the best for those who lived within 400m from a park and decreased significantly as people lived further away (Sturm & Cohen, 2014). The perception of greenness in the neighbourhood has been found to be significant, with individuals who believed that their neighbourhood had a high level of greenness were almost twice as likely to report reduced mental health based on the short form health survey than those who believed that there was little greenness in their neighbourhood (Sugiyama et al., 2008). A cross-sectional study of populations of cities in England that were in closer proximity to the coast had better health outcomes that those further away (Wheeler, White, Stahl-Timmins, & Depledge, 2012). However, White, Alcock, Wheeler, and Depledge, (2013) developed this research using individual-level data, finding that socio-economic status, ethnicity and personality attributes reduced the association significantly, although, the authors still found a very small association, which may be important at a public health level. In New Zealand, Nutsford, Pearson, and Kingham (2013) found that anxiety and mood disorder treatment is associated to the proportion of useable and total green space within 3km of the home, and the distance to nearest useable green space. Furthermore, Richardson, Pearce, Mitchell, and Kingham (2013) found a dose-response relationship between greener areas and lower risks for mental health across urban New Zealand.

3.3 Individual level factors

Individual compositional factors are important as there are differing baseline prevalences across groups, as well as the likelihood to seek help. As mentioned in the literature review of roads, some studies have found that the perceptions towards the environmental hazards associated with roads differ, as do risk factors across a population.

3.3.1 Age

Findings on the prevalence by age vary across the research. Many studies find that mental well-being decreases with age (Borson, Bartels, Colenda, Gottlieb, & Meyers, 2001; Choi & Gonzalez, 2005; Jones, Heim, Hunter, & Ellaway, 2014), although some have found the opposite (Ziersch, 2005). According to the New Zealand Health Survey (NZHS), the highest lifetime prevalence is the 45-55 age group in New Zealand for mood and anxiety disorders, with the 15-24 age group and 75+ having the lowest levels (Ministry of Health, 2014a).[1]

Age is believed to be associated with worse mental health outcomes as they have more medical problems (Borson et al., 2001) and more susceptible to physiological and psychosocial stressors (Borson et al., 2001; Perlin et al., 2001). Old age may correspond to shrinking social networks (Choi & Gonzalez, 2005). Some studies have found that treatment rates for older groups are lower (Conner et al., 2010; Mackenzie, Scott, Mather, & Sareen, 2008). However the reasons suggested for this reduced uptake has differed; Conner et al., (2010) found it be a result of reluctance due to stigma which is supported by Diala et al., (2000), while Mackenzie et al., (2008) found it to be a result of older people seeking care from their primary physician which is not accounted for in many North American studies.

Age also has a significant influence on how air pollution affects an individual. For example, elderly and children are more susceptible to adverse outcomes as a result of pollution exposure; children are also likely to have higher exposure due to more time (Makri & Stilianakis, 2008). However, this stress often falls on other members of the household such as caregivers (Gallina & Williams, 2014; Klæboe et al., 2000; Pattinson et al., 2015).

3.3.2 Gender

Treatment seeking behaviours differ by gender; women are more likely to be open to seeking advice and help which results in the higher levels of positive attitudes towards mental health services compared to men (Mackenzie, Gekoski, & Knox, 2006). However, older men have more positive attitudes towards seeking psychological help than younger men, which may be due to the reduced importance placed on 'masculinity ideology' at this life stage (Berger & Levant, 2005).

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[1] NZ Health prevalence figures are taken from 2013/2014 New Zealand Health survey to correspond with data used for this research. The New Zealand Health Survey measures psychological distress using the Kessler Scale.

These trends are reflected in New Zealand prevalence rates; women are more than 40% more likely than men to have been diagnosed with a mood or anxiety disorder and are 30% more likely to have experienced psychological distress (Ministry of Health, 2014a).

Women are more likely to have stronger attitudes towards environmental hazards as well. Women have higher levels of psychological distress in relation to proximity to industrial areas than men (Boardman et al., 2008), and the breakpoint for noise sensitivity, and likelihood to express annoyance were lower for women (Dratva et al., 2010; Jacquemin et al., 2007).

3.3.3 Ethnicity

In New Zealand, Asian and Pacific peoples have the lowest prevalence of diagnosed mood disorders, yet the rate of psychological distress is twice that of non-Pacific population. Māori also had higher prevalence rates of psychological distress (Ministry of Health, 2014a). Despite low treatment rates compared to psychological distress, Māori are over-represented in severe mental health outcomes reporting including under care of the Mental Health Act and in seclusion figures (Ministry of Health, 2014b). These differences may be the result of cultural factors and discrimination from health institutions and the wider community.

The disparity between diagnosis and prevalence of psychological distress amongst minority groups has been focus of research in international settings. There is debate regarding whether the low treatment of depression is a factor of lower incidence, or lower reporting as a result of a series of complex cultural characteristics (Chan & Parker, 2004). Non-dominant groups often prefer traditional methods, self-help and mutual support systems (Page & Blau, 2006). While Conner et al (2010) found that attitudes to treatment seeking differed across ethnicities, as the majority (80.5%) of white individuals reported feeling comfortable visiting a mental health practitioner of a different ethnicity, compared to half (56.6%) of African Americans. In the UK, religion rather than ethnic origin has been found to be the most important factor affecting attitudes to treatment, with those with no religious beliefs the most positive (Sheikh & Furnham, 2000).

In New Zealand, Māori, Pacific and Asian people report higher rates of discrimination in healthcare than people who identify as European or Other (Harris, Tobias, & Jeffreys, 2006). Experiences of discrimination affect usage of health services. Language is a driver as well, individuals who felt discriminated against based on language are more likely to use informal services or seeking help from family and friends rather than engaging with the health services (Spencer & Chen, 2004). There is a relationship between experiencing racism and lower self-rated physical and mental health (Harris et al., 2006; Mays & Cochran, 2001).

Overall, Māori are ten times more likely to report experiencing racism than Europeans in New Zealand, which is strongly associated with poor health, even after controlling for socio-economic factors (Harris et al., 2006).

Some differences have been reported in the literature about how attitudes regarding the effect of pollution on health by ethnicity. Flynn et al. (1994) and Johnson (2002) have found that white men perceive environmental risks much smaller than their female counterparts and non-whites; suggesting that it is their socio-economic and political orientation that influences perceptions of risk.

3.3.4 Socio-economic determinants

The most deprived in New Zealand are more likely to have been diagnosed with a mood or anxiety disorder, and even more likely to be psychologically distressed (Ministry of Health, 2014a), unsurprising given that people in more deprived areas have significantly higher levels of all health risks (Ministry of Health, 2014a).

Low-income individuals have additional risk and they have reduced capacity to minimise exposure, in the case of noise through double glazing or insulation, or the subsequent health outcomes (Makri & Stilianakis, 2008). Furthermore, there is an inverse relationship between concern about air quality and socio-economic status, as the poorest in society have been found to have the greatest concern about pollution (Bickerstaff & Walker, 2001)

4. Methodology

4.1 Study area

This study was conducted in Auckland City, New Zealand (Figure 2). Auckland is located on an isthmus in the northern North Island, with the natural harbours of Manukau Harbour and the Hauraki Gulf to the west and north respectively[2]. It is New Zealand's most populous city, accounting for 33.4% of the New Zealand population (Statistics New Zealand, 2013).

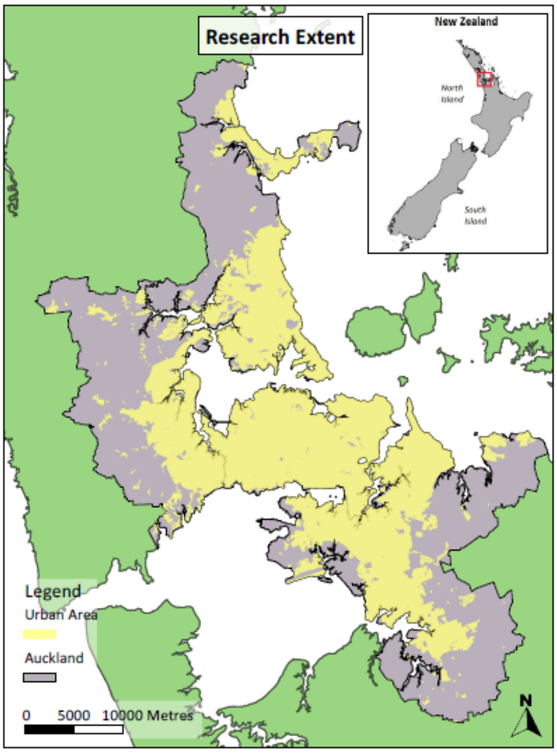


Figure 2 Research Extent

Auckland is among the most car-dependent cities in the world; it has traditionally taken a pro-automobile planning programme, resulting in the prioritisation of motorways over public transport (Mees & Dodson, 2006, 2007). More than 90% of Aucklanders have access to motor vehicles, which is the most common form of transport to work (Statistics New Zealand, 2013). The Auckland area has an extensive motorway network, consisting of 4 state highways, as shown in Figure 3.

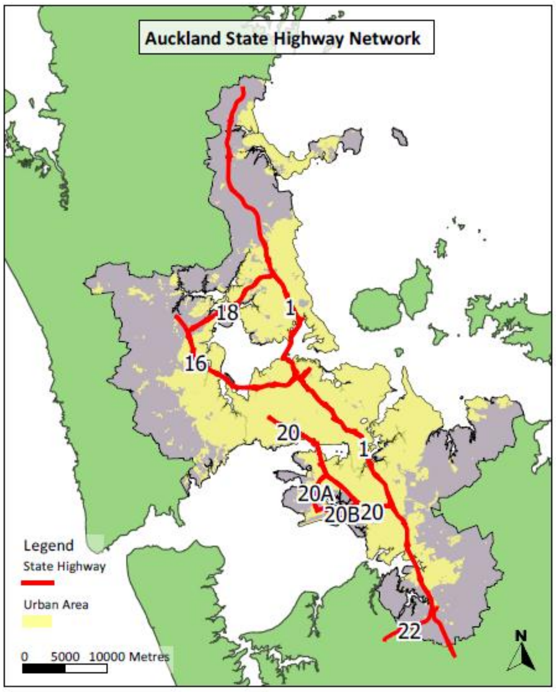


Figure 3 Auckland State Highway Network

High vehicle usage throughout the city has resulted in a physical pollution problem, and vehicles are believed to be responsible for 70-80% of the Auckland region's air pollution emissions (Auckland Council, 2012a), in particular, PM10 (Ministry for the Environment, 2008).

[2] The islands of the Hauraki Gulf were not included in this research.

4.1.1 Population demographics

The Auckland Region has a population of 1,415,550. On average, Aucklander's are slightly younger than the rest of New Zealand, more qualified, and have higher incomes (Statistics New Zealand, 2013).

Auckland has high ethnic heterogeneity compared to the rest of New Zealand (Thornton & Clark, 2010). In particular, Auckland has much higher rates of Asian and Pacific peoples (Statistics New Zealand, 2013). Immigration rates are much higher than the rest of the country, with 39.1% of the population born overseas compared to 25.2% for the country as a whole.

Immigration from Asian countries has been the most recent demographic trend (Manley, Johnston, Jones, & Owen, 2015). Ethnic segregation in Auckland is relatively low; only Pacific Island people are concentrated at a level that can be measured at small geographic scales (Poulsen, Johnson, & Forrest, 2002). However, using larger geographic scales, some clustering of minorities is found (Manley et al., 2015).

4.2 Overview of data sources

Table 2 shows a brief summary of the data used for this research and its source. Further details regarding cleaning and creation of variables can be found in the relevant sections.

Table 2 Summary of Data and Sources

Data	Source	Date
Health Data	Ministry of Health Programme for the Integration of Mental Health Data (PRIMHD)[3]	Calendar year, 2013
Traffic Data	Auckland Transport and New Zealand Transport Association AADT by Region	June 2013- December 2014 and 2010-2014
NZ Road Network	NZ Open GPS	
Address Points	LINZ Street Address (Electoral)	Sourced 18/01/16
Population Variables	New Zealand Census 2013, Statistics New Zealand	2013
Deprivation	University of Otago NZDep Index	2013
Green space	Green space layer as described by (Richardson, Pearce, Mitchell, Day, & Kingham, 2010)	Updated with Land Cover Database 3.3 2013

4.3 Overview of methods

The analysis was performed at meshblock level where data was available. Ethnicity and the Gini score were the exception and calculated at area unit. More than 92% of the data points that were used at meshblock level had associated data, and 98% for the area unit (AU) measures.

Meshblocks are the smallest areal aggregation available from Statistics New Zealand. Some variables have limited records due to the need to protect confidentiality of individuals within the meshblock. The average meshblock population in Auckland is 125 people. Meshblocks were preferred as they are useful administrative units, as they offer a rough approximation of real neighbourhoods (Harrison, 2001).

[3] Previous research using similar data in New Zealand may refer to Health Tracker

A variety of software was used for this research. Data preparation was done in Microsoft Excel and Esri ArcGIS. Esri ArcGIS 10.2 was used in the development of the traffic exposure variables. All statistical analysis was completed using RStudio Version 0.98.501.

4.4 Measure of mental health

There is a wide variety of metrics used to measure mental health. Both self-rated health and official diagnoses have been used in New Zealand, depending on the desired outcomes. Two nationwide datasets are available in New Zealand; the Kessler Scale collected by the NZHS, which measures psychological distress and treatment data from PRIMHD.

The Kessler scale provides a more nuanced view of psychological distress and prevalence across the population, but the relatively low number of cases within the Auckland Region may have restricted statistical analysis.

PRIMHD was selected as it provided a greater sample size for effective modelling. PRIMHD is a register of an individual's health records across administrative databases, which is collated using Individual National Health Index (NHI) number. The NHI numbers allow for linking across national health databases. This data can be attributed to address points. It contains information regarding all contact with the public health system, including prescriptions and referrals. For this study, individuals were included who had been treated for anxiety disorders, including depression, and for substance abuse, to represent individuals with impaired mental health. Addiction services account for 16% of the cases that were provided. Individual information regarding age, gender and ethnicity is associated with these cases. All geographic information and identifiers are stripped from the data by the Ministry of Health.

