TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON

Commuting without Polluting.

The Economic Geography of Active Transport in Aotearoa New Zealand

by

Laura McKim

A 90-point thesis submitted to Victoria University of Wellington,
in partial fulfillment of the requirements for the degree of
Master of Environmental Studies

School of Geography, Environment and Earth Sciences,
Victoria University of Wellington
April 2012

Abstract

New Zealand has one of the highest rates of car ownership in the world and as such contributes disproportionately to global climate change, cardiovascular disease and obesity. This need not be the case for, among other things, New Zealand cities have the potential to increase the use of walking and cycling.

There is substantial evidence that modifying the urban form and design of neighbourhoods can influence the use of active transport. However factors such as those related to employment and income have so far received far less attention as possible influences.

This thesis explores the impact of income on the use of active modes of transport for commuting. Modal choice is sensitive to both income and relative costs. While historically the car has replaced walking and cycling as wage rates have risen, in cross section the relationship between income and active commuting takes quite a different form. While higher incomes do allow people to purchase motorised transport, they also allow workers to purchase shorter commutes and to integrate active modes into more complex trip chains. As a result, the probability of active commuting rises with income. As such, raising urban density can help stem some of the negative environmental and health effects of rising affluence.

Keywords: Active transport, commuting, income, density, New Zealand Household Travel Survey

Acknowledgements

I would first like to extend deep gratitude to my supervisor, Professor Philip Morrison. The time, energy, thoughtful feedback, technical expertise and meticulous editing he afforded me over the course of this process were completely invaluable to the creation of this thesis.

I would also like to acknowledge and thank Lynley Povey (formerly) at the Ministry of Transport for facilitating use of the New Zealand Household Travel Survey data files and for her willingness to answer any technical questions; Claire Pascoe and the rest of the Sustainable Transport Team at Greater Wellington Regional Council for providing me with a fantastic work experience as well as an interesting data resource, and for ultimately helping to shape the focus of this thesis; the Victoria University Scholarships Committee for awarding me the Kathleen Stewart Scholarship; Cycle Aware Wellington for providing me with generous sponsorship to attend the excellent *2walk and cycle* conference in Hastings in February 2012, which helped to further invigorate my enthusiasm for active transport research; Elizabeth Connor and Elf Eldridge, organizers of the inaugural Victoria University postgraduate *Tell us a Story* science storytelling competition, for giving me an excellent opportunity to relay my active transport story to the public; my Oxfam Trailwalker team mates, Steph, Claire and Perrine who provided the best company imaginable throughout an active transport odyssey of epic proportions; Joe McCarter for the helpful comments; my office mates in room 102a who were a pleasure to share a little corner of the Cotton Building with; the Seine street crew for sharing ideas, encouragement and Sunday roast dinners; my friends and family for all the goodness they generate in my life; my partner Richie for being in my nature; and all the walkers and cyclists for getting on with the business of active transport.

Lastly I would like to acknowledge my beautiful Nan, Molly Miller, who passed away during the writing of this thesis but was and continues to be a great inspiration to me.

Commuting without Polluting.
The Economic Geography of Active Transport in Aotearoa New Zealand

List of tables

List of figures

Prologue

Perhaps walking is best imagined as an 'indicator species', to use an ecologist's term. An indicator species signifies the health of an ecosystem, and its endangerment or diminishment can be an early warning sign of systemic trouble. Walking is an indicator species for various kinds of freedom and pleasures: free time, free and alluring space, and unhindered bodies.

~ Rebecca Solnit,
Wanderlust: A History of Walking

The bicycle is the perfect transducer to match man's metabolic energy to the impedance of locomotion. Equipped with this tool, man outstrips the efficiency of not only all machines but all other animals as well.

~ Ivan Illich,
Energy and Equity

When I was younger, it was only during a torrential downpour that I was granted an exemption from my daily cycle commute to school. Even on the frostiest Waikato morning, I donned a scarf and woolen gloves and sulkily resigned myself to the familiar 5km ride across town. I resented my mum for being so hard-line about her 'no-lift' policy. As far as she was concerned, I had a perfectly good bike and a perfectly good body to power it with, and that was the end of that. No longer a sulky teenager (and with the luxury of retrospect), I am now incredibly grateful my mum forced me to appreciate the value of active transport early on. And these days it is with pleasure rather than reluctance, that I set out on foot or by bike!

I have written this thesis because I believe that physical inactivity is a major public health problem in New Zealand and that active transport constitutes a cost-effective and equitable way to reduce the incidence of serious health problems related to sedentary lifestyles, such as obesity, high blood pressure and cardiovascular disease.

Another fundamental position underpinning this research is that climate change poses an unprecedented challenge for humankind and that a modal shift from motorized to non-motorised transport is one way in which climate change-inducing carbon emissions can be reduced. I believe that active transport should therefore be recognized as an inexpensive and appealing instrument in addressing climate change.

My thesis is predicated on the assumption that an increase in travel by foot and bike will have a positive effect on community connectedness, through the creation of more livable, vibrant streets and the opportunity to generate greater social capital.

With these points in mind, I would happily describe myself as an active transport enthusiast with a keen interest in seeing a radical increase in the use of human-powered, non-motorised modes of travel.

Chapter 1. Introduction

Economic growth allows people to improve their material standard of living by raising their incomes. Average incomes in New Zealand rose by 67% between 1998 and 2011 and the upward trend shows no sign of abating (Statistics NZ, 2012).[1] As incomes have increased, however, so too has demand for car ownership. Nationally, the average number of vehicles per household increased from 1.36 in 1986 to 1.57 in 2001, and the proportion of households with more than one vehicle increased from 37% to 49% over the same period (Conder, NZ Transport Agency, 2009, p.22). Indeed, New Zealand is now among the countries with the highest rate of car ownership in the world, with 607 cars per 1000 population (The Economist, 2009, cited in Tin Tin et al, 2009).

Corresponding demand for car travel has also risen markedly. Results from the ongoing New Zealand Household Travel Survey show that kilometres travelled by car drivers increased by over 63% between the 1989/90 and 2005-08 survey periods. Time spent behind the wheel of a car increased by 30% between 1989/90 and 1997/98 and by a further 19% between 1997/98 and 2003-06. Driving time has increased since then, albeit more slowly (Ministry of Transport, 2009a, p.4-5).

One of the consequences of the purchase of motorised travel has been a decline in New Zealanders' use of active transport in general and active commuting in particular. Walking to work decreased over the 30-year period from 1976 to 2006 from 12.8% to 7.0%, and although the prevalence of cycling to work rose somewhat from 1976 (3.4%) to 1986 (5.6%), it has diminished since then (to 2.5% in 2006) (Tin Tin et al, 2009, p.3).

---

[1] The average weekly income across all demographic groups in New Zealand in 1998 was $419 compared with $703 in 2011.

Will even greater affluence continue to reduce active commuting in favour of the comfort and convenience of private vehicles? If so, what are the steps we need to take to weaken the positive relationship between income and car use and strengthen the connection with active transport? The answer lies not in the historical, longitudinal relationship between income and active commuting, but in the cross-sectional link and the way the relationship between the two is mediated by employment density.

1.1 Opportunities

There are at least five compelling reasons for stemming the movement away from active commuting and attempting to reverse it: health, sustainability, social connectedness, public finance, and labour productivity.

Physical activity is widely regarded as a crucial ingredient in achieving positive health outcomes. Yet physical (in)activity remains a significant public health issue in many countries, because of the way affluence buys relief from physical effort. In New Zealand, it is conservatively estimated that five times as many deaths result from a lack of activity as result from road trauma (Ministry of Health, 2003). As a result, up to a third of adults are insufficiently physically active to protect their health (SPARC, 2003).

Most efforts to engage people in greater physical activity have been promoted within the sphere of leisure (Ogilvie et al, 2004), but promoting physical activity as part of the work experience, as a mode of commuter transport, may be more cost-effective (Sevick et al, 2000). Incorporating physical activity within the commute may constitute a more convenient way to incorporate the necessary level of exercise into people's daily lives (World Health Organization, 2002; Garrard, 2009), while simultaneously producing myriad co-benefits (Litman, 2004).

Secondly, a modal shift from motorized to non-motorised modes of transport would help reduce society's reliance on fossil fuels, and reduce carbon emissions (Woodcock et al, 2007). Less cars on the roads also means less traffic congestion, ambient noise and air pollution, generating benefits for both environmental sustainability and physical health.

Thirdly, there may be social benefits as well; heightened engagement in non-motorised modes of transport such as walking, cycling, skating and scootering has been shown to cultivate more livable streets, inducing community enhancement and stimulating social capital (McKenzie-Mohr, 1999; Leyden, 2003). More people out walking and cycling is also likely to improve safety (or at the very least the perception of it), especially at night when the streets can feel dangerous and threatening, especially to the most vulnerable.

Fourth, from an economic perspective, the mental and physical health benefits gained through active transport may help reduce the financial burden on the health care system (Giles-Corti, 2010). Cost-benefit models show that investing in active transport in New Zealand costs a small fraction of the cost of investing in motorised modes, and that the health benefits of a five percent modal shift from car to bicycle outweigh the costs ten to one (Woodward and Macmillan, 2012).

Lastly, in a workplace context, productivity gains are achieved through a reduction in absenteeism (Parks and Steelman, 2008), as well as more energetic and alert employees. Research suggests that job performance is positively associated with moderate and vigorous-intensity physical activity engagement, and perceived work quality is positively linked to moderate-intensity physical activity engagement (Pronk et al., 2004).

The potential of more active transport to tackle a diversity of challenges such as the obesity epidemic (Bassett et al, 2008), resource scarcity, social isolation, and climate change has led to a substantial literature on the topic. Although concentrated primarily within the health and transport sectors, research now embraces several other disciplines including psychology, geography and economics.

1.2 Approaches

To date, the vast majority of work centred on active transport has focused either exclusively or predominantly on the barriers (e.g. Southworth, 2005; Nagel et al, 2008; Pucher et al 2010). For example, considerable attention has been given to the supply side, to urban planning and design, with particular emphasis on bike lanes, pedestrian walkways, and the level of access and linkage of pedestrian/ bicycle facilities to appropriate locations.

While the attention to barriers is necessary, attention to infrastructure solutions alone will not be sufficient to elicit behaviour change in commuters. It is equally imperative to examine those influences on demand that affect people's inclination and ability to take up active modes. Given that economic growth is the main objective of most governments around the world, including New Zealand's, it is important to question what effect increasing affluence might have on the propensity to get physically active within the daily commute.

From this perspective, the relationship between work and income is central. However, few authors have examined the interactive effects of work and income on active transport use, and even fewer have explored the impact of income specifically in an active commuting context. This is surprising given that work is a dominant activity in most adults' lives (Haworth and Veal, 2004), and that the commute is a daily reality for most working-age individuals. Work hours and personal income (which dictate the ratio of time to money at an individual's disposal) both inform and modify our lifestyle choices (Schor, 1991). The lack of attention to the cross-sectional relationships between affluence and active commuting is therefore the key point of departure for my study.

Essentially, contemporary paid work has two consequences for commuter mode choice. Employment creates income and the ability to substitute mechanical for physical effort, and this is the main reason why a smaller and smaller proportion of workers walk and cycle to work each day.