This data does not directly reflect the prevalence in a population as treatment seeking behaviours differ between groups and therefore affects rates of prescriptions across a population[4].

To represent individuals without mental illness, approximately 30% of the Auckland address points (125,334) that did not have a case associated were randomly selected.

[4] Exception of instances of severe mental illness who may be treated under the Compulsory Treatment Act 1992

4.5 Traffic exposure

The majority of studies cited in the literature review focussed on a particular outcome of traffic such as noise or physical pollution, rather the than the effect of traffic as a risk factor alone. Furthermore, it is uncommon for studies to consider an entire urban area. Most prior research has tended to have a relatively limited spatial scale with a high level of data detail within these areas. Spatially comprehensive traffic data appears to be a barrier internationally, therefore, the development of a unique exposure assessment was required.

4.5.1 Review of methodologies

A limited number of studies considered traffic as a standalone exposure, rather than as an estimate for noise or pollution. (Gundersen et al., 2013), who used road classifications to produce zones of high traffic exposure, and (Song et al., 2007) who estimated vehicle burden and presence of major streets by area, are exceptions. However, these measures were created to estimate exposure at an areal level rather than individual level.

The air pollution literature had a number of methods to estimate exposure for individuals. Weighted traffic exposure to model traffic intensity has been used effectively to consider exposure of pollutants and the effect of asthma, allergies, and lung functioning (Hansell et al., 2014; Rose et al., 2009). This methodology weights roads on their hierarchy classification, as an alternative when traffic data is unavailable. Rose et al. (2009) were able to validate this model using actual NO_2 measurements. A second possible methodology was proposed by A. Barnett et al. (2011) who used traffic counts of road segments within buffers and distance to the nearest road. This measure was successfully used to investigate the effects of traffic exposure on birth outcomes. Both of these methods rely on consistency on the traffic volume between road categories.

Noise is also a dominant theme in research relating to traffic exposure. Analyses incorporating noise relies heavily on interviews, surveys and subjective measurements of noise while objective studies use a limited scale, take physical measurements of the noise level, and often consider the extremes of exposure (Morrell et al., 1997). In some countries large scale noise modelling is available (Moudon, 2009), although it requires data and complex methodologies that were not available for this thesis.

4.5.2 Data preparation

Residential Auckland traffic data was downloaded from (Auckland Transport, 2015). The most recent data available was used, which included surveys from the June 2012 - December 2014. Where data were collected at the same location, the most recent traffic data was used. This data required extensive cleaning before geocoding due to the format of location information. Some records were unable to be accurately located due to incomplete location descriptions and were not included in the analysis. In total, 2,261 traffic data points were successfully geocoded out of 2,602 available records. The NZ Open GPS road layer was used as a base for the network.

Motorways are defined as 'access-controlled, high-speed roads that normally have grade separated intersections' (New Zealand Transport Agency, n.d.). In Auckland, motorways consist of the State Highway network, which is monitored by the New Zealand Transport Agency (NZTA). The NZTA provides publicly available universal traffic flow data for the entire State Highway network. Of the 563 records from the Auckland Territorial Authority region, 470 records were successfully attributed to the motorway network. The remainder were outside the study area, or were duplicates that used different methods of determining traffic counts. In these cases, the most accurate recording method was selected.[5] This data provided complete coverage of traffic volume data for all motorway sections in Auckland.

Table shows the variables that are measured in these data sets.

[5] Data collected using a loop was preferred over virtual. For a description of the data collection methods please see State Highway Traffic Data Booklet 2010-2014, (New Zealand Transport Agency, 2015).

Table 3 Traffic Flow measurements from Auckland Transport and NZTA

Auckland Transport Traffic Data	**NZTA State Highway Data (2013)**
5 Day average daily traffic volume*	Annual average daily traffic volume*
7 Day average daily traffic volume*	Percentage heavy vehicle*
Saturday volume*	
Sunday volume	
Morning peak volume*	
Midday peak volume*	
Afternoon peak volume*	
Percentage of cars	
Percentage of light commercial vehicles	
Percentage of medium commercial vehicles	
Percentage of Type I Heavy Commercial vehicles	
Percentage of Type II Heavy Commercial vehicles	
Percentage of Total Heavy Commercial Vehicles*	

*Variables used

4.5.3 Exposure to motorways

Exposure to the motorways was calculated by measuring the Euclidean distance from LINZ Street Address (Electoral) data to the centre line of the NZ Open GPS road layer. Euclidean distance was used by (Pattinson et al., 2015) in their research on perceptions of motorways, and is common across similar literature.

Living near a motorway can provide greater accessibility result in more positive perceptions of nearby motorways (Hamersma et al., 2014; Pattinson et al., 2015). Accessibility was assessed by calculating network distance from address points to the start of nearest motorway on-ramp. This measure is a development of a measure referred to by Theebe (2004), who used a Euclidean distance to motorway onramps. The use of network distance versus Euclidean distance is a logical improvement as accessibility provided by motorways is limited by the road network.

4.5.4 Creating a comprehensive vehicle exposure dataset

The distribution of traffic count survey locations in Auckland City was not comprehensive, many areas had sparse coverage (Figure 4). As the distribution of data was likely to impact unduly on analyses, a method based on Tobler's (1970) First Law was devised. Tobler's Law describes the effect of spatial proximity on characteristics of features; simply stated as "everything is related, but near things are more closely related"

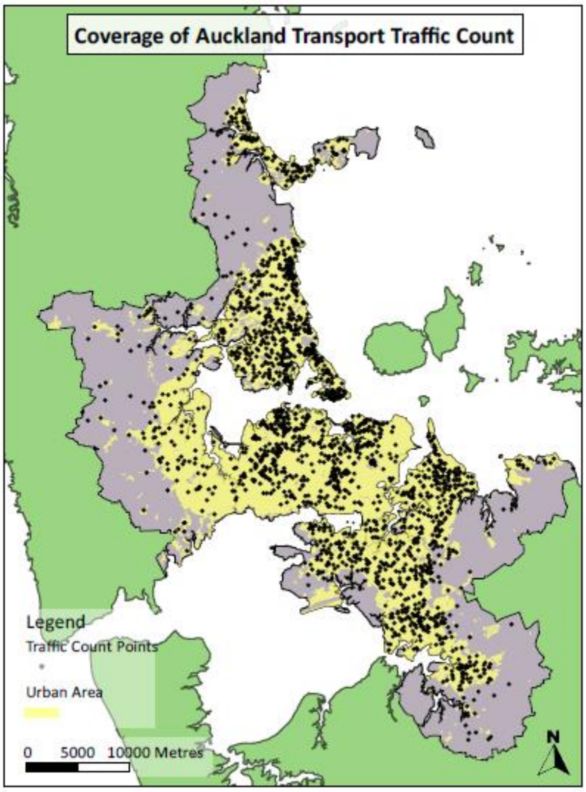


Figure 4 Auckland Transport Sampling Points

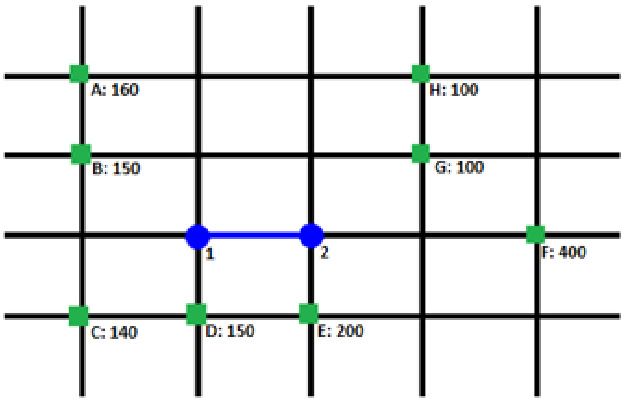
The NZ Open GPS road network was categorised into three classes using the 'types' field from the layer. Table contains a description of these classes.

Table 4 Classifications attributed to NZ Open GPS Road Network

Road Class	**Type**
Road Class 1 – Motorways	1, 2, 8*, 9*, 11*
Road Class 2 – Arterial routes	3-5
Road Class 3 – Residential and small roads	6, 7

* On ramps/off ramps

At each intersection with a valency greater than 2, a point was created. This was done to provide a start and end point for each road section which estimates could be attributed to. The road layer was then split into three separate datasets: road class 1, 2, and 3 because traffic volume is expected to vary considerably between the three types of road class. The intersection points were overlaid with each of the three road class datasets, and three corresponding intersection datasets were generated. Intersections where more than one class met resulted in duplicate points with different road class definitions. All available traffic volume data was attributed to the associated intersection points of that road class. Estimates (mean and median) were calculated from the nearest 5 or 10 intersections of corresponding road classes through the network (as shown in Figure 5), justified by Tobler's First Law.



Intersection	Point 1	Point 2
A	160	
B	150	
C	140	
D	150	150
E	200	200
F		400
G		100
H		100
Mean	**150**	**190**
Median	**150**	**150**

Figure 5 Diagram of traffic estimation based on 5 nearest points

By separating the data into road class, it was assuming that road class 2 volume is fundamentally different to road class 3, rather than solely using the nearest traffic volume for all road types. For all points, 48 traffic estimate values were created. If an intersection was connected to a motorway, it was assigned a road class value of 1 and the subsequent data from the motorway data, as all road segments had associated data. These points were used to create estimates of corresponding road class intersections without road data. Road segments were then attributed to data based on its corresponding start and end points, using the mean and maximum of the two values. This method was influenced by the road network estimates that (Rose et al., 2009) created, using available traffic flow data and data from Sydney Co-ordinated Adaptive Traffic System (SCATS)[6].

In the case of dead-end streets, it was inappropriate to create estimates from nearest traffic flow data points as there is no through traffic. Estimates were calculated using address points from the LINZ NZ Street Address (Electoral) data set. For each address point on a street, two trips were assigned per address per day.

To assess exposure for each household, Euclidean buffers of 50, 100, 200 and 300 metres were created for each address point, these buffers were based on previous research in Auckland and international examples. Welch et al. (2013) used a distance of 50 metres from motorways in Auckland to assess the impact of motorways on the quality of life. Random sampling of houses distances from motorways using Google Maps confirmed that 50 metres will not capture address points that have another address point between it and the motorway

[6] The use of SCATS was investigated for this research but data were unavailable.

which would create a buffering effect. Pattinson et al. (2015) found that there was a linear relationship between the distance from motorway and improved perceptions of their environment, even at a distance of approximately 100 metres from motorways is a very different perception to those within 40 metres. As an upper limit, 300 metres was commonly used. Hamersma et al. (2014) used a breakpoint of 300 metres, finding a distinct difference between basement of noise in the group within 300 metres of a highway compared to the further away group, but little difference in assessment of air quality. Three hundred metres was the maximum distance used for assessment for modelling the effects of highway noise on house prices (Kim, Park, & Kweon, 2007). Quantification of pollution exposure using Gaussian modelling showed pollution as insignificant past 300 metres (Pratt et al., 2014). Larger buffers were used by (A. Barnett et al., 2011), who extended their research out to 500 metres, although, their methodology of counting road segments was much less computationally intensive, and only freeways were found to be significant up 400 metres.

The volume of vehicles per day that passed through each buffer was calculated for each road class. This was calculated using the tabulate intersection function of ArcGIS. A secondary measure of vehicles per meter per day for each household was also created. The purpose was to attempt a more nuanced measure of vehicle traffic exposure. For example, theoretically, House A in Figure 6 could have the same exposure level as House B based on the volume of vehicles which travel that road each day; however, House B will have a much greater exposure as a result of having traffic on multiple sides of the house. This measure was calculated by multiplying the volume of vehicles per day for each buffer, by the length of road class that passed through each buffer.

Exposure measures were calculated for each of the three road classes so the effect of each road class can be tested both independently, and together.

An alternative is to use a weighted road density model, which has been used successfully in pollution research (Hansell et al., 2014; Rose et al., 2009). Rose et al. (2009) assigned weightings by road class (weighting of 3 for motorways, 2 for arterial and 1 for the distributor and local roads), however, it performed equally as well as the model that used estimated traffic count data. Rose et al., (2009) was able to validate their weighting models using actual pollution data, which is not available in this research.

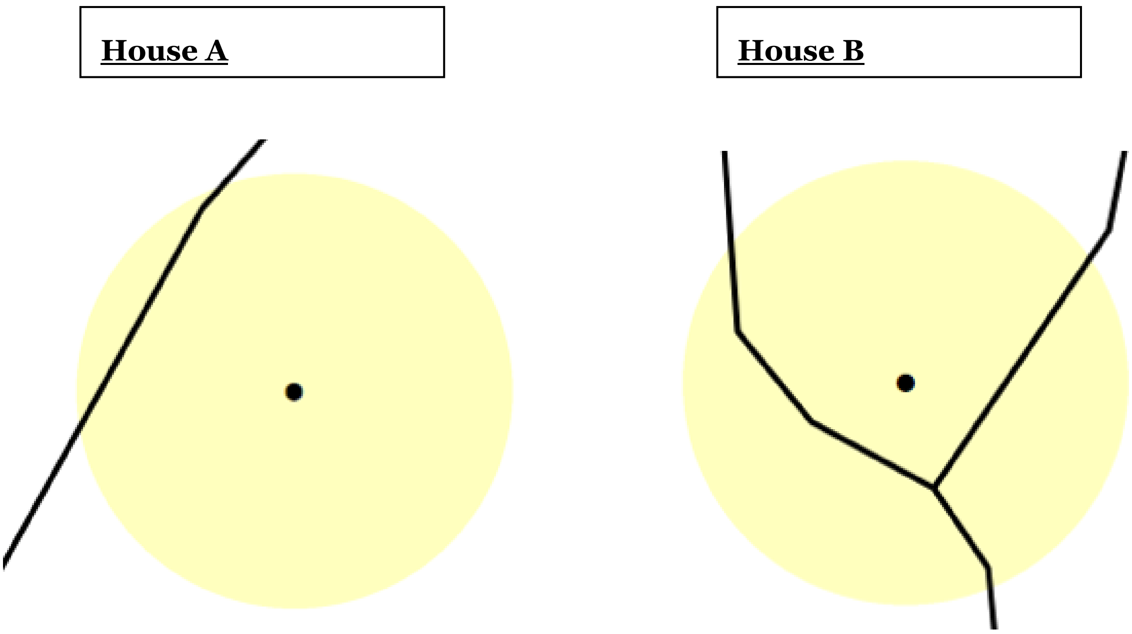


Figure 6 Evidence for necessity of traffic density measurement

Due to the uneven distribution of flow survey locations, it is difficult to add nuance to the model or validate it effectively. An alternative could have been to create a micro-simulation model, as it is a useful tool to extrapolate and combine data into an effective model (Bennan & Akehurst, 2000). However, for effective traffic-flow micro-simulation, complex road network models, generation activity models and route choice models are required (Balmer, Cetin, Nagel, & Raney, 2004). Without these components, the effectiveness of the micro-simulation would have been diluted. As the aim of this research is to investigate the influence of traffic on mental health, the development of an effective micro-simulation model was outside the scope of this thesis.

4.6 Confounding variables

4.6.1 Income

There are a number of theories as to how income affects health at the contextual level, including adverse effects of living in areas of high concentration of poverty (Almog et al., 2004; R. Atkinson & Kintrea, 2001; Sloggett & Joshi, 1994; Stafford & Marmot, 2003). Furthermore, for low-income people there are negative effects associated with living in areas of high inequality (Kahn et al., 2000; A. Pearson et al., 2013; Subramanian, Delgado, et al., 2003).

Absolute income

Median household income was selected as it is the most indicative of living standards.

Income inequality

Kawachi & Kennedy (1997b) found there to be little difference between a range of income inequality measures when considering the Gini coefficient, decile ratio, Robin Hood Index, Atkinson Index and Theil's Entropy. All measures were highly correlated with each other and the state level mortality indicator that they were compared to. Therefore, the choice of indicator is unlikely to affect the empirical analysis. The Gini Index was chosen as it is the most common across the literature and does not require decisions on weighting systems, which require judgement and therefore bias as to which group the researcher believes to be the most affected by inequality. It should be noted the Gini Index has its own bias, as it emphasises inequality in the middle of the income spectrum, opposed to the extremes (De Maio, 2007).

The Gini Index is calculated by the following formula:

$$G = \sum_{i=1}^{n} \left(\sum_{j=1}^{n} \frac{1}{2} \frac{|x_i - x_j|}{n^2 \mu} \right)$$

As census income is bracketed, x_i refers to the midpoint of income of each of the 6 brackets. The highest income bracket was attributed $100,000 for personal income, and $150,000 for household and family income (Armstrong & Clark, 2013).

The Gini coefficient returns a score between 0 and 1, 0 representing perfect equality.

The Gini coefficient was calculated in RStudio using the 'reldist' package. The Gini coefficient was calculated area unit due to limited data availability in many meshblocks. Median household income was used.

4.6.2 Deprivation

The most common measure of social deprivation in New Zealand is the New Zealand Deprivation Index. Developed at the University of Otago, is updated at each census to reflect changes in society (J. Atkinson et al., 2014). Table 5 provides a description of the variables included in the Index.

Table 5 Variables used in NZDep 2013

Dimension of deprivation	**Description of variable (in order of decreasing weight in the index)**
Communication	People aged <65 with no access to the Internet at home
Income	People 18-64 receiving a means-tested benefit
Income	People living in equivalised* households with income below an income threshold
Employment	People aged 18-64 unemployed
Qualifications	People aged 18-64 without any qualifications
Owned home	People not living in own home
Support	People aged <65 living in a single parent family
Living space	People living in equivalised*households below a bedroom occupancy threshold
Transport	People with no access to a car

*Equivalisation refers to controls for household composition   Source: Atkinson et al. (2014)

4.6.3 Indicators of social capital

Measuring social capital, or the effects of poor social capital, is highly dependent on available data at an ecological level.

Individual-level social capital is often measured with surveys. Some individual level characteristics, when concentrated in a neighbourhood have been found to have strong correlations with social capital, including ethnic diversity, education and home ownership (Putnam, 2007).

Education

Education has the strongest correlation with trust in society and civic engagement (Putnam, 1995). Rates of educational attainment are available in the New Zealand Census.

Home ownership

Homeowners are believed to have a greater incentive to invest in a community, as better neighbourhoods increase the value of their home, and they have much higher relocation costs relative to non-homeowners (Glaeser & DiPasquale, 1998).

Homeownership is recorded in the New Zealand Census.

Residential stability

Residential stability has been successfully used in both international and NZ social fragmentation indices to investigate suicide and depression respectively (Congdon, 1996; Ivory, 2008).

This research has defined residential stability from the NZ Census as 5 years or more at the current address, which has been used by (Breetzke & Pearson, 2014).

Ethnic fragmentation

As mentioned in section 3.1.4, the distribution of ethnicities is particularly important to minorities, as high levels of dispersion may lead to isolation from cultural specific resources and networks (Whitley et al., 2006).

The New Zealand Census reports ethnicity as six categories: European, Māori, Pacific Peoples, Asian, Middle Eastern/Latin America/African (MELAA) and Other.

Ethnic heterogeneity has been used in previous New Zealand research (Armstrong & Clark, 2013; Thornton & Clark, 2010). Ethnic fragmentation index is defined by the following equation:

$$F = 1 - \sum_{k=1}^{n} p_{k^2}$$

Where p_k is the share of group k among then possible groups. The fragmentation index returns a score between 0 and 1 (with a score of 0 referring to perfect homogeneity). As the total share of ethnicity is often greater than 100% due to individuals identifying with more than one ethnicity, the p_k was calculated using the total number of ethnicities reported opposed to total respondents as used by (Armstrong & Clark, 2013). This measure may over-estimate the true level of heterogeneity (Thornton & Clark, 2010).

This measure was calculated at area level.

Neighbourhood disorder

Social disorder, as defined by Skogan, (1990 cited by Wandersman & Nation, 1998), is an outcome of low social capital. It generally refers to the physical appearance of the neighbourhood, including the presence of litter, graffiti and empty or derelict buildings. Presence or perception of crime is also an important component. The measure most commonly used in the literature to represent social disorder on a large scale is single parent households, which was initiated by Wilson (1996 cited by Ross & Mirowsky, 2001). The reasoning is that high concentrations of single parent households have limited capacity to contribute to formal and informal networks in a neighbourhood, and unsupervised children often engage in anti-social behaviour (Wilson, 1996 cited by Ross & Mirowsky, 2001).

Single parent households are measured in the New Zealand census.

4.6.4 Green space

As discussed in section 3.2, there is variability in the reported influence that green space has on wellbeing, and whether it is just the presence of greenery, or a pleasant area that can be used for exercise and social activities. As a confounder, it was necessary to attempt to capture the effect the green space had on mediating the annoyance of noise and possible presence of a 'quiet side of house', as well as the health-promoting effects of green space on positive activity in the neighbourhood

Due to the relatively ubiquitous prevalence of green space across urban areas in New Zealand, associations with health have sometimes contradicted findings from international settings (Richardson et al., 2010). Quantity of total green space within 3km and distance to nearest useable green space of population weighted centroids have been found to have significant positive effects on mental health in New Zealand (Nutsford et al., 2013; Richardson et al., 2013). Similarly, a US study found the distance to nearest usable green space was significant up to 400 metres (Sturm & Cohen, 2014).

Overall, the literature was in favour of usable green space for its beneficial effects to counter noise (Dzhambov & Dimitrova, 2015a, 2015b; Gidlöf-Gunnarsson & Öhrström, 2007). A buffer of 300 metres was selected to match the traffic exposure, as it was hoped that this would capture the protective effect that green space has on traffic exposure and the positive activity benefits that have been found in the literature.

The green space data set developed by Richardson et al. (2010) was used, which was updated with LCDB 3.3. To determine the percentage of publicly available green space available within 300-metre address point buffers the ArcGIS tabulate intersection tool was used.

4.7 Analysis

Logistic regression was the primary statistical method used. The analysis was performed in a number of stages.

Initial univariate regressions were performed between the traffic variables and health outcomes, and confounders and health outcomes to understand the basic relationship. At this stage the most effective traffic variables were selected based on the Akaike information criterion (AIC) score. AIC is a measure of the relative quality of statistical model, where lower values indicate a better model.

Using the theoretical framework and understanding of the relationship between health and traffic developed in the literature review, a baseline traffic model was developed using the variables that were deemed to be most important. Robustness checks were completed on the subsequent models, including the addition and removal of variables and the testing of the probit link in the logistic regression.

The procedure was repeated in the creation of the models to describe neighbourhood characteristics and their associations to mental health. Two models were developed based on the literature review, one using the New Zealand Deprivation Index, a second using median household income. Again, variables were included based on the strength of the theoretical argument. In the case of New Zealand Deprivation, only items that were not already a component of the index were included.

Due to the complexities of the effect that ethnicity has on treatment seeking and prevalence, and the availability of individual level data, ethnicity was tested in a separate model. Logistic regressions were performed by selecting each ethnicity individually as a reference to be regressed against the proportion of the neighbourhood of the ethnicity selected.

To test whether exposure to traffic was a feature of residential selection, linear regression was run between some of the traffic exposure variables and the confounding variables.

Finally, logistic regression was performed with the neighbourhood effects model and baseline traffic model combined.

5. Results

The results of the analysis reported in this chapter will seek to answer the following research questions, as outlined in the Introduction:

I. Does proximity to motorways affect mental health treatment?
II. Does accessibility as a result of living near motorways affect mental health treatment?
III. Does traffic volume affect mental health treatment?

5.1 Summary statistics

General demographic data is presented in Table , comparing the treatment group to the Auckland population. As the random sample is of address points, rather than individuals, we cannot present a comparison with the random sample that is used in the following analysis.

Compared to national rates of treatment for mental health reported in the NZHS, men are over represented in the treatment group, as are Māori. According to the NZHS survey, Asian people are half as likely to be treated for mood disorders compared to other ethnicities which is reflected in the summary statistics, although we would expect a similar pattern for Pacific people as well (Ministry of Health, 2014a).

Table 6 Summary statistics of demographic variables

	Treatment Group	**Auckland Population**
Total	29,623	1,415, 550
Gender		
Male	51.6%	48.6%
Female	48.4%	51.4%
Ethnicity		
European	55.8%	59.3%
Māori	18.5%	10.7%
Pacific Peoples	13.7%	14.6%
Asian	8.2%	23.1%
MELAA	2.0%	1.9%
Other	0.1%	1.2%
NA	1.5%	
Age (Median)	37*	35.1

* Cases do not include individuals under the age of 15.

Table shows a comparison of summary statistics of the various traffic exposures between the cases and all Auckland address points. The length of road at each road class does not differ greatly across the two groups, although for the most part, cases have higher vehicle per day exposure and traffic density exposure compared to all Auckland address points. The exception is road class 1 at 50 metres. A similar pattern occurs for heavy commercial vehicles.

On average, the treatment group live closer to motorways and have a shorter distance to motorway on ramps.

Table 7 Summary statistics of traffic exposure for cases address points and all Auckland address points

	Cases		**Auckland Address Points**	
	Mean	**SD**	**Mean**	**SD**
Euclidean distance to motorway	2,395	2,249	2,614	2,482
Network distance to on-ramp	3,462	2,938	3,762	3,277
RC1 traffic density (TD) 50 metres	12,901	23,4194	14,038	286,328
RC1 vehicles per day (VPD) 50 metres	280	4,917	286	5,520
RC1 proportion heavy commercial vehicles (HCV) 50 metres	0	0.4	0	0.4
RC1 HCV VPD 50 metres	16	294	16	305
RC1 length 50 metres[7]	0.6	8.1	0.6	7.7
RC1 TD 100 metres	363,759	2,613,965	312,014	2,484,448
RC1 VPD 100 metres	3,401	22,532	2,797	21,024
RC1 proportion HCV 100 metres	0	1.2	0	1.0
RC1 HCV VPD 100 metres	209	1,372	164	1,238
RC1 length 100 metres	12	73	11	70
RC1 TD 200 metres	148,9374	7,138,616	1,229,044	6,742,201
RC1 VPD 200 metres	8,804	41,305	7,425	39,810
RC1 proportion HCV 200 metres	0	1.5	0	1.3
RC1 HCV VPD 200 metres	527	2,457	425	2,264
RC1 length 200 metres	47	220	38	189
RC1 TD 300 metres	3,766,118	14,267,386	3,128,841	13,350,599
RC1 VPD 300 metres	17,543	65,532	14,872	62,119
RC1 proportion HCV 300 metres	1	1.8	0	1.6
RC1 HCV VPD 300 metres	1,030	3,819	848	3,506
RC1 length 300 metres	120	453	97	387
RC2 TD 50 metres	217,246	473,626	187,459	441,509
RC2 VPD 50 metres	4,565	10,463	4,091	9,981
RC2 Proportion HCV 50 metres	1	2.0	1	2.0
RC2 HCV VPD 50 metres	171	491	98	336
RC2 length 50 metres	27	43	25	41
RC2 TD 100 metres	925,542	1,502,778	835,502	1,469,634

[7] Extreme motorway values are spatially clustered around Spaghetti junction, where it is possible for houses to have multiple motorways within a short distance. As centrelines were used, it is possible in rare cases for both carriageways to be counted within the 50 metres.