The second consequence of work is the time constraints it imposes. The opportunity cost of using slower modes of transport is higher for those with less free time. Furthermore, an increase in the wage rate has the effect of raising the opportunity cost of time spent outside the labour market. Therefore the opportunity cost of time rises with both work *and* income. This comprises an additional, and conceptually distinct, reason why historically active commuting has declined as income has risen.

Both resource *and* opportunity cost consequences of rising incomes interact with modal choice in ways that are not fully understood. What my thesis shows is that one cannot simply convert the historical experience of income and its associated demand for higher and higher rates of car ownership onto the contemporary urban experience. The spatial does not reflect the historical in any simple way. The way income relates to modes of commuting in cross section differs in a number of important respects. At any given point in time, active commuting does not simply decline with higher income as the historical experience might suggest. In fact, as I am able to show, the contrary applies, namely that the probability of using active modes of transport for commuting actually rises in the majority of circumstances, while, in other cases, it declines over the first half of the income distribution and rises thereafter. These patterns I uncover in contemporary New Zealand are not those one might expect – despite the fact that affluence is continuing to raise car ownership.

The resolution of this paradox of active commuting rising with income (in cross-section) lies in exploring the spatial, and the way in which the relationship between active commuting and income in New Zealand is modified by the characteristics of the urban environment and the way the geographical relationship between work and home is modified by income.

1.3 Outline

Chapter 2 will outline some of the reasons why active transport use has declined in recent decades, in parallel with an increase in car use. I will then describe how the term 'active transport' has been applied in previous studies, and its use has been measured.

Chapter 3 reviews the questions that others have asked about active transport, and active commuting in particular, as well as how their research was conducted and what they discovered.

This leads on, in chapter 4, to the development of my conceptual argument regarding the central relationship between active commuting and income. I then discuss my theoretical orientation, positionality, research paradigm and my application of mixed methods.

Chapter 5 introduces the New Zealand Household Travel Survey data set used in my analysis, and the opportunities for the study of active commuting this survey opens up. I then show the distribution of values for the main variables of interest and offer as background a descriptive analysis of regional and seasonal variations in commuter walking and cycling.

Having introduced the data, chapter 6 explores of the relationship between active commuting and income. I commence with an examination of individual and household variables (the aspatial story), and then move on to exploring different geographical levels and the way that location interacts with income in shaping commuter mode choices (the spatial story).

My next step, in chapter 7, is to retell the story in a multivariate framework, where I build a sequential model so that appropriate controls on the income-active commuting relationship can be introduced.

Chapter 8 explores the application of a multilevel model in order to better address the embedded nature of the geographical context in which the active commuting decision is made.

An interesting regional outlier revealed in the preceding chapters is a case study of Wellington, which I consider more closely in chapter 9. The case study incorporates qualitative interview data from a Wellington regional active commuting programme to deepen the understanding of issues surrounding walking and cycling to work in this region.

Finally, in chapter 10, I restate the aims of this research before considering what I have learned about the impact of income on active commuting and how policy-makers might use these insights. Limitations of the data and research design are then discussed.

Chapter 2. Active Transport

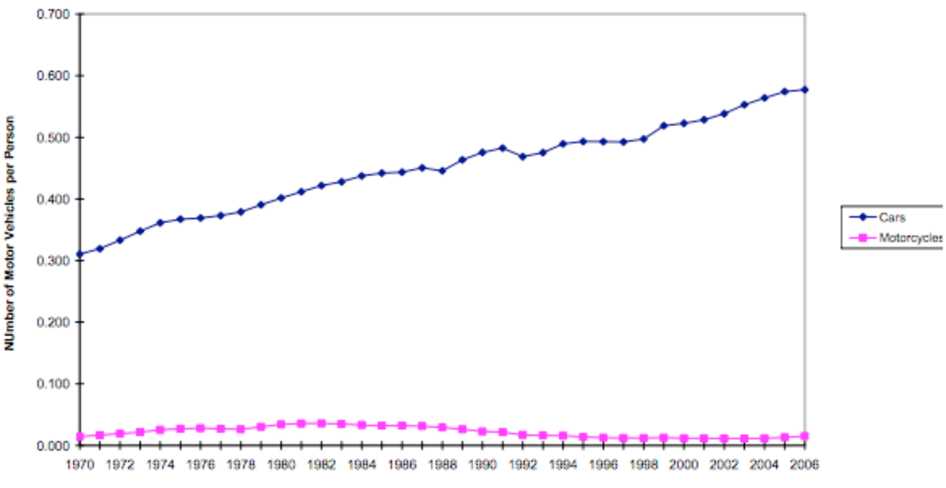
This chapter provides some context for the analysis to follow. I do this firstly by describing relevant aspects of New Zealand as the empirical setting. I then distinguish between the different ways others have defined and measured active transport use before showing how I use the term in this thesis.

2.1 Income and car use in New Zealand

The empirical setting for my study is the island nation of New Zealand (Māori: Aotearoa), in the south-western Pacific Ocean. It is made up of two main islands - the North (Te-Ika-a-Maui) and South (Te Wai Pounamu) Islands - and a number of smaller islands, with a total area of 268 000 sq km. New Zealand has a temperate maritime climate. The influence of the sea on the climate accounts for the less extreme differences between seasons than is found in many parts of Europe and the Americas (Virtual New Zealand, 2012).

The temperate climate means that, by and large, conditions for walking and cycling in New Zealand are relatively favourable year-round. Despite the favourable climate, there has been a steady rise in car ownership as figure 2.1 shows.

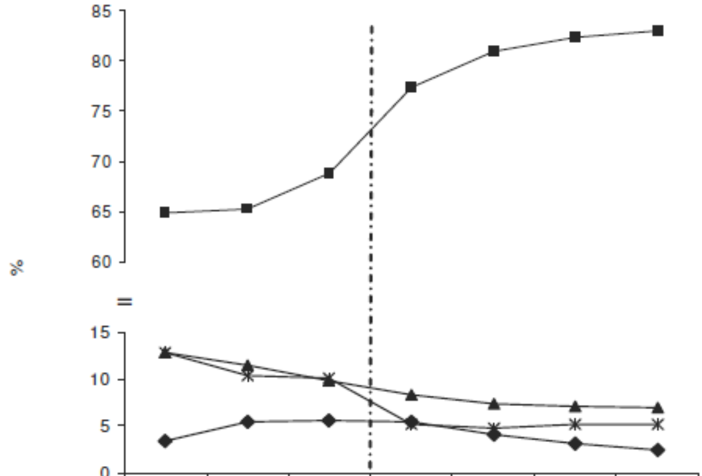
Figure 2.1. Motor vehicle ownership per person, New Zealand 1970-2006.



Source: Conder, 2009.

Correspondingly, over approximately the same period, the probability of commuters walking or cycling has declined, as depicted in figure 2.2. The percentage of all commutes which mainly involve walking fell by almost half over the thirty-year period, from 12.75% to 6.98%.

Figure 2.2. Mode of travel to work on the census day in the usually resident employed population aged 15 years and over. New Zealand 1976 to 2006.

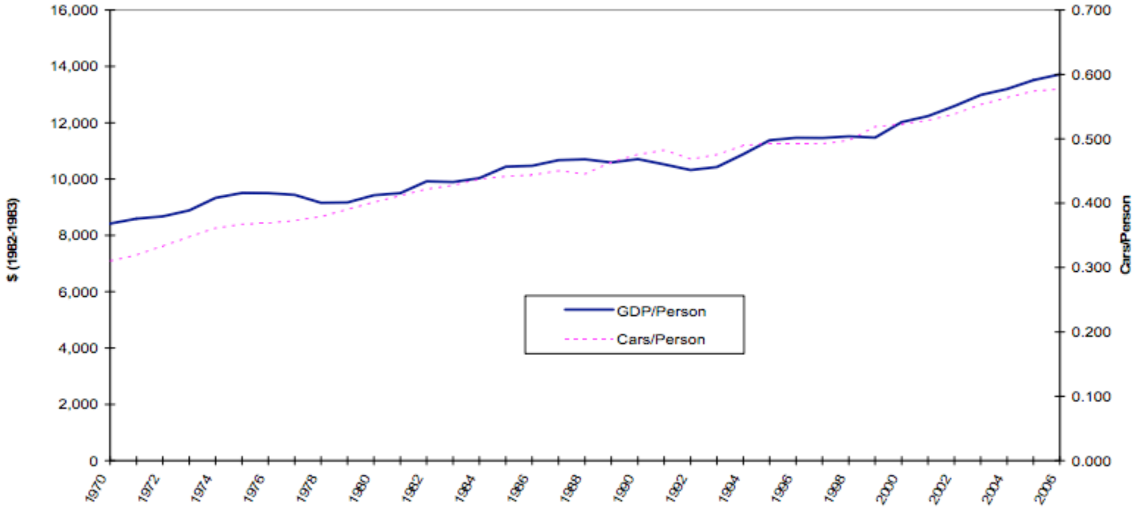


	1976	1981	1986	1991	1996	2001	2006
Vehicle driver/passenger	64.81	65.27	68.82	77.34	80.87	82.33	83.00
Bicycle	3.40	5.46	5.59	5.39	4.04	3.12	2.52
Walk	12.75	11.47	9.88	8.36	7.35	7.10	6.98
Public transport	12.75	10.37	10.05	5.14	4.77	5.16	5.24

Source: Tin Tin et al, 2009, p.3. *International Journal of behavioral Nutrition and Physical Activity.*

This thesis contends that commuters' propensity to walk or cycle to work in any period is affected by their level of income. We can see the extent to which car ownership levels parallel changes in real income (GDP per person) in figure 2.3. As GDP per person rose from $8,500 to $14,000, so cars per person rose from 0.31 to 0.58. While not establishing causation, this evidence is symptomatic of the well-known relationship.

Figure 2.3 Trends in GDP per person and cars per person, New Zealand 1970-2006



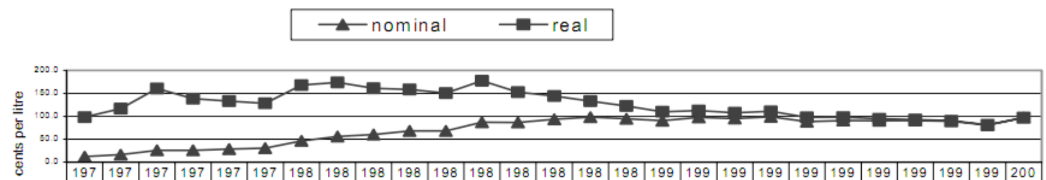
Source: Conder, 2009

The previous three graphs support the argument that there is a demonstrable relationship between rising income and car ownership, and a corresponding decreased use of active transport. However there are other factors besides income that have led to an historical increase in car use in New Zealand. The first of these is the affordability of fuel to consumers.

Price changes

Figure 2.4 shows that over the period 1974 to 2000 the nominal retail price (the dollar value paid at the pump by consumers) of petrol rose from 12.3 to 97.1 cents per litre. However, in terms of real retail prices (the price relative to the cost of living), the price in the 1990s was lower than prices in the late 1970s and 1980s (NZ Parliamentary Library, 2000). In other words, relative to the cost of living, petrol has become more affordable in New Zealand.