	Cases		Auckland Address Points	
	Mean	**SD**	**Mean**	**SD**
RC2 VPD 100 metres	11,628	19,197	10,519	18,595
RC2 proportion HCV 100 metres	2	2.2	2	2.3
RC2 HCV VPD 100 metres	442	869	57	837
RC2 length 100 metres	109	119	105	121
RC2 TD 200 metres	2,826,538	3,307,581	2,550,374	3,153,969
RC2 VPD 200 metres	30,173	38,788	272,66	37,127
RC2 proportion HCV 200 metres	3	2.1	2	2.2
RC2 HCV VPD 200 metres	1,235	1,868	640	1,251
RC2 length 200 metres	344	270	331	271
RC2 TD 300 metres	6,623,570	6,000,367	6,112,787	5,856,685
RC2 VPD 300 metres	63,318	63,790	58,350	62,584
RC2 proportion HCV 300 metres	3	1.9	3	2.0
RC2 HCV VPD 300 metres	2,363	2,928	308	1,961
RC2 length 300 metres	743	468	721	476
RC3 TD 50 metres	28,877	35,759	294,00	36,571
RC3 VPD 50 metres	462	703	487	755
RC3 length 50 metres	62	52	63	53
RC3 TD 100 metres	97,403	90,103	101,076	95,912
RC3 VPD 100 metres	1,285	1,440	1,351	1,596
RC3 length 100 metres	217	131	224	138
RC3 TD 200 metres	358,545	256,349	364,898	277,863
RC3 VPD 200 metres	3,177	3,299	3,330	3,837
RC3 length 200 metres	784	364	797	392
RC3 TD 300 metres	1,176,587	686,836	1,159,604	737,602
RC3 VPD 300 metres	5,931	5,884	6,030	6,663
RC3 length 300 metres	1,683	675	1,687	732

On average, people who have been treated for mental illness or substance abuse live at addresses with a smaller proportion of green space within 300 metres compared to address points without individuals who have received treatment. The census data tends to indicate that those who are treated live in neighbourhoods with lower household income, higher deprivation, greater ethnic fragmentation, where people are less likely to own their own home and have lower education levels (Table). Residential composition, such as single person households, is similar across the groups, as are residential stability and the proportion of recent arrivals.

Table 8 Summary statistics of neighbourhood composition of cases and all Auckland address points

	Cases		Auckland Address Points	
	Mean	**SD**	**Mean**	**SD**
Green space	13.9	13.6	14.2	14.4
Income Factors				
Median Household Income	73,543	28,710	82,630	29,466
NZ Deprivation Index	6.2	3.0	5.0	2.9
Income inequality (Gini) (AU level)	0.34	0.05	0.33	0.05
Neighbourhood Ethnic Composition (%) (AU level)				
European	54.2	23.3	59.6	22.7
Māori	12.4	8.5	10.2	7.4
Pacific People	18.9	19.8	13.8	17.0
Asian	23.4	14.6	23.9	15.2
Other*	3.1	1.4	3.1	1.3
Social Capital Factors				
Ethnic Fragmentation (AU Level)	0.58	0.14	0.54	0.15
Rate of single parent households	0.22	0.13	18.4	12.0
Rate of homeownership	0.35	0.17	0.41	0.17
Proportion of people with no qualifications	0.21	0.12	0.17	0.05
Proportion of people with high school qualifications	0.42	0.08	0.41	0.09
Proportion of people with bachelor's or higher	0.22	0.13	0.26	0.13
Residential stability – 5 years at usual residence	0.42	0.13	0.43	0.14

* Other includes MELAA and Other as identified in the NZ Census.

5.2 Assessing traffic exposure variables

Table 9 displays results of univariate logistic regressions of mental health against individual measures of traffic exposure. As described in section 5.5.4, 48 measures were produced for each traffic variable for road class 2 and road class 3, the variable with the lowest AIC score is presented in the table.

All measures were statistically significant, with the exception of length of road class 3 road within 300 metres and motorway measurements within the 50 metre buffer. The lack of significance at 50 metres for motorways is likely to be a result of the low number of addresses that fall within this distance in Auckland. These addresses only account for 0.6% of the total addresses sampled. This also may be an underestimation, as one way centrelines of motorways were used rather than a measurement from the edge of the road, and may be further affected by the location of the address point location attributed to the address parcel polygon.

While the results were statistically significant, the magnitude of effect was indiscernible for distance to motorway, distance to on ramp and vehicles per day and traffic density measures. Heavy commercial vehicles were found to have an effect; at road class 1 and road class 2, a 1% increase in heavy commercial vehicles resulted in 3-4% and 2-3% increase in rate of poor mental health, respectively. An increase of 1,000 heavy commercial vehicles per day resulted in a 3% increase for road class 1 at 100 metres, falling to a 1% increase at 300 metres (OR 1.03, CI 1.01-1.03, OR 1.01, CI 1.01-1.02). A similar pattern was found at road class 2 of increasing effect for those living closer, with an increase of 1,000 heavy commercial vehicles per day at 50 metres associated with a 6% increase in treatment, which falls to 2% at 300 metres (OR 1.06, CI 1.02-1.10, OR 1.02, CI 1.02-1.03).

Table 9 Results of univariate logistic regression of mental health outcomes versus traffic exposure type. Traffic volume is measured per 1000 vehicles

Traffic measure	OR	95% CI
Euclidean distance to motorway	**1.00**	**1.00-1.00**
Network distance to on-ramp	**1.00**	**1.00-1.00**
RC1 traffic density (TD) 50 metres	1.00	1.00-1.00
RC1 vehicles per day (VPD) 50 metres	1.00	1.00-1.00
RC1 proportion heavy commercial vehicles (HCV) 50 metres	1.01	0.98-1.03
RC1 HCV VPD 50 metres	1.01	0.96-1.04
RC1 length 50 metres	1.00	1.00-1.00
RC1 TD 100 metres	**1.00**	**1.00-1.00**
RC1 VPD 100 metres	**1.00**	**1.00-1.00**
RC1 proportion HCV 100 metres	**1.04**	**1.03-1.05**
RC1 HCV VPD 100 metres	**1.03**	**1.01-1.03**
RC1 length 100 metres	**1.00**	**1.00-1.00**
RC1 TD 200 metres	**1.00**	**1.00-1.00**
RC1 VPD 200 metres	**1.00**	**1.00-1.00**
RC1 proportion HCV 200 metres	**1.04**	**1.03-1.05**
RC1 HCV VPD 200 metres	**1.02**	**1.01-1.02**
RC1 length 200 metres	**1.00**	**1.00-1.00**
RC1 TD 300 metres	**1.00**	**1.00-1.00**
RC1 VPD 300 metres	**1.00**	**1.00-1.00**
RC1 proportion HCV 300 metres	**1.03**	**1.03-1.04**
RC1 HCV VPD 300 metres	**1.01**	**1.01-1.02**
RC1 length 300 metres	**1.00**	**1.00-1.00**
RC2 TD 50 metres	**1.00**	**1.00-1.00**
RC2 VPD 50 metres	**1.00**	**1.00-1.00**
RC2 proportion HCV 50 metres	**1.02**	**1.01-1.03**
RC2 HCV VPD 50 metres	**1.06**	**1.02-1.10**
RC2 length 50 metres	**1.00**	**1.00-1.00**
RC2 TD 100 metres	**1.00**	**1.00-1.00**
RC2 VPD 100 metres	**1.00**	**1.00-1.00**
RC2 proportion HCV 100 metres	**1.02**	**1.01-1.03**
RC2 HCV VPD 100 metres	**1.05**	**1.04-1.06**
RC2 length 100 metres	**1.00**	**1.00-1.00**

Traffic measure	OR	95% CI
RC2 TD 200 metres	**1.00**	**1.00-1.00**
RC2 VPD 200 metres	**1.00**	**1.00-1.00**
RC2 proportion HCV 200 metres	**1.02**	**1.02-1.03**
RC2 HCV VPD 200 metres	**1.04**	**1.03-1.05**
RC2 length 200 metres	**1.00**	**1.00-1.00**
RC2 TD 300 metres	**1.00**	**1.00-1.00**
RC2 VPD 300 metres	**1.00**	**1.00-1.00**
RC2 proportion HCV 300 metres	**1.00**	**1.02-1.03**
RC2 HCV VPD 300 metres	**1.02**	**1.02-1.03**
RC2 length 300 metres	**1.00**	**1.00-1.00**
RC3 TD 50 metres	**1.00**	**1.00-1.00**
RC3 VPD 50 metres	**1.00**	**1.00-1.00**
RC3 length 50 metres	**1.00**	**1.00-1.00**
RC3 TD 100 metres	**1.00**	**1.00-1.00**
RC3 VPD 100 metres	**1.00**	**1.00-1.00**
RC3 length 100 metres	**1.00**	**1.00-1.00**
RC3 TD 200 metres	**1.00**	**1.00-1.00**
RC3 VPD 200 metres	**1.00**	**1.00-1.00**
RC3 length 200 metres	**1.00**	**1.00-1.00**
RC3 TD 300 metres	**1.00**	**1.00-1.00**
RC3 VPD 300 metres	**1.00**	**1.00-1.00**
RC3 length 300 metres	1.00	1.00-1.00

Statistically significant results are bolded (0.05 level).
All traffic density and vehicle per day measures are per 1000 vehicles.

5.3 Neighbourhood composition and mental health

The univariate analysis between mental health and the contextual neighbourhood factors are displayed in Table 10.

The proportion of useable green space within 300 metres was not found to have an effect on mental health outcomes. Absolute income has a mild association with mental health treatment (OR 0.99, CI 0.99-0.99). The Gini score has a particularly high odds ratio of 318; this may be a result of the low variation between neighbourhoods or the strong spatial similarities between deprivation and income inequality, as shown by Figure 7 and Figure 8.

Table 10 Univariate logistic regression of health outcomes versus neighbourhood contextual features

Variable	**OR**	**95% CI**
Green space	**1.00**	**1.00-1.00**
Income		
Median Household Income ($000)	**0.99**	**0.99-0.99**
NZ Deprivation Index	**1.15**	**1.15-1.15**
Gini Coefficient (AU Level)	**318**	**318-318**
Neighbourhood Ethnic Composition		
European	**0.85**	**0.29-0.40**
Māori	**34.95**	**34.80-35.10**
Pacific Peoples	**1.31**	**4.50-4.63**
Asian	**0.97**	**0.73-0.90**
Other*	**0.82**	**0.69-0.99**
Social Fragmentation and Social Capital Indicators		
Ethnic Fragmentation (AU Level)	**5.61**	**5.52-5.70**
Rate of single parent households	**12.94**	**12.85-13.05**
Rate of homeownership	**0.12**	**0.04-0.20**
Proportion of people with no qualifications	**26.00**	**25.92-26.14**
Proportion of people with high school qualifications	**2.71**	**2.55-2.87**
Proportion of people with bachelor's or higher	**0.09**	**0.01-0.19**
Residential stability – 5 years at usual residence	**0.67**	**0.58-0.76**

Statistically significant results are bolded (0.05 level).

*Other includes MELAA and Other as identified in the NZ Census.

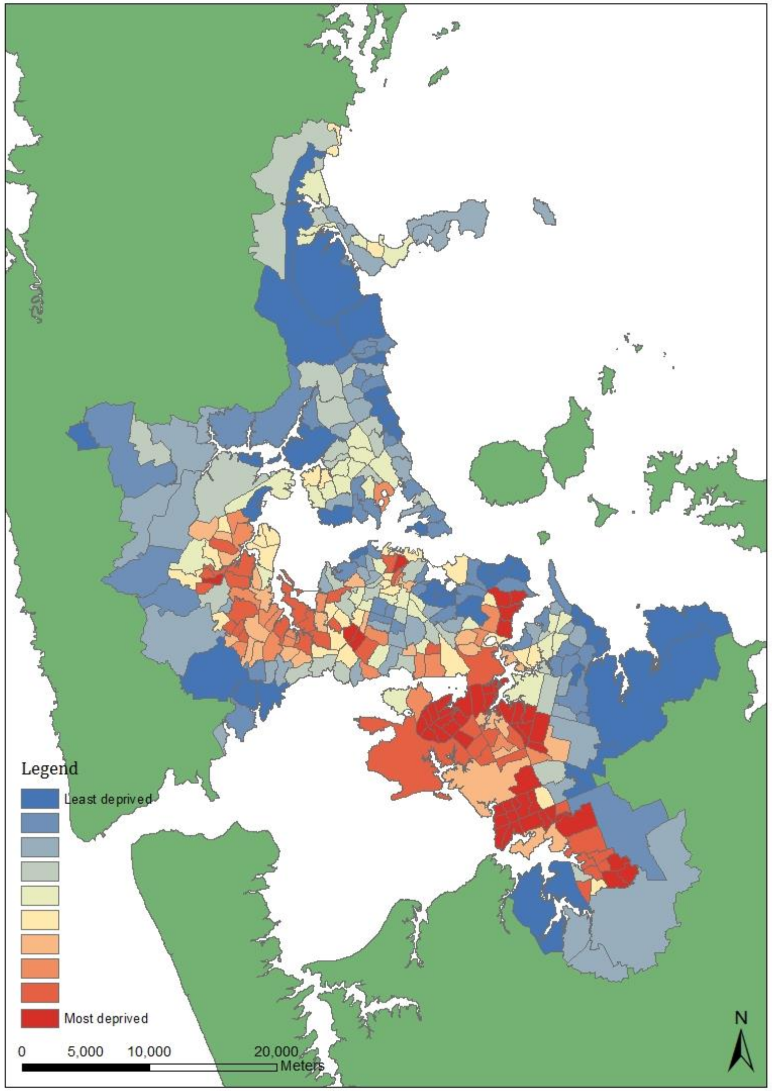


Figure 8 Spatial variation of deprivation in Auckland (Deciles)

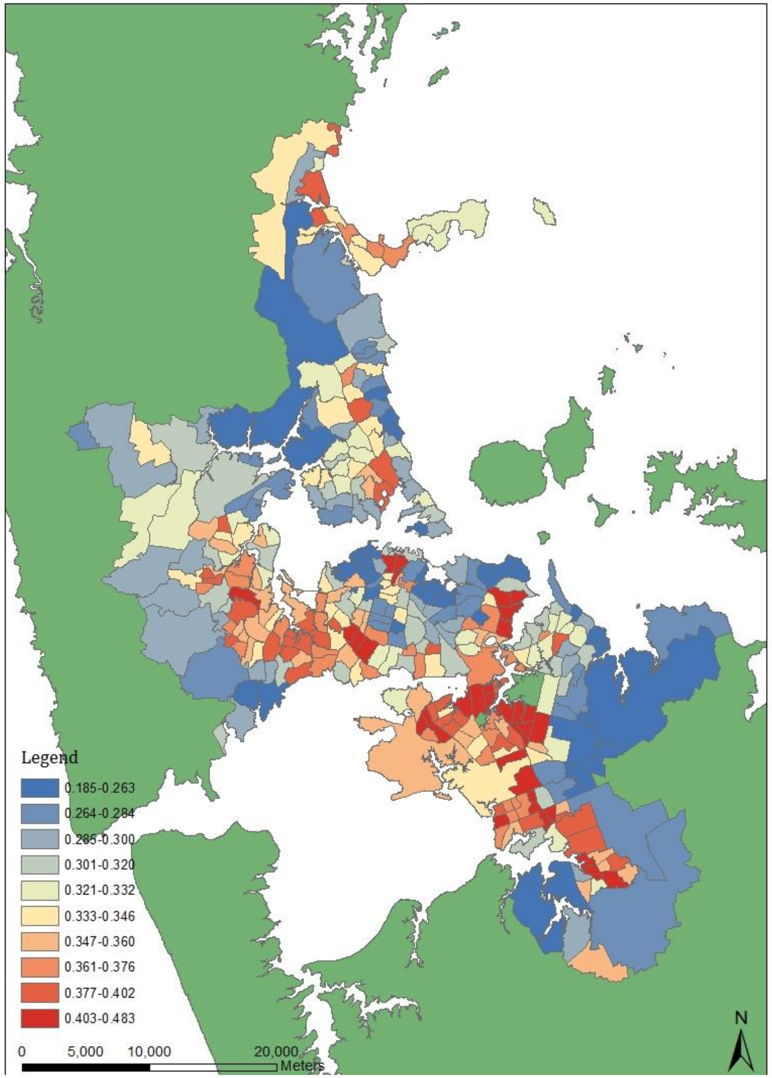


Figure 7 Spatial variation of income inequality in Auckland (Deciles)

The proportion of each ethnicity in a neighbourhood has mixed effects. Higher proportions of European, Asian and Other ethnicities indicate reduced odds of being treated (OR: 0.85, 0.97, 0.69). Higher proportions of Māori in a neighbourhood is associated with very high odds of treatment (OR:34.95, CI 34.80-35.10).

Neighbourhoods with high proportions of single parent households and people with no qualifications also have strong associations on the likelihood of an individual being treated for anxiety disorders or addiction (OR: 12.94, 26.00). High rates of home ownership, residential stability and higher education are associated with lower odds of treatment (OR: 0.12, 0.09, 0.67).

All univariate regressions were statistically significant.

5.4 Baseline traffic model

A series of initial baseline traffic models, Model 1-6 (Table 11 and 12), influenced by the literature reviewed in Chapter Two were developed. Traffic volume was selected at 100 metres for motorways, based on estimates of noise levels of high volume 100km roads without noise barriers from NZTA. A 50 metre buffer was selected for road class 2 as the majority of the literature only considers houses directly adjacent to roads. As heavy commercial vehicles produce more noise, vibrations, and pollution than personal vehicles, and are frequently reported to be more "annoying", this measure was included as well. Road class 3 was not included as this level of road is ubiquitous for all addresses.

There was little variation between using traffic volume or traffic density as a measure, nor did adding road class 3 traffic exposure.

For the most part, the multivariate traffic models returned similar correlation patterns to the univariate regression analysis, with no detectable association between distance to motorways, on ramps, normal traffic volume, and density on mental health. At road class 1, heavy commercial vehicles volume resulted in a 7% increase in likelihood of mental illness (OR 1.07, CI 1.04-1.09) in the traffic density models when controlling for distance to motorway, distance to on ramp and traffic density (Model 1 & 3). In the traffic volume models for every increase of 1000 vehicles per day, there is a 9% associated increase in mental health treatment (OR 1.09, CI 1.05-1.13) (Model 4 & 6). The response was more muted for proportion of heavy traffic, with odds of 1.05 and 1.04 in the density and volume models respectively (Model 2 & 4). However, volume of heavy commercial vehicles at road class 2 results returned inverse correlation of the univariate regression in Model 1 & 3. These results suggest a protective factor in the traffic density model of approximately 11% per 1000 vehicles when heavy commercial vehicles traffic volume was the measure used. All other road class 2 heavy commercial vehicles results were not statistically significant.

Table 11 Effects of traffic density on mental health treatment: Multivariate logistic regression

	Model 1		**Model 2**		**Model 3**	
Traffic Measure	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Distance to motorway	1.00	1.00-1.00	1.00	1.00-1.00	1.00	1.00-1.00
Distance to on-ramp	**1.00**	**1.00-1.00**	**1.00**	**1.00-1.00**	**1.00**	**1.00-1.00**
RC1 Traffic Density 100m	**1.00**	**1.00-1.00**	**1.00**	**1.00-1.00**	**1.00**	**1.00-1.00**
RC2 Traffic Density 50m	**1.00**	**1.00-1.00**	**1.00**	**1.00-1.00**	**1.00**	**1.00-1.00**
RC1 HCV VPD 100m	**1.07**	**1.04-1.09**			**1.07**	**1.04-1.09**
RC2 HCV VPD 50m	**0.90**	**0.86-0.94**			**0.90**	**0.86-0.94**
RC1 Proportion HCV100m			**1.05**	**1.03-1.06**		
RC2 Proportion HCV 50m			0.99	0.98-1.00		
RC3 Traffic Volume					1.00	1.00-1.00
AIC	150,871		150,885		150,873	

Statistically significant results are bolded (0.05 level).

All traffic density and vehicle per day measures are per 1000 vehicles.

Table 12 Effects of traffic volume on mental health treatment: Multivariate logistic regression

	Model 4		Model 5		Model 6	
Traffic Measure	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Distance to motorway	1.00	1.00-1.00	1.00	1.00-1.00	1.00	1.00-1.00
Distance to on-ramp	**1.00**	**1.00-1.00**	**1.00**	**1.00-1.00**	**1.00**	**1.00-1.00**
RC1 Traffic Volume 100m	**1.00**	**1.00-1.00**	1.00	1.00-1.00	**1.00**	**1.00-1.00**
RC2 Traffic Volume 50m	**1.00**	**1.00-1.01**	**1.00**	**1.00-1.00**	**1.00**	**1.00-1.01**
RC1 HCV VPD 100m	**1.09**	**1.05-1.13**			**1.09**	**1.05-1.13**
RC2 HCV VPD 50m	0.96	0.91-1.00			0.96	0.96-1.00
RC1 Proportion HCV100m			**1.04**	**1.02-1.06**		
RC2 Proportion HCV 50m			1.01	1.00-1.02		
RC3 Traffic Volume					1.00	1.00-1.00
AIC	150,942		150,940		150,943	

Statistically significant results are bolded (0.05 level).
All traffic density and vehicle per day measures are per 1000 vehicles.

5.5 Effects of the neighbourhood on mental health

Two models of residential selection factors were investigated. Mental health was regressed against deprivation, median household income and social capital confounders. Green space was also included as it is associated to improved mental health (Nutsford et al., 2013; Sturm & Cohen, 2014), and as it is believed to meditate the psychosocial response to traffic noise (Dzhambov & Dimitrova, 2015a; Gidlöf-Gunnarsson & Öhrström, 2007; Li et al., 2010)

5.5.1 NZ Deprivation Index

The following models (Table 13) used the New Zealand Deprivation Index as the primary measure of socio-economic status. Due to the inclusion of variables such as education and single parent families in the index, these variables were not included here (see section 4.6.4 and Table 5). Living in a more deprived meshblock is statistically significant in all variations of the model, and the odds ratio is consistently 1.02 (CI 1.02-1.02), indicating a 2% increase in the odds of being treated for the selected mental health outcomes with each unit increase in deprivation.

Ethnic fragmentation is not statistically significant.

The Gini score is statistically significant, as income inequality increases the odds of being treated for mental illness or substance abuse increase. The association is reduced significantly from the univariate regression in Table10 which would be expected if it correlated closely with deprivation (OR 318 reduced to OR of 1.06-1.08).

The association between mental health and residential stability in the multivariate model differs from the univariate model (Table 10), where the odds ratio indicated that areas with less residential stability had odds of higher mental health treatment of 49%, compared to the 2% increase in treatment in areas with greater residential stability. This reversal suggests that there is collinearity with another variable in the model.

There is little variation between the models in terms of the magnitude of association of the variables.

Table 13 Effects of the neighbourhood on mental health treatment: Deprivation

	Model 7		Model 8		Model 9		Model 10		Model 11		Model 12	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
NZ Deprivation Index	**1.02**	**1.02-1.02**	**1.02**	**1.02-1.02**	**1.02**	**1.02-1.02**	**1.02**	**1.02-1.02**	**1.02**	**1.02-1.02**	**1.02**	**1.02-1.02**
Ethnic Fragmentation	1.01	0.99-1.02	1.00	0.99-1.02	1.00	1.00-1.02					1.00	1.00-1.02
Gini Score	**1.08**	**1.02-1.14**	**1.06**	**1.00-1.12**					**1.08**	**1.30-1.14**		
Residential Stability	**1.02**	**1.00-1.03**			**1.02**	**1.00-1.04**	**1.02**	**1.00-1.04**	**1.02**	**1.00-1.03**		
Green space	1.00	1.00-1.00	1.00	1.00-1.00	1.00	1.00-0.00	1.00	1.00-1.00	1.00	1.00-1.00	1.00	1.00-0.00
AIC	134,943		135,789		134,968		134,942		134,970		135,820	

Statistically significant results are bolded (0.05 level).

5.5.2 Median income

The following models (Table 14) use median household income as the primary measure of socio-economic status.

Median household income does not appear to be a causal factor, as the correlation is no longer detectable when the important confounders of ethnic fragmentation, income inequality, home ownership, education, residential stability and green space are controlled for.

In contrast to the deprivation models, the ethnic fragmentation correlations are statistically significant when controlling for median income, Gini score, homeownership, single parent households, residential stability and green space. An increase in ethnic fragmentation increases the odds of treatment for mental health by 24% when all of the previously mentioned confounders are controlled for. This increases to 30% when income inequality is no longer controlled for.

In the multivariate models, the proportion of home ownership continues to have a strong association with reduced treatment for mental health with odds ratio between 0.19 and 0.24. Likewise, the proportion of people in a neighbourhood with tertiary education is associated with odds ratio of 0.26-0.36.

The proportion of single parent households are associated with odds of increased mental health treatment of 2.00-2.05.

Again green space has no detectable effect.

All models have similar AIC values.

Table 14 Effects of the neighbourhood on mental health treatment: Household Income

	Model 13		**Model 14**		**Model 15**		**Model 16**		**Model 17**	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Median Household Income ($000)	1.00	1.00-1.00	**1.00**	**1.00-1.00**	1.00	1.00-1.00	**1.00**	**1.00-1.00**	**1.00**	**1.00-1.00**
Ethnic Fragmentation	1.01	1.00-1.03	**1.02**	**1.01-1.04**	1.02	1.00-1.03	**1.03**	**1.01-1.04**	**1.02**	**1.01-1.04**
Gini Score	1.09	1.03-1.16			**1.10**	**1.04-1.17**				
Home ownership	**0.78**	**0.77-0.80**	**0.79**	**0.77-0.80**	**0.80**	**0.78-0.81**	**0.76**	**0.75-0.78**	**0.80**	**0.78-0.81**
Bachelor's or higher	**0.85**	**0.83-0.86**	**0.84**	**0.82-0.86**	**0.84**	**0.82-0.86**	**0.80**	**0.79-0.82**	**0.83**	**0.81-0.85**
Residential stability (5 years)	**1.04**	**1.02-1.05**	**1.03**	**1.02-1.06**						
Single parent household	**1.14**	**1.12-1.18**	**1.15**	**1.12-1.18**	**1.16**	**1.13-1.18**			**1.16**	**1.13-1.18**
Green space	1.00	1.00-1.00	1.00	1.00-1.00	1.00	1.00-1.00	1.00	1.00-1.00	1.00	1.00-1.00
AIC	132,229		132,306		132,311		132,683		132,319	

Statistically significant results are bolded (0.05 level).

5.5.3 Neighbourhood ethnic composition

Due to the unavailability of individual level data for the random sample, it was not possible to control for ethnicity directly in the models. The literature has indicated that ethnicity is important to understand prevalence and treatment seeking behaviour, but also that the ethnic composition of a neighbourhood can have an impact an individual's mental health as it affects access to social capital and feelings of inclusion. In order to explore this possible association, the ethnicity of the treatment group was regressed against the proportion of the neighbourhood of the relevant ethnicity. As shown in Table 15, these regressions were not statistically significant.

Table 15 Effect of neighbourhood ethnic composition on each ethnic group

	European		**Māori**		**Pacific**		**Asian**		**Other**	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Proportion of neighbourhood of reference ethnicity	1.01	0.98-1.03	1.03	0.97-1.08	1.00	0.98-1.02	0.99	0.97-1.01	1.07	0.68-1.66

5.6 Transport exposure and residential selection

In order to investigate whether mental health treatment is affected by systematic residential selection, univariate linear regression was performed between traffic exposure variables and the neighbourhood contextual variables (Table 16, 17 and 18). If the same variables that affect mental health also affect traffic exposure through residential selection (e.g., 'deprived' households living in less expensive houses near busy roads), any observed relationship between traffic exposure and mental health would not necessarily be causal.

Median household income of a neighbourhood is associated with traffic exposure. For every $1000 increase in the median household income of a neighbourhood, address points are approximately 11 metres further to motorway and 14 metres further to the nearest on ramp. For traffic density, there is an 800 vehicles decrease at road class 1 and 1400 decrease at road class 2. At road class 2 a decrease in median income is associated with an increase in the volume of heavy commercial vehicles of 6000 per day, while there is a negligible effect for heavy commercial vehicles at road class 1.

Deprivation has a large effect on proximity to motorways: for each one unit increase in deprivation index, the model predicted address points to be 213 metres closer to a motorway, and exposed to 23,000 more road class 1 vehicles per metre per day, and 17,000 more road class 2 vehicles per metre per day. The association with heavy commercial vehicles and deprivation is negligible.