Figure 2.4 'Nominal' and 'real' retail prices for regular grade petrol, 1974-2000, years ended March

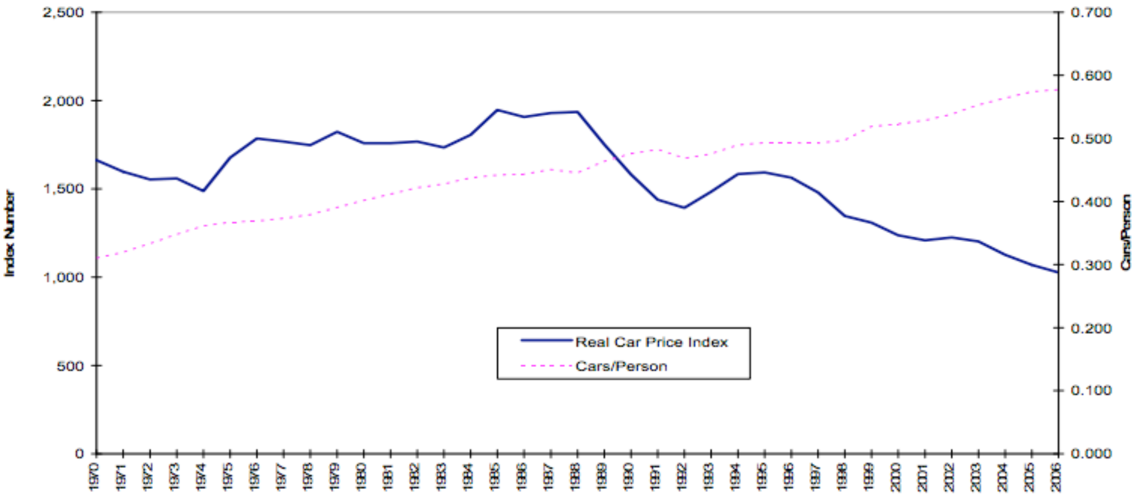


	197	197	197	197	197	197	198	198	198	198	198	198	198	198	198	198	199	199	199	199	199	199	199	199	199	199	200
nominal	12.3	16.4	26.1	26.1	28.7	30.7	46.5	56.0	60.0	68.0	68.0	87.0	86.3	93.5	97.9	94.5	90.1	97.7	94.8	98.7	88.3	90.9	90.1	90.9	89.0	80.9	97.1
real	97.9	116.	160.	138.	132.	128.	167.	173.	160.	158.	150.	177.	152.	144.	133.	122.	109.	112.	107.	110.	97.6	98.1	94.2	93.0	90.1	81.1	97.1

Source: *New Zealand Energy Data File*, Ministry of Economic Development, July 2000, Tables I.3 and I.4.

Cars themselves have also become cheaper. Figure 2.5 shows that car prices have decreased over successive decades and how, since the late 1980s at least, this has coincided with an upward trend in cars per person.

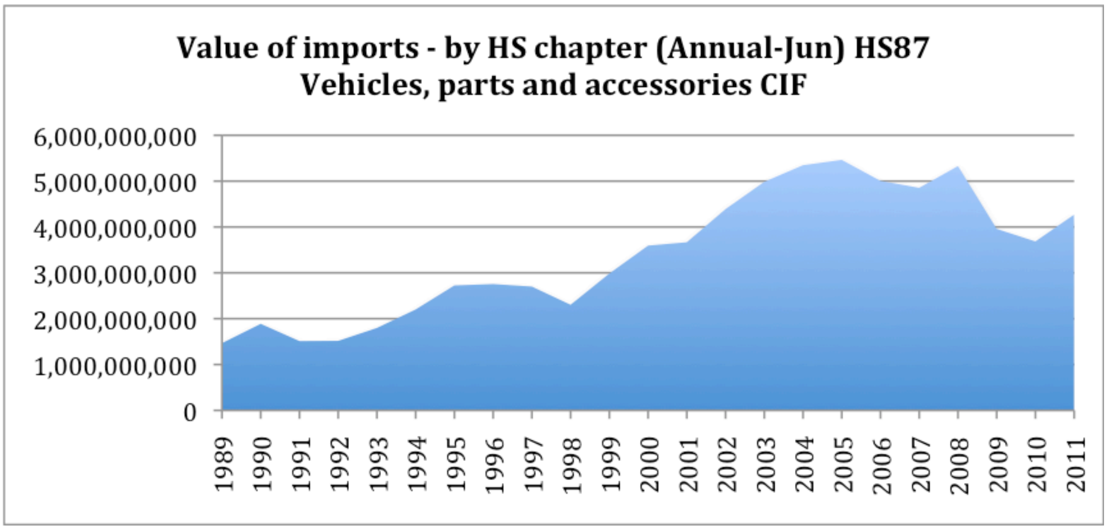
Figure 2.5. Trends in average real car prices and cars per person, New Zealand, 1970-2006.



Source: Conder, 2009

These trends are reflected in the value of vehicle imports to New Zealand as evident in figure 2.6. The vast increase in imported cars on the market up to 2008 contributed to their greater affordability, an upsurge referred to as "the used import epidemic" (NZ Automobile Association, 2008).

Figure 2.6. Value of vehicle imports, annual to June. New Zealand 1989-2011



Source: Statistics NZ, 2011

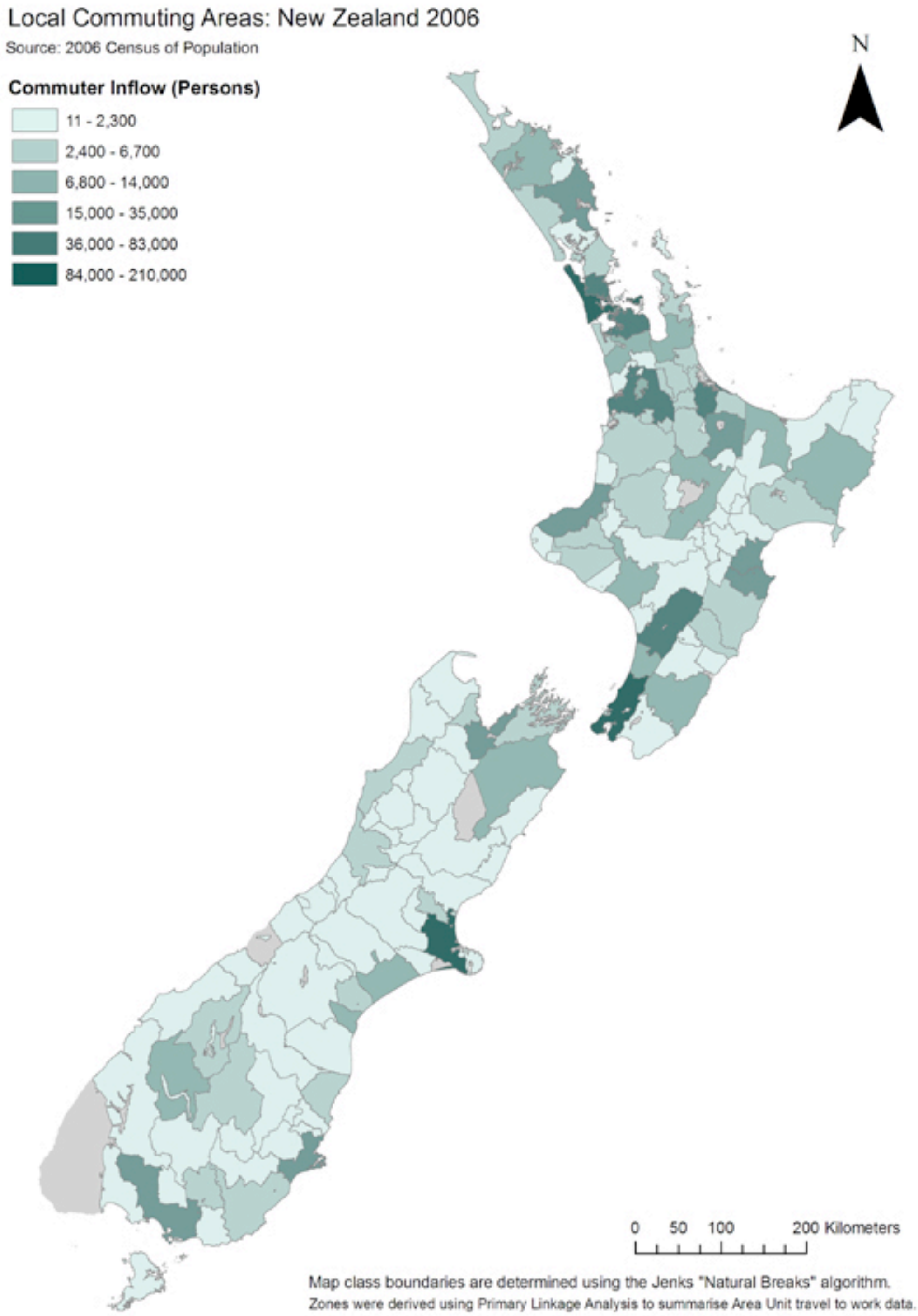
Infrastructure

Another factor to consider in the growth of the automobile market is the pattern of transport infrastructure investment. Transport policy in New Zealand has traditionally been, and continues to be, dominated by roading projects. To illustrate this point, the current National government proposes to spend \$21 billion on roading infrastructure after 2012, yet only \$0.7 billion on other transport projects such as public transport, walking and cycling (New Zealand Press Association, 2010).

The increase in average incomes and car use and simultaneous decrease in active transport use has occurred in the context of growing urbanization and the expansion of local labour markets throughout New Zealand. By world standards, New Zealand is a highly urbanized nation, with 72% of the population residing in the 16 main urban centres (NZ Department of internal Affairs, 2011).[2] New Zealand's increasingly urban distribution has implications for commuting patterns across the country. Figures 2.7 and 2.8 depict the degree to which the largest urban areas dominate employment in New Zealand. Figure 2.8 shows domestic commuting zones based on the inflows of employed people into the area's employment sites. The Auckland metropolis, Wellington's four cities, and Christchurch had the largest commuting inflows. Other cities in New Zealand, such as Hamilton and Dunedin, are also major commuting centres (Statistics NZ, 2007).