The Gini coefficient predicts that increases in inequality will be associated with living 8,000 metres closer to motorways, increased exposure to traffic density at road class 2 of 823,000 vehicles. The association is opposite for road class 1, where the results indicate that there is a reduction of 369,000 vehicles per metre per day when income inequality increases. Heavy commercial vehicles are expected to increase by 140 vehicles per day and 460 vehicles per day at road class 1 and 2 respectively.

Neighbourhoods with high proportions of Europeans are likely to be further from motorways and are negatively correlated with traffic density and volume of heavy vehicles. These associations are reversed for all other ethnicities with the exception of Māori at road class 2, and Asian people at road class 2, which are not statistically significant. Houses in more ethnically fragmented neighbourhoods have much greater exposure to traffic and motorways; an increase in ethnic fragmentation predicts that an address point will be 6,000 metres closer to a motorway, have 280,000 more road class 1 vehicles per meter per day, and 230 more heavy commercial vehicles at road class 1.

Neighbourhoods where a higher proportion of people own their own home, fewer single parent households and neighbourhoods that have greater proportions of people who have lived at the same address for more than five years have lower exposure to motorways, traffic density and heavy commercial vehicles. Educational attainment is not as consistent of a predictor – it is not statistically significant for traffic density at road class 1.

These results indicate that there are associations between neighbourhood characteristics and residential traffic exposure, and therefore controlling for these variables is important to understand the association that traffic exposure may have on mental health.

Table 16 Univariate linear regression: Distance to motorway and on-ramp versus neighbourhood contextual factors

	Distance to motorway		Distance to on ramp	
	Co-efficient	**P-value**	**Co-efficient**	**P-value**
Green space	**21.63**	**<0.001**	**30.46**	**<0.001**
Income Factors				
Median Household Income	**10.91**	**<0.001**	**13.59**	**<0.001**
NZ Deprivation Index	**-213.23**	**<0.001**	**-284.55**	**<0.001**
Income inequality (Gini) (AU level)	**-8,527.70**	**<0.001**	**-11,619.87**	**<0.001**
Neighbourhood Ethnic Composition (%) (AU level)				
European	**3,831.89**	**<0.001**	**3,578.57**	**<0.001**
Māori	**-4,416.80**	**<0.001**	**-3,074.51**	**<0.001**
Pacific People	**-3,405.33**	**<0.001**	**-2,998.62**	**<0.001**
Asian	**-3,863.43**	**<0.001**	**-2,700.02**	**<0.001**
Other*	**-1,7082.71**	**<0.001**	**-2,6241.48**	**<0.001**
Social Capital Factors				
Ethnic Fragmentation (AU Level)	**-6,483.26**	**<0.001**	**-8,690.32**	**<0.001**
Rate of single parent households	**-2,783.42**	**<0.001**	**-3,758.55**	**<0.001**
Rate of homeownership	**5,185.43**	**<0.001**	**6,962.57**	**<0.001**
Proportion of people with no qualifications	**-2,055.37**	**<0.001**	**-2,474.25**	**<0.001**
Proportion of people with high school qualifications	**259.50**	**<0.001**	**1,428.33**	**<0.001**
Proportion of people with bachelor's or higher	**-866.23**	**<0.001**	**-1,860.99**	**<0.001**
Residential stability – 5 years at usual residence	**3,379.50**	**<0.001**	**4,487.07**	**<0.001**

Statistically significant results are bolded (0.05 level).

Table 17 Univariate linear regression: Traffic density versus neighbourhood contextual factors

	RC1 Traffic Density 100m		**RC2 Traffic Density 50m**	
	Co-efficient	**P-value**	**Co-efficient**	**P-value**
Green space	**-2.53**	**<0.001**	**-0.72**	**<0.001**
Income Factors				
Median Household Income	**-0.83**	**<0.001**	**-1.37**	**<0.001**
NZ Deprivation Index	**23.61**	**<0.001**	**17.57**	**<0.001**
Income inequality (Gini) (AU level)	**-368.59**	**<0.001**	**823.28**	**<0.001**
Neighbourhood Ethnic Composition (%) (AU level)				
European	**-234.28**	**<0.001**	**-211.12**	**<0.001**
Māori	**435.33**	**<0.001**	-12.75	0.42
Pacific People	**325.22**	**<0.001**	**140.16**	**<0.001**
Asian	35.99	0.39	**288.82**	**<0.001**
Other*	**2,117.85**	**<0.001**	**783.99**	**<0.001**
Social Capital Factors				
Ethnic Fragmentation (AU Level)	**280.73**	**<0.001**	**232.20**	**<0.001**
Rate of single parent households	**624.30**	**<0.001**	**191.54**	**<0.001**
Rate of homeownership	**-1003.50**	**<0.001**	**-417.69**	**<0.001**
Proportion of people with no qualifications	**252.88**	**<0.001**	**191.46**	**<0.001**
Proportion of people with high school qualifications	68.09	0.40	**88.13**	**<0.001**
Proportion of people with bachelor's or higher	5.16	0.92	**-80.94**	**<0.001**
Residential stability – 5 years at usual residence	**-1,290.51**	**<0.001**	**-348.26**	**<0.001**

Statistically significant results are bolded (0.05 level).

Table 18 Univariate linear regression: Volume of Heavy Commercial Vehicles versus neighbourhood contextual factors

	RC1 HCV VPD 100m		**RC2 HCV VPD 50m**	
	Co-efficient	**P-value**	**Co-efficient**	**P-value**
Green space	**-0.001**	**<0.001**	**-0.000**	**<0.001**
Income Factors				
Median Household Income	**-0.001**	**<0.001**	**-6.168**	**<0.001**
NZ Deprivation Index	**0.018**	**<0.001**	**0.009**	**<0.001**
Income inequality (Gini) (AU level)	**0.137**	**0.024**	**0.459**	**<0.001**
Neighbourhood Ethnic Composition (%) (AU level)				
European	**-0.176**	**<0.001**	**-0.074**	**<0.001**
Māori	**0.481**	**<0.001**	0.022	0.057
Pacific People	**0.245**	**<0.001**	**0.048**	**<0.001**
Asian	0.02	0.357	**0.101**	**<0.001**
Other*	**0.972**	**<0.001**	**0.863**	**<0.001**
Social Capital Factors				
Ethnic Fragmentation (AU Level)	**0.231**	**<0.001**	**0.118**	**<0.001**
Rate of single parent households	**0.488**	**<0.001**	**0.119**	**<0.001**
Rate of homeownership	**-0.588**	**<0.001**	**-0.196**	**<0.001**
Proportion of people with no qualifications	**0.287**	**<0.001**	**0.094**	**<0.001**
Proportion of people with high school qualifications	**0.118**	**0.004**	0.003	0.765
Proportion of people with bachelor's or higher	**-0.124**	**<0.001**	**-0.038**	**<0.001**
Residential stability – 5 years at usual residence	**-0.562**	**<0.001**	**-0.163**	**<0.001**

Statistically significant results are bolded (0.05 level).

5.7 Complete Model

The univariate regressions of mental health against the neighbourhood confounders and univariate regressions of traffic exposure versus confounders indicate that there is a relationship between both, therefore it is necessary to regress the multivariate traffic model (Model 1, Table 11) against the neighbourhood contextual models (Model 12 and 17, Table 13 and Table 14) to understand the effect that traffic exposure has on mental health. The results of the combined models are displayed in Table 19 and Table 20.

Regarding the effect on the traffic exposures, when controlling for deprivation, ethnic fragmentation and green space, only the heavy commercial vehicles are statistically significant. The magnitude of the association is reduced from the multivariate models (OR of 1.07 and 0.90 for road class 1 and road class 2, reduced to OR of 1.01 and 0.97). Deprivation is the only other statistically significant confounder in this model, returning estimated odds of 1.02, which was the same as in the original neighbourhood model.

In the multivariate model containing traffic and the median income neighbourhood model, all variables are statistically significant except median income. The heavy commercial vehicle measures display a similar pattern to the traffic vs deprivation model (Table 19), with reduced OR of 1.01 and 0.98. The associations for the confounders remain the same, with the exception of ethnic fragmentation, where the odds reduce to 1.02 from 1.03.

Table 19 Complete multivariate model: Traffic vs Deprivation and Social Capital

	OR	**95% CI**
Distance to motorway	1.00	1.00-1.00
Distance to on-ramp	1.00	1.00-1.00
RC1 Traffic Density 100m	1.00	1.00-1.00
RC2 Traffic Density 50m	1.00	1.00-1.00
RC1 HCV VPD 100m	**1.01**	**1.0-1.01**
RC2 HCV VPD 50m	**0.97**	**0.97-0.98**
NZ Deprivation Index	**1.02**	**1.02-1.02**
Ethnic Fragmentation	1.02	1.00- 1.03
Green space	1.00	1.00-1.00
AIC	135,763	

Statistically significant results are bolded (0.05 level).
All traffic density and vehicle per day measures are per 1000 vehicles.

Table 20 Complete multivariate model: Traffic vs Median Household Income and Social Capital

	OR	95% CI
Distance to motorway	**1.00**	**1.00-1.00**
Distance to on-ramp	**1.00**	**1.00-1.00**
RC1 Traffic Density 100m	**1.00**	**1.00-1.00**
RC2 Traffic Density 50m	**1.00**	**1.00-1.00**
RC1 HCV VPD 100m	**1.01**	**1.01-1.01**
RC2 HCV VPD 50m	**0.98**	**0.97-0.99**
Median Household Income ($000)	1.00	1.00-1.00
Ethnic Fragmentation	**1.03**	**1.01-1.04**
Home ownership	**0.80**	**0.78-0.81**
Bachelor's or higher	**0.83**	**0.81-0.85**
Single parent household	**1.16**	**1.13-1.18**
Green space	**1.00**	**1.00-1.00**
AIC	132,267	

Statistically significant results are bolded (0.05 level).

All traffic density and vehicle per day measures are per 1000 vehicles.

6. Discussion

This chapter will discuss the findings in relation to the two aims of this research; an investigation into whether there is an association between exposure to traffic and treatment of mental health, and secondly, the development of a wide scale traffic exposure assessment methodology.

Firstly, mental health in the Auckland context is discussed, followed by a discussion of the effects of the traffic exposures and confounders and a critique of the data and methods.

The following section will critically assess the quality of the traffic exposure methodology, and discuss in relation to other methods used in the literature.

The key findings of the literature review and the analysis of this research will inform a discussion of the implications for public health and urban design professionals.

Finally, opportunities for future research are identified and discussed.

6.1 Is there an association between exposure to traffic and mental health?

6.1.2 Mental health in Auckland

The summary statistics presented of the treatment group and the Auckland population present some anomalies when compared to the NZHS and other research into the treatment of mental health disorders in New Zealand.

When comparing to the NZHS, it would be expected that males are underrepresented in the treatment group, rather than the 3% difference between proportion of population and proportion in the treatment group. Regarding ethnicity, the NZHS suggest that the proportion of Māori that are treated for mental illness reflects the distribution of the population (the treatment group is 18.5% Māori, compared to 10.7% of the Auckland population (Ministry of Health, 2014a, Statisitcs New Zealand, 2013).

These rates also contradict the rates of prescription dispensing for antidepressants reported by Exeter et al. (2009) where women represented two-thirds of all prescriptions, and Māori were under represented, especially in the Counties Manukau District Health Board region which is included in the is study area.

These anomalies could be a result of the inclusion of substance abuse data, which accounts for 16% of the treatment group. In regards to the NZHS, it may also indicate that there is a degree of response bias, as people may offer ‘socially desirable’ responses when discussing their mental health status with strangers (Ross & Mirowsky, 1984)

6.1.2 Traffic exposure and mental health

No association was found between living in proximity to motorways or having better access to motorways via on ramps and mental health. Previous research in this area indicates that there are benefits and disbenfits of living near motorways. The research from Auckland which influenced this study suggested that quality of life was reduced when living near motorways (Pattinson et al., 2015; Welch et al., 2013) while research by Hamersma et al. (2013) and Witten et al. (2003) commented on the positive effects of living near motorways due to the accessibility that was offered. This thesis differs substantially to the cited literature as the methodology used self-reported and qualitative measures rather than treatment rates. In reality, the added accessibility that motorways offer in an urban area are unlikely to be of magnitude great enough to affect mental health.

No detectable effect of traffic volume or density across all road classes and buffer distance were found. While there is limited previous literature that considers traffic volume or density as a metric as a stressor in its own right, we can compare these findings to other literature which considers air and noise pollution. Literature that used self-reported measures such as annoyance, frequently found associations between the stressors (Belojević et al., 1997; Forsber et al., 1997; Klæboe et al., 2000; Llop et al., 2008; Öhrström et al., 2007; Ouis, 1999; Yoshida et al., 1997). However, considering psychiatric disorders did not find a statistically significant association with traffic noise (Stansfeld et al., 1996). The caveat to this finding is that when individuals who report annoyance from noise are considered, an association has been found between noise and psychiatric symptoms (Öhrström, 1991). This thesis research supports the latter findings, that traffic may not be enough of a stressor in its own right to affect mental illness.

Heavy commercial vehicles are found to have an effect of mental health when both volume and proportion of vehicles is considered across road class 1 and road class 2. Furthermore, the effect decreases as the buffer size increases, indicating the presence of a dose response relationship.

The presence of a dose response relationship is interesting in the context of the wider literature. Stansfeld et al. (1996) found that exposure to noise did increase psychiatric symptoms, however, the relationship was not statistically significant. The authors critiqued the lack of dose response relationship as evidence that the relationship was spurious. Other research has found that there is a ‘break point’ in exposure, where after a certain number of vehicles or noise level, any further increase does not have an associated effect (Dratva et al., 2010; Rylander & Dunt, 1991).