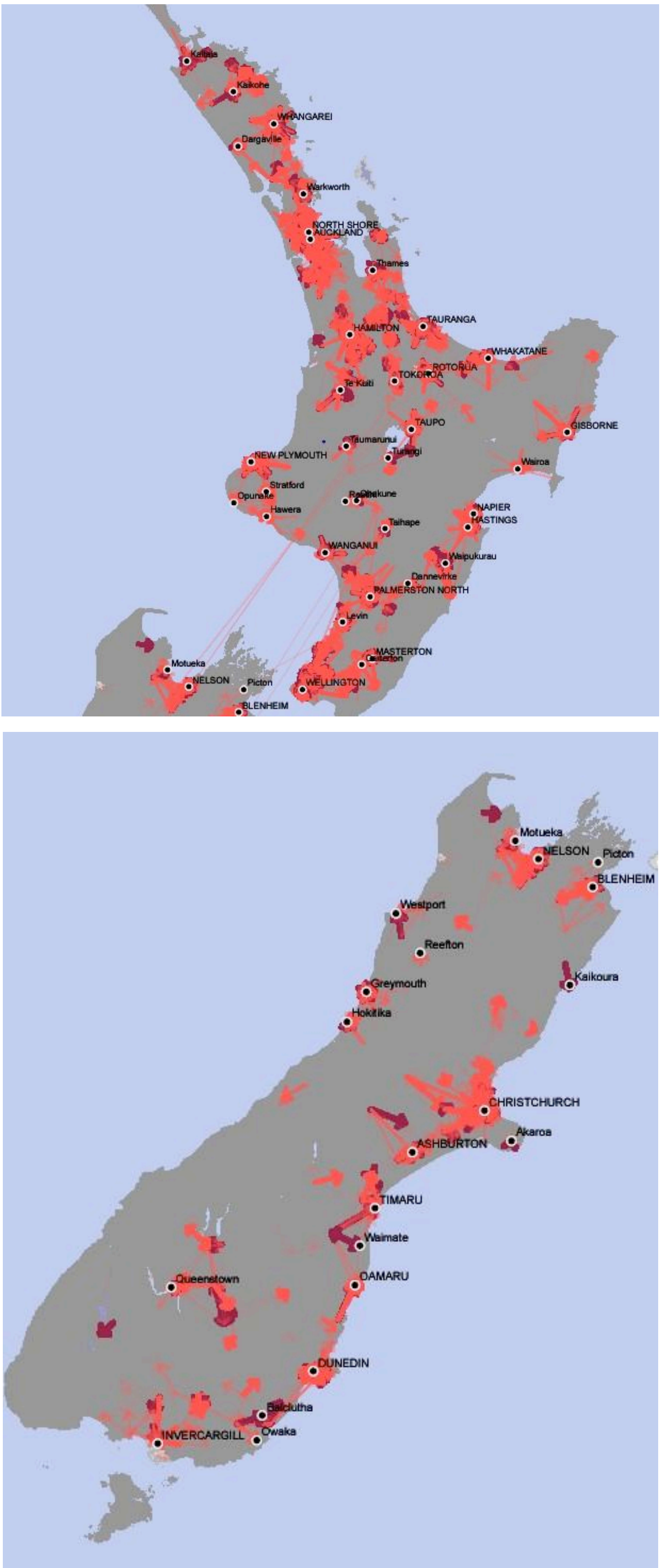
[2] Nearly 87% of New Zealanders live in urban areas, compared with 65% in Japan, 60% in Ireland and 22% in Samoa (Population Division of the United Nations Secretariat, World Urbanization Prospects, 2004).

Figure 2.7 Local commuting areas in New Zealand. 2006 Census.



Source: *Workforces on the move,* Statistics NZ, 2007.

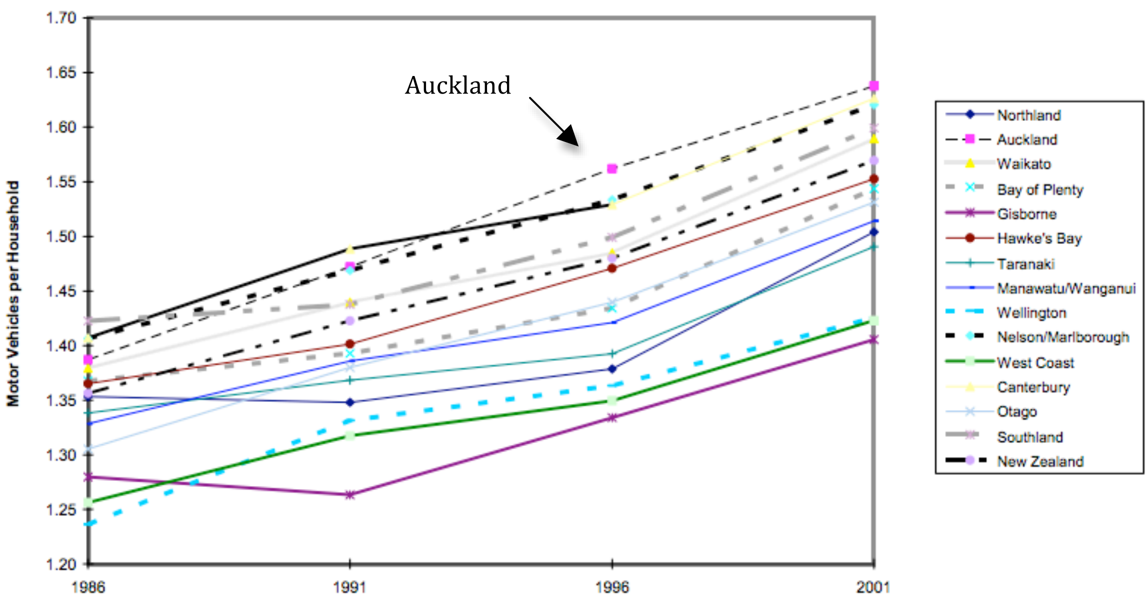
Figure 2.8. Commuting flows in North Island and South Island. 2006 Census.



Source: *Workforces on the move,* Statistics NZ, 2007.

Despite recent population growth across all regions of the country, New Zealand's population is small and highly dispersed compared with other countries its size. Though in area it is comparable in size to Italy, Japan, or the United Kingdom, in population it is much smaller than any of the above, with only 4.4 million people (Statistics NZ, 2012). The highly dispersed nature of the population is another factor implicated in New Zealand's dependence on the car as a mode of travel. To illustrate, while Auckland has the fastest growing population in the country, the population of the region is quite geographically dispersed, and this low urban density accounts for the higher rate of car ownership per household in Auckland than elsewhere, as demonstrated in figure 2.9. Auckland had the highest level of vehicles per household in 2001 at 1.6.

Figure 2.9. Vehicle ownership per household by region, New Zealand 1986-2001.



Source: Conder, 2009.

2.2 Active transport - Definitions and measurement tools

What is the best way to analyse active transport use? The following describes how active transport has been defined in previous studies, as well the methods employed to measure active transport use.[3] I discuss the unit of measurement used, such as whether prevalence of walking and cycling was calculated by number of trips, by trip duration, by distance travelled, or a combination of these as well as the field or discipline in which the research was carried out.

As of 1976 the New Zealand Census has asked respondents to identify their "main means of travel to work" on Census day. Analyses are typically limited to respondents aged 15 years and over. The terms "active travel" and "active transport" are used interchangeably throughout one such study to refer to the use of walking and cycling for commuting purposes (Tin Tin et al, 2009).

A health-related study based on the University of Bristol Staff Travel Survey used the terms "active travel" and "active commuting" to describe walking and cycling as modes of daily transport (Brockman and Fox, 2011). The main survey variable used was the employees' usual mode of transport to work. This was determined through responses given in the survey to the question, "How do you travel to work?", categorised into 'usually', 'sometimes' and 'occasionally'. Responses were grouped into 'walk', 'cycle', 'car user' and 'other' categories.

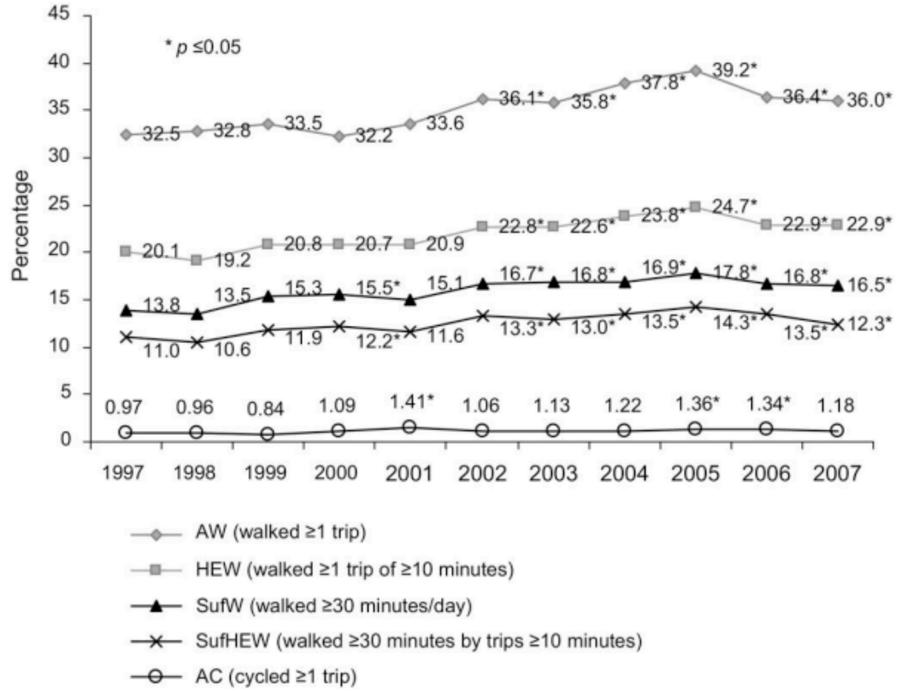
An epidemiological application of the Australian Household Travel Survey used the term "active travel" to refer to utilitarian walking and cycling trips, which were broken down in terms of purpose, duration and distance (Merom, 2010).[4] These responses were obtained from respondents' travel diaries covering a 24-hour period. Merom's analysis measured active travel use over time by exploring three dimensions: number of trips, duration in minutes, and distance in kilometres. Figure 2.10 shows two of the three measures (number of trips and trip duration). It demonstrates that, compared to 1997, all indicators were significantly higher from 2002 onwards.

---

[3] Measurement refers to the particular active transport-related question/s posed in a survey instrument as well as the methods used to directly observe such use.

[4] Utilitarian walking and cycling refers to trips made for purposes such as work and errands, as distinct from trips made for the purpose of leisure.

Figure 2.10. Adjusted prevalences of any walking (AW), any cycling (AC), health-enhancing walking (HEW), sufficient walking (SufW), and sufficient health-enhancing walking (SufHEW) in the Sydney Greater Metropolitan Area from 1997 to 2007



Source: Merom et al, 2010, p.118. *American Journal of Preventive Medicine.*

Data from the 2005 UK Time Use Survey was used to assess the prevalence and socio-demographic correlates of health-enhancing active transport in the UK (Adams, 2010). Active transport was defined as, "any walking, jogging or pedal biking for purposes other than enjoyment." Total time spent on active transport was calculated from the number of 10-minute slots in which the main activity was travelling by walk/jog or pedal bike, and the reason anything other than enjoyment. The Time Use Survey was used to determine whether any active transport was engaged in and, amongst those who reported any, how much time was spent on it. The sole unit of measurement in this study, therefore, is time in minutes.

The four active transport studies outlined above were all undertaken by researchers working in the area of health and physical activity. Researchers in other fields have sometimes used looser or more ambiguous definitions. For example, a psychological study introduces the term 'active transportation' as simply "moderate intensity activities…such as walking and cycling" (de Bruijn et al, 2009, p.189). Unlike other active transport research (e.g. Merom, 2010; Adams, 2010), de Bruijn's study does not specify that active transport is typically only used to describe utilitarian walking and cycling trips rather than those whose main purpose is leisure. Also, this research only examines bicycle use as a form of active transport. A questionnaire asked respondents to indicate how many days per week they used a bicycle as a means of transportation (n=317 as well as how long (in minutes) they were riding (de Bruijn, 2009, p.190).