This result is not unexpected, as heavy vehicles are commonly cited to be more annoying due to the greater noise, dust and vibrations that are produced (Hoeger et al., 2002; Jacquemin et al., 2007; Paunović, Belojević, & Jakovljević, 2014; Paunović et al., 2009). This may be because heavy vehicles are more noticeable due to the vibrations and the substantially greater noise produced, therefore each event may be identified by residents, rather than a continuous level of noise that may be produced by regular traffic. This is theory is supported by work by Rylander and Dunt (1991), who found that people are more annoyed by the number of discrete events rather than noise level (Rylander & Dunt, 1991). The results from research into aircraft noise, which is rated as the most annoying source of transportation noise (Miedema & Vos, 1999), provides futher evidence for this case as aircraft noise has been linked to an increase in admittances to psychiatric care and increased prescription of medication relating to anxiety and depression (Morrell et al., 1997).

With the addition of neighbourhood confounders (median household income, deprivation, proportion of home ownership, residential stability, single parent households, higher education and green space), the pattern persists, although the magnitude of the effect is lessened.

In the baseline traffic models when distance to motorways, on ramps and traffic volume were considered, the association between heavy commercial vehicles is lessened slightly for road class 1 heavy commercial vehicles, but for road class 2 the results indicated that there is a protective effect of heavy commercial vehicles. This may be a result of correlation between other traffic variables included in the model.

6.1.3 Neighbourhood effects

As expected, deprivation has a strong and consistent relationship with mental health treatment; increased deprivation is associated with greater odds of treatment. In contrast, the relationship with median household income was weaker, as the addition of other neighbourhood factors such as education, home ownership and single parent households, resulted in median household income being no longer statistically significant. This finding suggests that rather than 'material ability' of deprivation contributing to reduced mental wellbeing, it is the ability to access social support and resources that may be more detrimental.

Income inequality had a very strong relationship to mental health in the univariate models, however, was mediated by the addition of deprivation associated variables. As shown in Figure 7 and Figure 8, it correlates very strongly with deprivation in Auckland. As an association with mental health treatment remained when NZ Deprivation Index was controlled for, these results may provide evidence for the theory that income inequality has a separate effect on mental health over and above deprivation (Eibner, Sturn, & Gresenz, 2004; Kahn et al., 2000; Subramanian, Delgado, et al., 2003).

The univariate linear regression of distance to motorways and on-ramps, versus the neighbourhood confounders indicates that there may be inequality in exposure to traffic in Auckland based on across both the income and social capital measures. Similar patterns of environmental inequality are found with distance to motorways and traffic density although the results are stronger for road class 1 than road class 2 may be a result of road class 2 being more common across the urban environment. This research may not have fully captured the extent of environmental inequality, as there is strong gradient in house price with distance and therefore measuring at the neighbourhood scale may mask some of this effect (Kim et al., 2007; Theebe, 2004). Although previous Auckland research indicates that those living directly adjacent to motorways in Auckland are more likely to be from higher socio-economic groups (Enriquez, 2015), so this may not be relevant in the Auckland context.

Ethnicity proved difficult to assess. As discussed in section 3.3.3, there are a number of competing factors, including prevalence, treatment seeking behaviour, access to social and cultural networks for support and attitudes towards the environment (Chan & Parker, 2004; Conner, Koeske, & Brown, 2009; Flynn et al., 1994; Macias, 2015; Page & Blau, 2006).

Ethnic fragmentation was included in the model as the literature indicates that it is strongly associated with social capital (Putnam, 2007). The results of the univariate logistic regression support this finding, however, it did not have a statistically significant effect when deprivation is controlled for. This suggests that there is a relationship between ethnic fragmentation and deprivation. This may be similar to the findings of (Thornton & Clark, 2010) who found that ethnic fragmentation had a negative effect on volunteering in New Zealand, suggested to be a reflection of the underlying patterns of income inequality and language heterogeneity

However, it is plausible that the effect varies across ethnicities based on the proportion of that group. Ethnic fragmentation is particularly important for minority groups, with minorities who live in areas where they are more underrepresented have worse mental health as they have less access to culturally specific services and social networks (Whitley et al., 2006). Although if ethnic fragmentation is highly correlated with deprivation, the effect of ethnic orientated support networks may be second to the effect of material deprivation (Pickett & Wilkinson, 2008).

An attempt to investigate these associations was made by regressing each ethnicity in the treatment group against the proportion of ethnicity in their neighbourhood, these results were not statistically significant. Individual level data on both the treatment and random sample would enable future research to investigate these relationships further.

Education, single parent households, homeownership, residential stability and ethnic fragmentation were used to approximate the social environment of the neighbourhood. The univariate regression returned statistically significant associations that were in line with the relevant literature (Glaeser & DiPasquale, 1998; Hill et al., 2005; Putnam, 2007; Ross & Mirowsky, 2001; Subramanian, Lochner, & Kawachi, 2003).

Homeownership was a particularly protective factor, and remained consistent when deprivation, ethnic fragmentation, income inequality, education, residential stability single parent household and green space were controlled for. The literature suggests that high levels of homeownership encourages people to invest in their neighbourhood and community to make them safer and more pleasant, which may include involvement in community organisations (Glaeser & DiPasquale, 1998; McCullock, 2003). It was not possible to test this theory as we are considering the neighbourhood not individuals. If testing at an individual level, we would also hypothesis that homeownership provides a greater level of control over their environment, and therefore reduced stress. For example, homeowners would have the ability to install sound proofing and double glazing if reducing noise was an important objective for them.

When added to the multivariate model, residential stability became associated with higher levels of mental health. This may be the result of collinearity with other deprivation or social capital indicators.

Green space was included throughout the models as it has been associated with improved mental health (Nutsford et al., 2013; Richardson et al., 2013; Sturm & Cohen, 2014), and in the noise research, it is believed to mediate the effects of traffic noise (Dzhambov & Dimitrova, 2015a; Gidlöf-Gunnarsson & Öhrström, 2007; Li et al., 2010). This research found no detectable effect of green space on mental health in all models, and frequently the result was not statistically significant. This may be due to the measure used of proportion of useable green space within 300 metres, where previous New Zealand literature found a statistically significant effect between green space and mental health when proportion of useable green space at 3km was used (Nutsford et al., 2013). 300 metres was specifically chosen for this research to match spatial extent of the traffic exposure variable.

As no association was found between traffic and mental health, it is not possible to determine whether green space has an effect on traffic annoyance in the research.

6.1.4 Limitations

Health data

As used in this research, the classic approach to population level health research is to assume people as healthy unless there is a specific demarcation which indicates the contrary (e.g. diagnosis, treatment by health professional) as the data regarding mortality, morbidity and impairment is often easily collectable (Morrell et al., 1997). While data may be readily available for this method, it often results in a harsh definition of illness being used and is difficult to determine the level of the relevant illness at the margins. In this case, annoyance, irritation and psychological distress was not accounted for unless these individuals had been treated for anxiety, depression or substance abuse.

The lack of detectable effect of traffic on mental health may be a result of using treatment to assess mental health. Treatment is particularly problematic for mental health disorders, as it is heavily influenced by treatment seeking behaviours which varies by gender, ethnicity and age (Chan & Parker, 2004; Diala et al., 2001; Mackenzie et al., 2006; Page & Blau, 2006). As discussed earlier, the results from this research contradict the findings of the NZHS, which may indicate response bias issues with survey collection rather than reluctance to seek treatment.

This measure of mental illness may have some bias as a result of the co-payment requirement for appointments and prescription which may be prohibitive for individuals with low incomes.

Despite the limitations, this approach is a relatively robust measure of the use of services, as all New Zealand permanent residents and most temporary visa holders are eligible for public funded health services. While judgements cannot be made about the prevalence of psychological distress in the general population as a result of exposure to traffic, from a public health perspective it offers valuable insight into the treatment patterns of mental health and substance abuse, and therefore interventions can be targeted accordingly.

Individual level attributes

The lack of individual level information is a significant limitation of this research. The data provided was limited to cases of individuals who had been prescribed medication or accessed treatment for depression, anxiety and substance abuse. The treatment group had ethnicity, age and gender information associated. In order to have a control group to compare the sample against, a sample of 30% of Auckland addresses was used. Because the control group was address points rather than individuals, this data had associated traffic and neighbourhood exposure figures, but not individual level data such as age and gender.

The lack of individual level ethnicity data is a significant limitation for this research and limits the exploration of how different ethnic groups may respond to the exposure, and secondly possible associations between the ethnic composition of the neighbourhood and mental health. Understanding the effect of ethnicity patterns and mental health is likely to be of value for public health professionals as it enables effective targeting of at risk populations.

Similar to ethnicity, international literature has found that there may be different perceptions towards the environment by gender, age and socio-economic status (Bickerstaff, 2004; Flynn et al., 1994). This research could be developed with this additional individual level data for the control group and the use of a case control methodology.

Temporal factors

A limitation of this research is inability to consider temporal factors. This research theorised that reduced mental health is likely to be a result of chronic environmental stress, therefore adverse mental health outcomes as a result of roads and traffic would develop over an extended period of time (Blakely & Woodward, 2000). As individual level information regarding length of residence is not available, this theory cannot be investigated. Investigation into temporal factors would also rely on consistency of traffic volume over time, a limitation that will be discussed in the following section.

The research method used cannot make inferences about causality. A possible solution to this limitation would be to find a 'natural experiment', for example, where traffic volume changed permanently or temporarily. There is a small amount of research that has considered the effects of traffic changes on psychosocial health. Due to the documented highly perceptual effect of traffic on annoyance and stress, many studies found that the effects were lower when residents knew it would be temporary (Laszlo, McRobie, Stansfeld, & Hansell, 2012; Öhrström, 2004). This may not be an appropriate study method, as there may be a 'change of effect' response found to noise, often in excess of expected exposure-response (Brown & van Kamp, 2009). Brown & van Kamp (2009) summarize and critique the possible mechanisms for this effect, concluding that it is most likely to be the result of an associated increase in some other exposure, differing scaling criteria at different levels, or the effect that of existing coping strategies on different noise levels.

The effects of random experiments from short term variation in exposures would be more suited to a more in-depth study, rather than the methodology employed here.

Spatial extent

This research primarily used meshblocks, an administrative boundary, to model the confounding effects of neighbourhoods. This approach is common in ecological research to investigate, however, it is also widely critiqued as an individual's social behaviours are not bound by small area administrative boundaries (Northridge, Sclar, & Biswas, 2003).

Other data

Other aspects of this research would have been improved by better availability to data, for example social disorder and crime is a significant contributor to stress for residents (Hill et al., 2005; Parkes et al., 2002; Ross & Mirowsky, 2001). Social disorder is commonly assessed by the presence of litter, graffiti and vacant buildings, which is unrealistic at the scale at which this research was performed. Official crime data may have offered a more robust method to assess this.

If noise is a significant contributor to this relationship, general neighbourhood noise levels should also be taken into consideration (Braubach et al., 2015).

Social capital proved to be an important confounder in this research. An alternative to social capital is social fragmentation. Ivory produced an index for New Zealand which has been found to be associated with mental health (Ivory et al., 2012, 2011; A. Pearson et al., 2014). This index was not available for this research.

6.1.5 Summary

Referring to the research questions outlines in the Introduction, this research does not find evidence to suggest that there is an association between living near motorways or on ramps directly, nor between exposure to traffic volume or density on the treatment of mental health. However, if you consider the type of traffic on roads, higher volumes of heavy commercial vehicles were found to be correlated with increased rates of treatment of mental illness. While traffic is routinely proven to be annoying and a cause of concern for residents, this research suggests that annoyance does not necessarily translate into detrimental health outcomes. Heavy commercial vehicles may be the exception, as they may be intrusive enough to be noticed by residents.

The univariate and multivariate regression between the neighbourhood confounders, and mental health and traffic exposures provided interesting insights into the spatial patterns of mental health treatment in Auckland. As expected, mental health treatment is associated with higher deprivation and indicators of reduced social capital, and higher deprivation and reduced social capital indicators are associated with exposure to traffic. Again, this it is common to find that the people who are most likely to be affected by environmental pollution are more exposed to it (O'Neill et al., 2003). While this inequality is problematic, it is hard to influence spatially where people live. Research such as this which identifies the spatial patterns of ill-health are valuable, as understanding the spatial patterns can contribute to effective targeted interventions.

6.2 Can an effective large scale traffic exposure methodology be developed from publicly available data?

The methodology to determine traffic exposure used in this research was largely dictated by the availability of data. The access to, and availability of individual address point health data at a large scale offered a unique research opportunity, the challenge was to develop an environmental exposure methodology that would provide effective insight into possible associations between health and the environment.

Quality of, and access to, reliable environmental indicators and data is a common challenge for epidemiological research (Kingham & Dorset, 2011; Northridge et al., 2003). Furthermore, noise is particularly problematic (G. Evans & Kantrowitz, 2002) While estimating any exposures across a wide scale, such as an urban area, adds further difficulty (Briggs, 2005). As this is a common problem across many research contexts, there were a number of solutions presented in the literature to inform the development of a methodology that suited the research aims and the data available. In developing the methodology, data availability, computational requirements, accuracy, and developing nuance in the exposure outcome were considered.

The most common methodology in the literature used variations of road classification or audits of the infrastructure (e.g. counts of intersections, number of cul de sacs) as a proxy for traffic (A. Barnett et al., 2011; Gee & Takeuchi, 2004; Rose et al., 2009; Song et al., 2007). A limitation of this approach is that it relies on consistency of traffic volume by the classification across the network. Investigation into the available traffic data in Auckland indicated that this would not be an accurate assessment of exposure. For example, if road classification were to be used, Dominion Road and Blockhouse Bay Road would have the same traffic exposure assigned despite a 10,000 vehicle difference over the 5-day average daily traffic volume surveyed.

The majority of previous research considered one aspect of negative traffic externalities, such as noise or air pollution. This research could have been developed further if it were possible to test for air pollution and noise pollution separately. While pollution has been successfully modelled and is measured in New Zealand, research using noise modelling or wide spread noise monitoring related to health outcomes was not found. Noise can be effectively modelled, although the quality of modelled noise is contingent on the quality of the data inputs. A high quality noise model would consider meteorlogical conditions, terrain models, building type and density, traffic type, road surface, and noise barriers (Allen et al., 2009; Calixto, Pulsides, & Zannin, 2008; Foraster et al., 2011; Pattinson et al., 2015; Roorda-Knape et al., 1998; Shu et al., 2014; Xie & Kang, 2010; Y. Zhou & Levy, 2007). As comprehensive traffic volume data was not available as a minimum input, there was minimal value considering modelling of this complexity.

This research used two sources of traffic count data; data for road class 1 was sourced from NZTA, while Auckland Transport data was used for road class 2 and 3. The data from NZTA provided comprehensive coverage of the state highway network, and was routinely monitored, providing an annual average measure. The data was accompanied by a comprehensive description of the collection techniques and could be geocoded effectively. In contrast, the traffic data for road class 2 and 3 was not as robust. The coverage of the data was not comprehensive and the researcher did not have information as to why certain streets or areas were selected for monitoring. As the monitoring window for each survey point was limited, it does not account for seasonal variations or one-off events such as detours, events or road works. The incomplete data meant that a solution was required to create a comprehensive coverage. The method developed was influenced by Tobler's Law of spatial proximity, using nearby traffic volumes to estimate the traffic volumes of streets without data. A basic fallacy of this approach is that it did not meet the "conservation of vehicles" requirement, i.e. that the sum of vehicles leaving a road and the vehicles entering a road should sum to the total number of vehicles travelling on the road (G. Olivares, personal communication, December 12, 2015). Other researchers who are interested in modelling pollution in Auckland have used Auckland Transports traffic models (ART3), which consider census data, house hold travel survey and surveyed data. However, this data was not publicly available.

A limitation of this methodology is that it was not possible to validate the traffic exposure. There was no explanation of why surveying occurred at the particular location and the clustering of data points. In order to effectively validate it would have required data that was systematically collected, spatially and temporally. Furthermore, Auckland Transport indicated that some data points were estimates, limiting the value of validation further. One possible validation solution would be to survey traffic in areas that were estimated to compare against reality. Other proxies for traffic could also be used for validation, such as a measure of noise or pollution (Rose et al., 2009), although as dispersion is greatly affected by meteorological and topographical features, there are limitations to this method as well.

The use of buffers to assess exposure can also be problematic, as it assumes that the exposure is constant across the buffer. In reality, noise and pollution decay rapidly as distance between the source and the target increases, and is affected by meteorological conditions, and physical barriers such as buildings and topography. The buffers do not account for location of the road within the buffer, or the presence of mitigating factors within the buffer such as noise barriers or other houses. The addition of the traffic density measure (traffic volume multiplied by the length of road within the buffer) was designed to mitigate some of this effect. The buffer size was selected based on previous research in Auckland and evidence about noise and pollution dispersion (Hamersma et al., 2014; New Zealand Transport Agency, 2010; Pattinson et al., 2015; Pratt et al., 2014; Welch et al., 2013). Altering the size of the buffer may have offered further refinement of the exposure variable. While there are limitations to the use of buffers, this method is a development on the common methodology of assigning exposure based on a geographic area.

The literature review identified a research gap in relation to ecological level investigations between traffic and mental health as previous research generally investigated the extremes of exposure and used limited sample sizes. The availability of, and quality of a wide scale of data may be a contributing factor to this deficiency, of which this method has endeavoured to overcome. In order to contribute to this research area, a novel approach to developing an exposure assessment was required. While it was not possible to determine the efficacy of the method, it offers an alternative to area based exposure systems. Ideally, this methodology can be developed and validated in future research.

6.3 Implications of research

Auckland currently has, and is projected to have New Zealand's highest population growth rate for the foreseeable future (Statistics New Zealand, 2016). This population growth is exceeding the capacity of the road network to provide effective transport and has created housing pressures in the city. Both of these issues are currently the focus of cross agency collaboration, with proposals for light rail and densification of Auckland among the solutions proposed (Auckland Council, 2012b). An understanding of the possible externalities of development are critical in order to effectively reduce the impact. The benefits that densification and public transport provide to health through reduced air quality and a more physically active population are regularly investigated and discussed, in contrast, the effect and mitigation of noise is lacking despite the wide body of evidence indicating that there are serious health consequences of noise (World Health Organisation, 2011).

The lack of focus on the mitigation of noise in urban areas may be that the effect of noise and pervasiveness of the problem is not well understood may contribute to this lack of discussion (Moudon, 2009). As an initial starting point, King and Davis, (2006) suggest initially improved monitoring and surveillance to develop an understanding of the problem. Improved data measurements and research into determining the harmful levels and the extent of the population that are exposed are important first steps to developing effective legislation and guidelines (Moudon, 2009).

Generally, there is a lack of regulation around noise and sound (Miedema, 2007). In New Zealand, policy related to noise is governed by the Resource Management Act 1991 (RMA) which requires 'best practicable option to ensure emission of noise does not exceed a reasonable level' (RMA 1991 No. 69 Part 3 Section 16), where excessive noise refers to noise that affects the 'peace, comfort and convenience of any person' (RMA 1991 No. 69 Part 12 Section 326). For the NZTA, this manifests as a suite of planning guidelines and documents regarding best practical option regarding road building and alterations. However, as the RMA is a performance guideline, it does not apply definitive limits, and therefore the ability to impose a hard limit that results in the minimal harm is difficult.

Currently the NZTA (2015) proposes management of noise by:

- Imposing separation and setback distances between sensitive activities (e.g. schools, residential areas, care facilities, community meeting places) and the road edge
- Encourage non-sensitive land use to separate sensitive activities from the road edge
- Adopt effective urban design principles such as noise barriers
- Require design and construction standards to achieve desired noise and vibration levels

These are common solutions and offer some protection, however poor design or implementation can produce other detrimental outcomes. For example, noise barriers can create opportunities for crime and vandalism and affect residential satisfaction (Arenas, 2008; New Zealand Transport Agency, 2010), while separating busy roads from sensitive land use can promote urban sprawl (Moudon, 2009).

Technology will offer some solutions, for example electrically propelled vehicles that have been developed produce very low levels of noise, (Alden, 2014). Quieter road surfaces are also being developed (Freitas, Mendonça, Santos, Murteira, & Ferreira, 2012; Golebiewski, Makarewicz, Nowak, & Preis, 2003), with some pavements offering the same reduction in noise as a 20km lower speed (Golebiewski et al., 2003).

Alterations can be made to homes and buildings to reduce exposure as well. Installing façade insulation in Norway reduced noise by 7dB, resulting in the proportion of people who reported high annoyance dropping from 42% to 16% (Amundsen, Klæboe, & Aasvang, 2011) Likewise, the installation of double glazing has been found to increase positive feelings towards noise (Whitley, Prince, & Cargo, 2005). Insulation and double glazing not only protects individuals from noise, but offer insulation and energy efficiency benefits which aligns with other Government objectives such as New Zealand Healthy Homes programme (New Zealand Government, 2016).

One of the traditional solutions proposed to the ill-effects of vehicle orientated transport is the development of dense, walkable urban areas (Badland & Schofield, 2005; Giles-Corti & Donovan, 2002; Saelens, Sallis, & Frank, 2003). However, this requires densification, which if not planned well may have detrimental effects. As dense cities have intense public space use and may result in high noise (Duarte & Cladera, 2008). Older research regularly found relationships between high urban density and poor negative mental health outcomes (Laird, 1973; Schmitt, 1966). Although more nuanced research suggests that it is not high density which is the issues, rather the other social environmental factors such as crime and social connections that is associated with reduced wellbeing that are affected (Adams, 1992). For example no significant relationship was found between urban sprawl and self-reported physical and mental wellbeing in Australia, but a significant association was found between self-reported health and perceptions of the neighbourhood being a safe place (Jalaludin & Garden, 2011). Currently, the reduction of air pollution and the increase in activity are cited as the primary benefits of densification. For example it has been estimated in New Zealand that a 5% modal shift to active transport options would reduce deaths by 116 people every year due to increased physical activity and 6 deaths as a result of improved air quality

(Lindsay, Macmilan, & Woodward, 2011). Further research into the benefits of reduced noise may provide further motivation to consider these options.

While dense neighbourhoods may reduce the vehicle kilometres of private vehicles, the transport of goods and public transport will still require larger vehicles which this research has found to be associated with increased treatment of mental health. International literature has found that public transport is a significant predictor of noise annoyance (Paunović et al., 2014). Rail is less annoying than vehicles (Brons, Nijkamp, Pels, & Rietveld, 2003; Miedema & Vos, 1999). If reducing both air and noise pollution is a goal, light rail may be favourable compared to buses due to their use of electric propulsion, although the development of hybrid buses may offer improved outcomes in the future (Brand & Preston, 2003). These results also suggest the prioritisation of rail for the transport of goods between urban areas, rather than via road, should be a serious consideration in the future.

Alternative solutions offer more immediate resolutions to reduce the harm of these vehicles, for example, zones can be introduced based on time of day or neighbourhood land use. As the level of noise and vibrations increases with speed (Brons et al., 2003), having strict lower speed limits for these vehicles in residential areas, near schools, and hospitals will likely be beneficial (Woodcock et al., 2009).

This discussion highlights the necessity of a good understanding of how decisions about the environment impact health and well-being. While altering the environment is a useful policy as it can impact multiple focus points simultaneously, it also offers the risk of unintentionally creating adverse outcomes on alternative dimension. Including a range of perspectives during the design and planning on interventions is recommended to alleviate this risk. Although despite the obvious benefits of collaboration, there continues to be very little cross-disciplinary education and engagement between public health and urban planning (Botchwey et al., 2009; Pilkington, Grant, & Orme, 2008). The current Auckland context with multiple critical pressures may offer a catalyst for this process.

6.4 Future research opportunities

Future research should be considered with improved data, including the traffic exposure measures, neighbourhood confounders, and individual level data for both the treatment group and control group.

Using a case control or a cohort methodology with a similar exposure variable would allow for greater insight into the difference between ethnic groups, gender and age. As discussed earlier, ethnicity in particular proved to be difficult to detangle the variety of effects that it may have possibly had on mental health. Other components that should be considered with improved individual data should include the effect of exposure time, and the individual level income and living environment (e.g. live in own home versus renting).

The use of a measure of mental distress such as the Kessler score rather than treatment would offer the benefit of reducing the bias that treatment seeking behaviours may have had on the treatment group, and providing a graduated measure of mental wellbeing opposed to the more severe level that prescription is associated. However, as highlighted in the discussion of the summary statistics, there may be bias in the NZHS if individuals do not feel comfortable discussing their personal details directly with an interviewer.

Improved traffic data, and/or actual noise and air pollution measurements would provide an opportunity to develop this research further. As discussed previously, high quality monitored data across a wide urban area is rare, but it would offer the opportunity to investigate whether one component has a greater impact than the other. The availability of noise data would enable a variety of health research in the New Zealand context, and contribute to our understanding of what is harmful and how it could be managed.

This thesis briefly touched on environmental inequality, with the simple univariate regressions indicating that there may be disparities in traffic exposure between socio-economic and cultural groups in Auckland. This component may warrant further investigation, especially to ensure that vulnerable groups are targeted effectively.

This research has assumed that the primary component of traffic that affects mental health is air pollution and noise pollution, which is a reflection of the literature available on the subject. As highlighted throughout this thesis, mental health outcomes are likely to be affected by an individual's perceptions of their environment. Chronic stress, feelings of powerlessness, and the disruptive effect it has on wellbeing, are all very plausible routes for explaining the effects of these exposures and reactions. A qualitative study that investigates the perceptions and possible mechanism in which these stressors affect health would be valuable. In particular, how these perceptions vary across ethnicity, socio-economic status, gender, and age, in the New Zealand context.

7. Conclusion

Previous research into the effect of motorways and heavy traffic in Auckland have found that roads and traffic are a source of stress, and reduce quality of life (Pattinson et al., 2015; Welch et al., 2013). The international literature widely reports roads and associated pollution as a source of annoyance and concern, and some studies have found an association with adverse mental health outcomes.

There are a number of possible mechanisms by which roads may affect mental health, and identified the stress and disruption to daily activities from air and noise pollution to be the most pertinent stressors. As far as the author is aware, no research exist that has explored the relationship between mental health and traffic exposure at the scales used in this thesis. The majority of previous research considered small areal studies, comparing the extremes of exposure and measuring well-being with self-reported measures. This thesis contributes to this research gap due to geographic scale that it was performed at, and the use of address level environmental exposure and health measures.

A significant strength of this research was the access to address point level data for individuals treated for mental health for the entire Auckland urban area. A challenge of the research was to create a point level exposure methodology to reflect the expected variation. The availability of high quality and comprehensive data for non-state highways roads required the development of a methodology to extrapolate out the data available. The methodology used has limitations, and requires further research in order to validate the assumptions made.

The analysis found no association between traffic volume or traffic density and mental health treatment for all road classes and at all buffer distances. However, statistically significant correlations were found with the proportion of heavy commercial vehicles for motorways (road class 1) and arterial roads (road class 2). Controlling for neighbourhood contextual features including a combination of deprivation, median household income, ethnic fragmentation, home ownership, proportion of individuals with bachelor's degrees, single parent families and green space, did reduce the odds of the observed relationship to mental health.

Other findings of interest include the strong relationship between contextual neighbourhood factors that are associated with deprivation and social capital, and mental health. Mental health treatment correlated strongly with higher deprivation and lower social capital indicators, while there is also an association between these neighbourhood qualities and exposure to traffic, suggesting an element of environmental inequality in Auckland. While it is difficult to influence the location in which people live, it does offer the opportunity to target these groups effectively with relevant interventions. Such an approach, informed by spatial patterns, may help to reduce the negative effects that living in these neighbourhoods has.

Other implications of the research suggest that the issue of traffic noise in urban areas should be considered by urban design and public health professionals. While the spatial exposure research investigating traffic noise and mental health is limited, there is a growing body of literature indicating that traffic noise can be damaging to a wide range of health outcomes. The findings of this research regarding heavy commercial vehicles contribute to this, as they are noticeably louder and produce annoying vibrations. Despite this evidence, the conversation regarding controlling noise is lacking in comparison to air pollution. Initial steps of monitoring to understand the extent of the problem in New Zealand, and to develop effective guidelines around noise levels that result in stress and disruption would be required to develop effective policy that will produce healthier environments for New Zealanders.

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