Definitions of active transport can sometimes be even broader. A study in the area of Transport Policy that assesses commuting habits in an Australian university (n=2,210), for example, states that, "Active forms of transport—such as walking, cycling and public transport use—are 'active' because they involve physical activity. Even public transport fits the definition of an 'active mode' because typically it involves walking or cycling at either end of the journey" (p. 240). This study used an online survey instrument containing two questions on participants' current travel behaviour, as well as a one-week travel diary where respondents were asked to identify the mode used for each trip to or from the University during the previous week. The measurement of active transport use incorporated two dimensions: frequency and trip distance.

The above discussion reveals some subtle differences in how the terms 'active transport', 'active travel' and 'active commuting' have been defined. It also highlights the variety of measurement techniques. Five of the six studies outlined above included *frequency* of active transport use in their analyses by recording the number of trips taken by active modes. Three of these studies also incorporated *distance* into their analyses by calculating the distance travelled by participants using active modes. Three of the studies used the dimension of *time* by establishing the duration of respondents' active transport trips in minutes. Only one of the six studies (Merom et al, 2010) incorporated all three dimensions.

None of the studies reviewed above measured active transport use by directly observing walkers and cyclists. This approach is rare but has been utilised by one or two researchers. For instance, an Austrian study concerning the effects of weather on cycling used hidden video to record working day and weekend cycling patterns (Brandenburg et al, 2007). These data were used to classify recreation and commuting cyclists. However, in order to gain greater insight into individuals' overall active transport patterns, the researchers also obtained additional information via a questionnaire distributed to commuter cyclists in the study area (n=890).

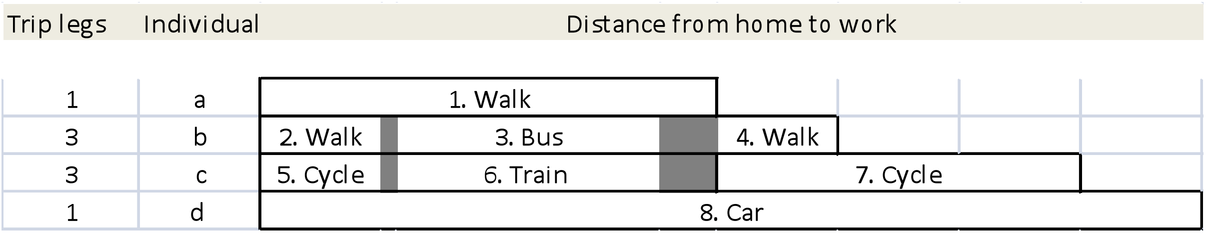
My thesis conceptualises active transport in a way that aligns well with previous definitions. It also seeks to provide a definition that is a good fit for the quantitative data I use in chapters 6 to 8 and the qualitative data I draw on in chapter 9. In my study I define active transport as human-powered, non-motorised modes of travel for utilitarian (non-leisure) purposes. In practice this refers exclusively to walking and cycling. More specifically, I focus solely on active *commuting*: those physically active trips made by the employed from home to work. However, the commute can take many forms, varying by length, segments and modes. In order to recognize this formally I define the whole journey as a trip *chain* and segments as trip *legs*. Figure 2.11 illustrates just a few of the ways in which individuals might choose to commute.

My conceptualization is based on the structure of trip diaries where respondents are asked to record their journey from home to work by time, mode and transition between modes. Suppose four individuals return diary entries corresponding to their respective commutes. Respondent 'a' travels the shortest distance to work, walking all the way. Respondent 'b' takes a longer commute, walking, then waiting for a bus (shaded segment), travelling by bus, stopping for a coffee, (second shaded segment), then walking the rest of the way.[5]

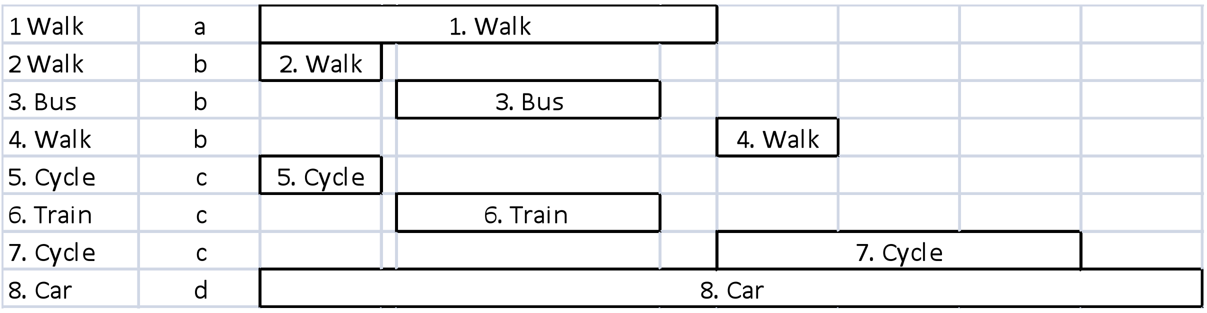
[5] These shaded stop phases typically have a time limit, which is 90 minutes in the case of the travel survey I use. As long as these limits are not exceeded then the home to work sequence can be regarded as a trip chain for the purpose of getting to work.
.

Figure 2.11 A travel diary interpretation of the journey to work

A. Trip chains of four individual commutes



B. Eight trip legs identified from the four commutes in A



The third person, 'c', in the example cycles from her home to the train station, takes the bike on board, travels by train, then also takes a short break before setting off for the final and longest leg which she covers by bike. The fourth commuter, d, simply gets in the car at home and drives to work. The composition of the commute varies between commuters, but so too does the distance, and the time travelled.

These features of the travel sequence greatly impact the way active transport is analysed. I have redisplayed the four trip chains in A of figure 2.11 as individual trip legs, B, to illustrate. There are now eight trip legs, out of four trip chains.[6] Which unit of analysis is used, the chain or the leg, clearly has important implications for the quantification of active travel, and by extension, active

[6] I have excluded the transitions.

commuting.[7] Given the conceptual difference between a trip chain and a trip leg it is not surprising that researchers estimate active transport differently, leaving a literature with a conflicting picture of the degree and nature of active transport in general and active commuting in particular (Krizek, 2003; McGuckin and Murakami, 1999; O'Fallon and Sullivan, 2005).

For instance, since walking is often a secondary mode of travel, occurring as it typically does at the beginning and ends of dominant trip legs, when only the dominant mode is reported, the incidence and extent of active travel is likely to be considerably under reported. However in the travel survey, drawing as it does on the completed travel diary, the unit of analysis switches from the individual commuter (the trip chain) to the trip leg. So, in the example above I would shift from analyzing the four individuals in A to the eight distinct travel legs in B.

With the data file organized as trip legs it is possible to more accurately estimate the incidence of active commuting (the probability that any given trip leg in a selected population involves active travel). In the example above, the probability that walking has taken place will be 3/8, since three of the eight legs are walking legs. Similarly the probability that a cycle will be used in a trip leg over this hypothetical population will be 2/8. And so on.

Compare those possible statistics to those that might be generated from file A based on individuals reporting dominant modes. Only one respondent, a, has walking as the dominant leg, so the probability (now in terms of trip chains) will be 1/4, as will the probability of cycling. Unless clearly identified, statistics generated on the basis of trip chains and trip legs will therefore be quite different and virtually impossible to compare.

---

[7] When people analyse the Census of Population and Dwellings, for example, two constraints are imposed. Firstly, all respondents are asked about the usual mode of travel in the week preceding the census. The only mode chosen is the dominant mode. It will be clear from Figure 2.11 that there is considerable loss of information, especially if 'dominant' is ambiguous with respect to time or distance. Even if exactly the same commute was undertaken each day, an individual's non-dominant modes are completely ignored.

In addition to the incidence, it is also possible to calculate the distance of each leg. [8] Summing the total distance covered by walking over the available trip legs will provide a dependent variable, distance, which itself can be analysed. I use such a measure later in the study when I ask how income affects the distance people travel by active modes.[9]

In summary, in quantifying active travel it matters considerably how active travel is measured.[10] There is a further consideration, which I broach later in context, and that is what is being assumed statistically about the independence of the units of analysis. Statistical analyses of records that come in the form of A in figure 2.11 above typically assume the independence of sampled individuals. In practice this is rarely a valid assumption. Those that group in local labour markets and share similar local market contexts will be subject to similar 'environmental' influences.

However, when using trip legs as I do, another set of assumptions is being made. It is clear that legs within a given chain commuted by the same individual are not independent – for two reasons. Firstly, certain common sequences are conditional such as when walking takes place to and from public transport. Secondly, the independence assumption is violated by the fact that the legs within a given chain are travelled by the same individual. They are nested as it were within that individual.[11] In practice, 63% of commuter trip chains contain only one leg so the degree of nesting is not particularly high. In the travel survey

---

[8] from which I can then calculate the probability

[9] Instead of distance, one could use time and do the same calculations. This would allow the total fraction of commuting time devoted to walking (and cycling) to be calculated and these too could be compared across different groups of interest, say young commuters versus old.

[10] E.g. whether it is by chain or by leg, then whether it is the incidence of a mode, the distance travelled or the time it is recorded as taking.

[11] In chapter 8 I consider the use of multilevel analysis as a way of dealing with two kinds of nesting which travel surveys raise – the fact that individuals (travel chains) are nested within local labour markets, and, when trip legs are analysed, that they are nested within individuals.

I use, there is a further level of nesting, the nesting of individuals within households. Given the sharing of transport modes (e.g. the family car), individual trip chains within the same household are highly unlikely to be independent. In summary, there are several levels of nesting that are present when travel legs are analysed: legs within individuals, individuals within households, and households within local labour markets. Rarely is this hierarchical nesting taken into account in the study of active travel but I am signaling my awareness of them here and will make some attempt at addressing some of them in chapter 8.[12]

2.3 Summary

This chapter has outlined how the decline in the use of active transport modes over successive decades has paralleled the rise in automobile ownership and use. Rising incomes, lower car and petrol prices, the greater abundance of vehicle imports, and investment in roading have all played a role in making private vehicle ownership more affordable and more accessible for New Zealanders. With its dispersed, low density population, automobile use spread rapidly as New Zealanders sought access to a large number of quite small local labour markets widely distributed throughout the country.

This chapter also examined how active transport has been defined and measured in previous studies and how I have defined the term and measured active transport use using the New Zealand Household Travel Survey.

The following chapter critically examines the international research, the questions other researchers have asked, how they structured their analyses and what they found.

---

[12] A higher order approach was demonstrated in a recent report using the New Zealand Household Travel Survey data (Milne and Abley, 2011). These authors overcame the problem of recording the same commuter twice by transforming the survey data from trip legs into trip chains before analysis. However this involved a complex and time-consuming process that was beyond the scope of my study.

Chapter 3. Literature Review

Now that some of the definitional and measurement issues surrounding active transport have been discussed, I will explore the contribution that other studies using similar data sets have made, especially the conclusions they have reached regarding the impact of income on the decision to walk or cycle to work.

Among the few studies that have explored the influence of income, results are extremely varied. This suggests either that the impact of income is highly context-specific, or that there are marked differences in the respective research designs across studies. These discrepancies will be discussed at the end of the chapter.

3.1 Empirical literature

Cross-country comparisons demonstrate that income does impact use of active modes in different places. A recent study uses two comparable national travel surveys to investigate the determinants of active transport in Germany and the USA (Buehler et al, 2011). Buehler et al examined the impact of income, gender, car access and employment status on walking and cycling and compares the employed with the unemployed (full and part timers together). The daily physical activity analysis used three different thresholds: any walk or bike trip; 30 minutes or more of walking and cycling; and 30 minutes or more of walking and cycling accumulated in bouts of at least 10 minutes each, thus excluding trips shorter than 10 minutes. Their study found that the incidence of walking *decreased* with income in both Germany and the US. Cycling *increased* with income in the US but *decreased* with income in Germany. Overall, there is much less variation in active transport use between socioeconomic groups in Germany than in the US.

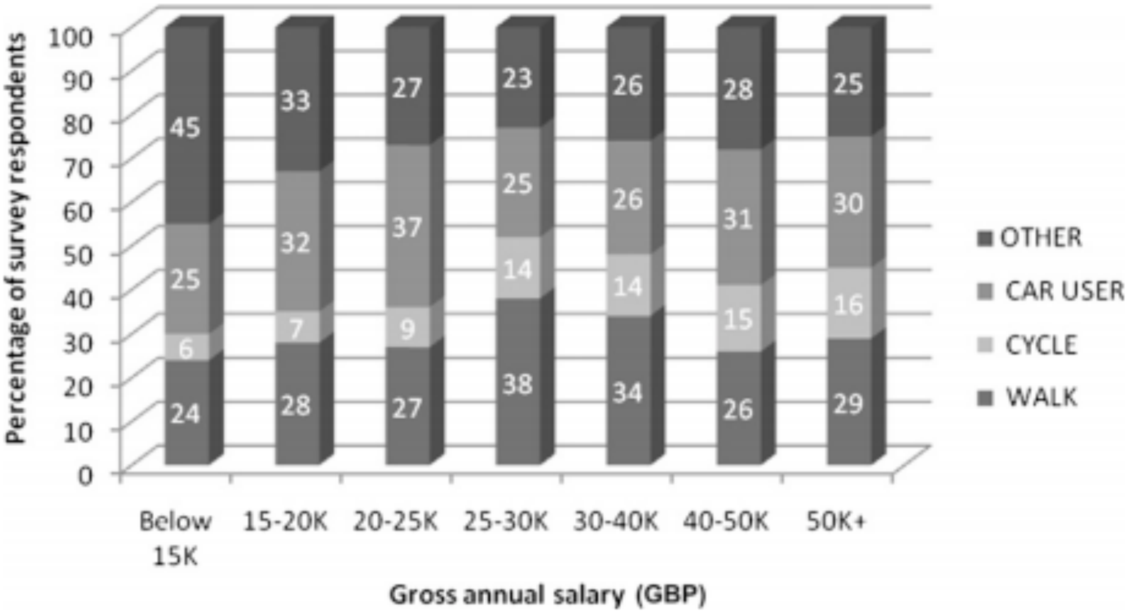
In addition to research using national travel surveys, time use surveys have also been used to assess relationships between active transport use and other factors. A British study using the 2005 UK Time Use Survey found that active transport participation is greater in younger people and those without access to a car or van. Being sufficiently active through active transport is additionally associated with being unemployed, being in a less affluent social class, and leaving full time education at an older age (Adams, 2010).

Brockman and Fox's (2011) report used panel data obtained from University of Bristol staff to explore correlates of active commuting and the effects on health in a UK context.[13] Usual mode of commuting, gender, age, worksite location and distance commuted to and from work are obtained from the University of Bristol Staff Travel Surveys conducted at five points in time between 1998 and 2007. The largest and most recent survey (2007) was used to calculate the effects of gender, age and salary band on mode of transport, length of commuter journey, and the extent to which active commuting contributed to meeting national recommendations for physical activity. Respondents were asked to identify their main mode of transport to work, so, unlike my study, this analysis is based on the idea of the whole commute (the chain) rather than each segment of the commute (the leg).

These authors suggested that the probability of walking rose then fell with income: from 0.24 through to 0.38 with middle-income levels, returning to 0.26 and 0.29. They found that the highest proportion of walkers were those whose salary was £25e30 K/year (38%), and the greatest proportion of cyclists earned >£50 K (16%). Low income respondents, i.e. those who earned <£15 K/year, were the most infrequent walkers and cyclists (24% and 6%, respectively), but the greatest users of other modes of transport (45%) (Brockman and Fox, 2011, p. 213). See figure 3.1.

[13] Panel data comprises observations observed over multiple time periods.

Figure 3.1. Usual mode of transport by salary band. Bristol, UK. 2007.



Source: Brockman and Fox, 2011, p. 214.

While the Bristol panel study is highly relevant to my research in both focus and method employed, their data was obtained exclusively from staff working at one university in one UK city. As such, the results are unlikely to hold across different workplaces or cities, nor be generalisable to a regional or national level. At the same time, their tight control in terms of design may also be an advantage in isolating the impact of income.

An Australian study aimed at monitoring active travel at different health-enhancing thresholds was able to produce generalisable results at a regional level through a panel study of the Sydney Greater Metropolitan area (Merom et al, 2010). Using data spanning a decade from the Household Travel Survey (1997-2007), the researchers obtained a large quantity of personal travel data for this substantial geographical area, covering 75% of the population, and the three largest cities in the state of New South Wales. Roughly 5000 households are selected at random each tax year. As such, they constitute a representative sample of the study area. (Merom et al, 2010, p.114). A number of variables that are incorporated in the analysis of data in my research are also examined in this Australian study: gender, age, marital status, income, working status, household structure and number of cars.

As in my study, each leg of a trip is treated as a unique trip. Therefore, a trip to work consisting of walking to the station, catching the train, and then walking to work from the train station is defined as three different trips, even though they were conducted by the same person as part of the same trip chain.

Their results reveal that walking tends to *decrease with income* in quite a linear fashion, while cycling tends to *increase* with income, but not in a linear way. For all three survey periods, a U-shaped pattern for cycle use emerges, with the lowest income earners and highest income earners reporting the greatest use of cycling for transport Perhaps surprisingly, this epidemiological application of travel survey data finds that, in the Sydney Greater Metropolitan area, time spent on active travel has increased between 1997 and 2007.

A Dutch study which, like the Australian study above used national travel survey data obtained from individuals over a one-day period, explored the influence of socioeconomic characteristics, land use and travel time considerations on mode choice in the Netherlands (Limtanakool et al, 2006). The researchers used data from the 1998 Netherlands National Travel Survey to conduct a descriptive analysis of factors related to mode choice such as trip purpose and socioeconomic characteristics. A multivariate analysis was then employed, controlling for the influence of socioeconomic characteristics of individuals and households, as well as travel time**.** They find that spatial configuration of land use and transport infrastructure has a significant influence on mode choice processes. This effect remained even when the impact of socioeconomic characteristics and travel time were taken into account (Limtanakool et al, 2006, p.339).

A New Zealand study examining the relationships between transport mode choice and city size over time uses New Zealand Household Travel Survey data from between 2002-2006 (Keall, Chapman and Howden-Chapman 2009). The authors obtain estimates by classifying the respondents in terms of age and by the size of the population centre where they live. For each survey, the percentage of time travelling is calculated across various modes (p.16). The key finding from this analysis is the observed shift away from active transport by New Zealand children. The shift appears to have been strongest in main urban areas. Of relevance to my thesis is the observation that changes in travel mode in big cities may be influenced, among other things, by changes to work force locations and working hours. At the same time, while it seems that changes in mode choice vary with city size, the authors conclude that it cannot be assumed that urban form is causing these modal shifts.

Another study to use New Zealand Household Travel Survey data also examines the differing trends in active transport use in main urban areas compared with less densely populated settlement types (Milne and Abley, 2011). This research extends the work presented in an earlier NZ Transport Agency report describing daily travel patterns (Abley et al 2008) A key output of the research is the production of a suite of models which can be used to test changes in travel behaviour where variables such as age, car ownership and household compositions change over time.

A key finding of the analysis pertaining to commuting specifically is that the journey from home to work was undertaken predominantly as a vehicle driver for all area types tested. The highest use of motor vehicle as a means of transport from home to work was associated with the secondary urban areas and rural areas, likely reflecting in these areas the more dispersed relationship between residential and employment land-use activities, lower levels of public transport service, lesser provision of facilities for active modes and the lack of congestion as a disincentive to driving (Ibid. p.76). While this study explores the influence of car ownership (which I showed in chapter 2 to be closely related to increased income), surprisingly it does not explore the impact of income itself. In fact, I could find no studies to have used NZHTS data to specifically explore the impact of income on the use of active modes of transport for the commute, making my study unique in its use of this large national survey.[14]

[14] A summary of previous publications to have used data from the NZHTS can be found in appendix 3.

3.2 Summary

While my thesis explores the relationship between income and active commuting (in the context of other sociodemographic and locational factors) it appears as though very few studies have done so. A number of the studies do explore the income relationship, but their focus has been on other environmental and demographic correlates of active transport use.

Even when they are included, the results regarding income are rather inconsistent. For instance, while one British study found that active transport use was more prevalent among the less affluent (Adams, 2010), another British study found the opposite to be true: it was the lower-income earners who were the most infrequent walkers and cyclists (Brockman and Fox, 2011). In an Australasian context, the results are similarly contradictory. An Australian study shows that income had a negative impact on walking but a positive one on cycling (Merom et al, 2010), while a New Zealand study revealed a negative but non-linear relationship between income and walking, but that cycling exhibits little response to income at all (Tin Tin et al, 2009).

The discrepancy in the UK results might be explained by the different size and composition of the survey samples. While Adams' study uses national data from across the entire UK, Brockman and Fox's results reflect only the commuting habits of a relatively affluent group within a single tertiary education institution. Likewise, the difference in the Australian and New Zealand results could be indicative of the varying scales of the respective research designs, with the former being a region-wide and the latter a nation-wide sample.

Whatever the reasons, these mixed results indicate the need for a much more specific enquiry into the relationship between active transport (especially active commuting) and income. Ideally this will be based on a conceptual framework constructed to help elucidate the functional form the income-active commuting relationship might take. The framework I suggest in the following chapter is a step in that direction.

Chapter 4. Conceptual and Methodological Framework

Chapter 3 revealed major incongruities in the results of the small number of previous studies that have explored active transport use in relation to income. Further exploration of this relationship is clearly needed at both the conceptual and methodological level. This chapter will state what my prior expectations are regarding income's influence on the use of active modes. I start with the historical evidence that suggests a negative relationship between active commuting and income. I then introduce spatial considerations, which lead me to quite a different consideration of the relationship.

4.1 A conceptual framework

How are workers' travel-to-work decisions affected by their income? Other things equal, one might expect additional income would buy more comfort and ease of travel, and raise the opportunity cost of time.

If everyone lived the same distance from work and had equal access to transport modes, the national evidence would suggest the motorised transport option would be more attractive the higher the income. As successively higher incomes are encountered, I would expect to see walking and cycling replaced by motorised commutes.

The above interpretation implies that active transport is negatively elastic in income; its consumption falls as income rises. It is, in the language of economics, an inferior good.[15] There is historical evidence for such a negative relationship between income and active commuting in the aggregate case (Jacobson et al, 2011; Milne and Abley, 2011). There is certainly strong evidence for the positive relationship between income and car use from panel surveys (Dargay, 2001, 2007). Far less attention has been paid to the cross sectional relationship between income and active commuting within the context of the local labour market.

---

[15] This very example is used in a popular dictionary of economics: "…as people become richer, they may substitute more cars for bicycles, and bicycles would be regarded as an inferior good" (Baxter and Rees, 1972, p.215).

Complicating such an interpretation of active transport are the demographics of work and income. Generally speaking, wages rise with age so higher income earners tend to be older. To the extent that age might impose more effort and cost on the active transport option, we might expect commuters to opt for non-active modes as they age quite independently of their higher income.

There are further considerations such as hours of work. Part-time workers earn lower incomes and may for this reason be more likely to take the cheaper, active modes. They may also have more time and be willing to commute for longer. At the same time, part-time workers are much more likely to be women, which may influence the choice of active transport options especially if there are child care responsibilities to be considered, which entail both time and feasibility issues.

This brings me to an additional aspect to consider: the structure and dynamic of the household that a person lives in. The options for travel may be more highly constrained in a household of two young adults and several young children, compared to that of a single male or older couple without dependents. There are at least three primary constraints associated with the former. The first is time, the second is perceived safety and logistics associated with young children, and the third is resources. Take a young couple both working full time to pay off a mortgage in a suburban property twenty or more kilometres from both work places who also need to drop off and pick up children, do the shopping and run other errands but with only one car. In summary, discretion and choice over transport options are likely to vary markedly across households quite apart from the various characteristics of individuals, including their income level.

The issue is even more complicated when viewed in a wider context. When it comes to the choice of active transport, probably the most important of these wider decisions is where to live. This has several components. The first is the choice of the local labour market - whether it is a major metropolitan centre, a medium sized town or a small village in a largely rural area.

The second component is residential location at a regional level. Regional differences are likely to affect the choice of commute mode in a number of ways. Differences in average air temperatures, rainfall, wind speed and sunshine hours will impact the desirability of engaging with the elements on foot or bicycle. There are also the geographical differences between various regions, such as whether the commuter faces predominantly hilly or flat terrain. Varying levels of investment in pedestrian and cycling infrastructure across regions will also play a role in facilitating or constraining the use of active modes. Availability of public transport options (buses and trains) in different regions may also be relevant, as use of public transport often involves some degree of walking at either end.

Thirdly, those who have chosen to work in a large dense labour market face several distance-to-work options. Faced with a downtown work location and an a priori preference for a commute of say 20 minutes, one can choose to live within a few blocks and walk to work or live some 20 minutes drive away in a suburban location. Such decisions cannot be made independent of income of course and, other things equal, it is the higher income person who is most likely to be able to afford to live very close to a downtown work place.[16] Their location decision at the same time opens up commuting alternatives not available to the lower income suburban dweller. For this reason, we may find that walking or cycling to work may rise with income, largely because higher income individuals can access residential locations closer to their workplace.

The decision to choose active transport therefore is not simply one of economics, but of economic geography. Making the picture even more complex are a myriad of other facets, among them culture, habit, autonomy and control, and relative preferences for physical health. All of this means there are two ways of looking at the choices involved in the use of active transport. The first is the standard modal choice framework, which is about the daily choice on what transport mode to use to get to and from work. This is the classic modal choice problem.

The second set of choices are the prior long term ones, but they may be just as crucial in framing the daily commute mode decision. Those decisions made some time ago effectively set the wider context in which the daily transport decision is made: the decision on the type of household, life style, region of residence, type of settlement and location within large settlements. In other

[16] Assuming they live in a city where employment is concentrated in the centre.

words, the whole gamut of past choices lead to the socio-economic and geographic context that frame the daily choice of commuting mode. These earlier choices, on where to live in relation to work, between urban centres and within large centres have a major constraining influence on the relative costs that feature as constraints in the typical model of modal choice.

Therefore, modal choice models as such do not capture the embedded nature of the commuting decision. Because modal choices are made in the context of a broader set of prior situational factors, they often result in habitual choices, which may not adjust for new information. When performing repetitive behaviours such as commuting to work, people may be likely to ignore new information, even when the information may rationally be deemed to be a relevant input in the decision-making process. To ignore the repetitive nature of commute mode choices may result in the formation of unrealistic assumptions about the reasoning that precedes such choices. To some extent, habit helps explain the observed predictive importance of situational variables such as socioeconomic characteristics and car ownership (Diana, 2010).

Also, the endogenous nature of underlying residential self-selection processes can make it tricky to evaluate causation among locational, temporal and individual elements, and associated outcomes. For example, a researcher might observe that suburban dwellers walk to work less and drive a car more than their urban counterparts. However what is difficult to determine is the extent to which the observed patterns of travel behaviour can be attributed to the settlement type itself, as opposed to the prior self-selection of residents into a built environment that is consistent with their predispositions toward certain travel modes and land use configurations (Mokhtarian and Cao, 2008). Assertions regarding such causal mechanisms will always be questionable unless data is available that maps both the residential *and* commute mode choices of the same individuals over time. Typically, this type of longitudinal data is not available and certainly not in New Zealand.

Whether a negative relationship between active commuting and income applies to individuals over the course of their own working lives is not easily discernable from the literature, as I demonstrated in chapter 3. Without the available longitudinal samples in New Zealand we are forced to rely on cross sectional evidence, and to look at the propensity to actively commute across a range of incomes at a point in time.

What is of immediate interest is the degree to which the available cross-sectional evidence from the NZHTS is consistent with a conceptual position that argues for a negative relationship between active commuting and income. In addition to the geographical considerations that can alter the way active commuting might relate to income, there are several other possibilities. For example, active transport may rise with income because of the impact of education. To the extent that higher incomes are associated with higher levels of education (about, for instance, the health benefits of active transport), healthy options can be expected to play an increasingly important role in people's decisions about life style as their incomes rise. In this respect, one might also want to add a social consciousness and concern for environmental sustainability, both of which might be expected to rise, at least with the education component of rising income.

There is some support for this line of thought in the literature, though the role of affluence in explaining socially and environmentally-motivated actions is quite contentious. According to the affluence hypothesis, environmental quality is a luxury good that becomes of concern only when basic needs have been met (Duroy, 2008). It is thus assumed that income is the most important determinant and that affluent nations are more likely to display greater demand for environmental quality than developing nations (Meyer and Liebe, 2010). This argument is reminiscent of Maslow's *hierarchy of needs theory* (1954), and also Inglehart's *Theory of Post-Materialist Values* (1990, 1997), which postulates that, with growing prosperity in post-industrialized nations, people are freed from burdensome economic concerns and able to pursue other goals such as improved health and environmental sustainability (Duroy, 2008; Meyer and Liebe, 2010).

But the view that rising social and environmental concern are the result of economic affluence is rejected by many authors (e.g. Martinez-Alier, 1995; Shiva and Jafri, 1998; Escobar, 2006), who have noted that, while concern for global issues such as climate change is higher in developed nations, grassroots movements and action at the local and community level are negatively correlated with GNP per capita - i.e. stronger in poorer countries (Dunlap and Mertig, 1995; Duroy, 2008).

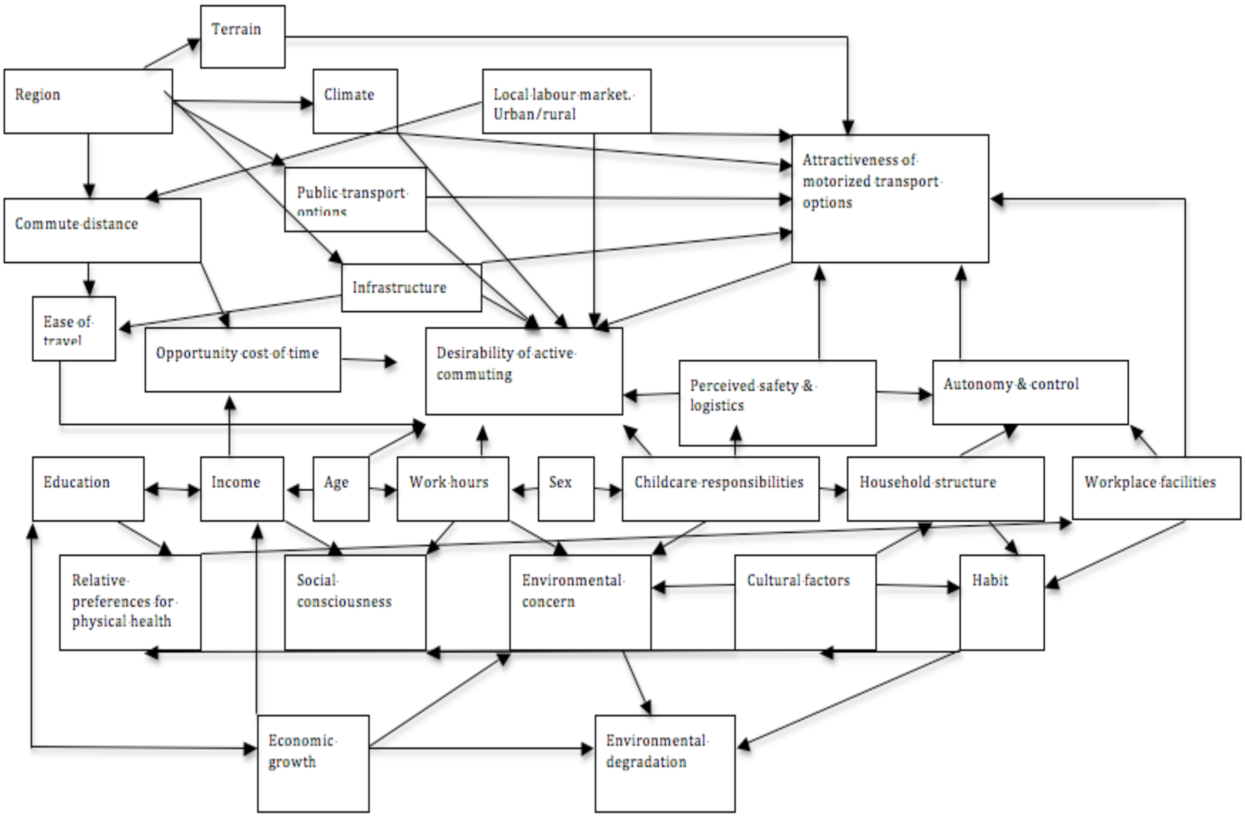
Add to this the argument that affluence, which necessitates greater levels of production and consumption, is itself a major cause of environmental degradation. This could provide an explanation for why environmental concern might increase along with it. By this rationale, an increase in environmentally-friendly behaviours, such as the use of non-motorised transport modes, among better-educated individuals could be expected. According to this argument active commuting will decline with income up to a point (as car ownership becomes possible), after which it will begin to increase, as people become better educated and more socially and environmentally-responsible.

In summary, modeling modal choice only involves modeling the immediate daily decision on how to get to work. As such, it ignores or takes as a given those prior decisions made at previous junctures in people's lives. Many of those choices point to the crucial nature of earlier decisions that have nothing to do with active commuting per se. The simple act of deciding where to live in relation to the workplace (or, conversely, where to work in relation to the residential location) is possibly the most important of these 'non active commuting' decisions. Although the residential location decision certainly locks many individuals into particular commuting options, there usually remains some choice within these 'external constraints'. I contend that the choice made within those constraints will be influenced by income.

But more importantly, I am interested in income because of its link to economic growth, whose primary purpose is to raise incomes. If raising incomes also lowers the propensity to use active transport for the daily commute then we may not have an economic growth model that is sustainable, either in terms of public health or environmental impact. If, however, I find that other characteristics of income actually encourage active commuting (e.g. one in which settlement type and proximity to workplace are more closely associated with income) then we might be closer to a more sustainable type of economic growth. From the urban, local labour market perspective, the empirical relationship between active commuting and income becomes quite central.

Figure 4.1 attempts a more structured approach to displaying the complex web of variables surrounding the central relationship between income and active commuting that have been identified in my conceptual framework. I have created a directed acyclic diagram, which is an instrument useful for clarify thinking and making explicit underlying assumptions (Greenland, 1999).

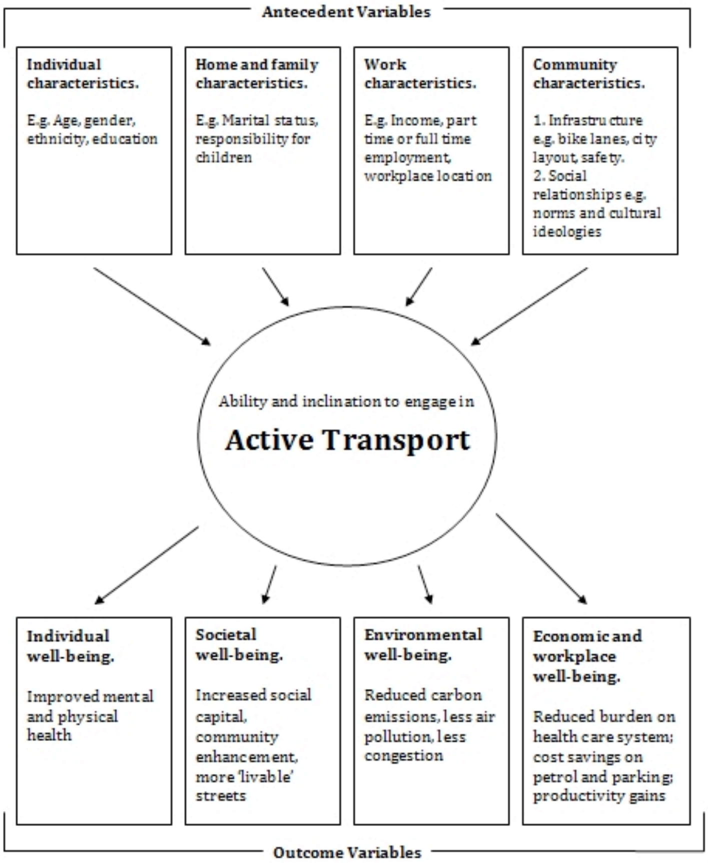
Figure 4.1. Directed acyclic diagram outlining factors related to the relationship between income and active commuting.



4.2 Theoretical Orientation

It is clear from the above discussion that there exists a very complicated universe of variables and relationships influencing active transport use. While it is true that engagement in active transport will be facilitated (or constrained) by contextual aspects, constructed from both structural and interactional factors, my model below also outlines mechanisms by which active transport can achieve outcomes of interest. Many of these outcomes of interest, such as mental and physical well-being, reduced carbon emissions, and greater community connectedness, are outlined in the introduction.

Figure 4.2. The theoretical context in which active transport is framed in this thesis.



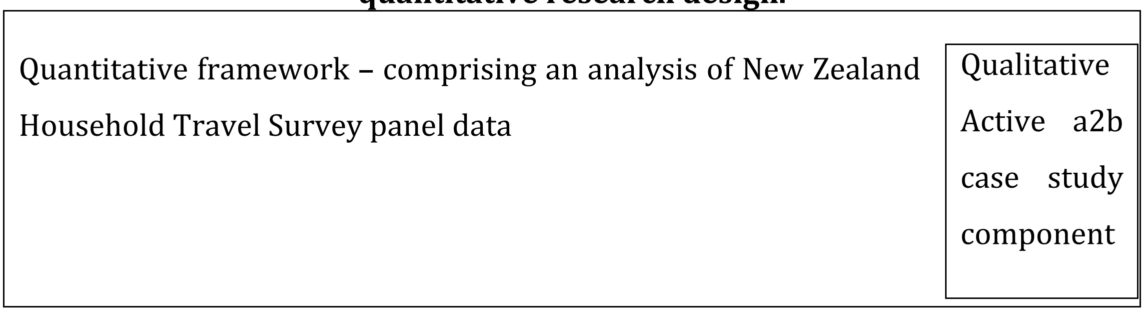
Model guided by Hill et al (2008) *Conceptualizing Workplace Flexibility*, after Bronfenbrenner's *Bioecological Systems Theory* (1989).

4.3 Mixed Methods Design: Embedded correlational model

This mixed methods study will address the use of active modes of transport for commuting in New Zealand. An embedded mixed methods design will be used, and it is a design in which one data set provides a supportive, secondary role in a study based primarily on the other data set. The primary purpose of this study will be to use quantitative data from the New Zealand Household Travel Survey to test the theory that rising affluence will negatively influence the use of active modes of transport for trips to work.

A secondary purpose will be to use qualitative data from Greater Wellington Regional Council's Active a2b health and wellbeing programme to explore the barriers and benefits of active commuting from the perspective of Wellington workers who participated in the programme. The reason for including the secondary database is to use this programme as a case study in order to discover what other factors are salient for employed persons in New Zealand when making the decision to commute using active modes. The inclusion of the secondary qualitative data fits with the pragmatic tradition of using diverse approaches and valuing both objective and subjective knowledge (Creswell and Plano Clark, 2007, p.26).

Figure 4.3. Diagram to illustrate the embedded mixed methods design of this study. The qualitative component is nested within the overall quantitative research design.



However, the act of combining qualitative and quantitative approaches does raise potential validity issues. Within a mixed methods context, validity can be defined as "the ability of the researcher to draw meaningful and accurate conclusions from all of the data in the study" (Creswell and Plano Clark, 2007, p. 146). Mixed methods writers have used the term "inference quality" (Tashakkori and Teddlie, 2003) to refer to the accuracy with which researchers draw inductive and deductive conclusions from a study. Steps are taken in this mixed methods study to ensure that potential threats to validity are minimized, and that inferences drawn from both types of data are logical and well-substantiated.

In some mixed methods designs (e.g. the Triangulation Model), data from the quantitative and qualitative components are merged during the interpretation or analysis through a process of transformation. For this study, such an approach would be inappropriate, given that the quantitative and qualitative samples are drawn from different populations. Since the qualitative Active a2b data is used to provide a regional case study (to elucidate some finer points that the quantitative NZHTS data is not capable of expanding upon), a merging of the data sets is not required. It is sufficient for the qualitative data to sit alongside the quantitative analysis in a complementary fashion.

Quantitative research question: What does the NZ Household Travel Survey data (2003-2008) tell us about the impact of income on the use of active modes for commuting among different sub populations in New Zealand?

Qualitative research question: What other factors, beyond those captured in the NZHTS data set, influence commuters' decisions when considering the use of active modes?

Mixed methods question: How do the interviews with Active a2b participants broaden our understanding of the quantitative data from the NZHTS regarding the use of active modes for commuting?

4.4 Summary

Chapter 4 commenced by outlining the conceptual framework underpinning this investigation into the relationship between active commuting and income. Many issues feeding into the commute mode choice decision were discussed, the most important point being that the immediate daily commute decision is made in the context of prior, long term decisions, and that the latter dimension is difficult to capture in modal choice modeling. The theory that economic growth and associated affluence will likely have a negative impact on the use of walking and cycling for the commute was put forward, though counter arguments were also discussed. I also argued that the urban setting and the cross-sectional treatment of income alter the way in which active transport relates to income empirically.

I then outlined my theoretical orientation, guided by Bioecological Systems Theory, and how this framework fits with my conceptualisation of active transport in this research. Lastly, I gave details of my mixed methods approach, and stated my research questions.

In chapter 5 I will outline the characteristics of the data set I am using, before conducting some basic descriptive analysis, in preparation for the more in-depth analysis to follow in chapter 6.

Chapter 5. The New Zealand Household Travel Survey

Studies of active transport typically draw on two types of data, large travel surveys designed to monitor travel behavior generally, and small specialist sample surveys of those using active transport.[17] When it comes to understanding who uses active transport, and active commuting in particular, the small local sample can be a disadvantage because of the important role the different settlement contexts play in conditioning people's choice of travel mode.

The second type of survey, the omnibus travel survey, although not designed specifically to address issues of active transport, routinely collects such data along with attributes of travelers, location, time periods and travel distances. Most importantly however, because these surveys are designed to monitor travel behaviour nationwide, they capture the location choices people have made, both nationally and within their chosen settlement. Associated with these location choices is their travel behavior and it is the nature of this joint decision that appears to be particularly important in understanding the relationship between worker's incomes and the way they travel to work. It is for this reason that I have chosen a large, multi-year survey to investigate the way changes in income are associated with active commuting.

I begin this chapter by introducing the New Zealand Ministry of Transport Travel Survey (hereafter, NZHTS or survey), and the specific variables used in the chapters to follow. There are a number of conceptual and empirical features of this survey that are important, including the way commuting and associated trips are defined, locational and temporal characteristics of the survey, and how patterns of transport use vary over time.

As a major data source for transportation planning in New Zealand, the NZHTS has already received considerable attention from within the Ministry of

[17] The latter has the advantage of capturing specific travel behavior, such as respondent attributes and their attitudes and views. Their disadvantage lies in their typically small sample size and the fact that they are usually confined to particular locations only.

Transport.[18] Beyond the Ministry and contracted consultancies however, the survey appears to have received very little attention indeed, for only a couple of peer reviewed publications by academics and few graduate students appear to have drawn on these files.

One of the consequences of the limited attention these data have received outside the Ministry is that few higher-level questions not directly related to the Ministry's brief have received sustained attention. One of these questions has to do with the role personal income plays in selection of travel mode. The settlement structure and the way it conditions travel patterns has received some attention (Keall, Chapman and Howden-Chapman, 2009). There are many related questions such as the impact of household composition (including the impact of children) on travel choice in both commuting and non-commuting realms that warrant closer attention.

5. 1. Introduction to the New Zealand Household Travel Survey (NZHTS)

The survey in its current form was first introduced in 2003/04. Since then seven waves of the sample have been completed, although only five were available when my thesis was proposed and I have been given access to these under a confidentiality agreement with the Ministry.[19]

Sample design

The survey's sample design is important in the way it opens up analytic opportunities in some areas, and closes them down in others. In the NZHTS participating households are chosen from randomly selected census meshblocks, with about a hundred households per city block. Over a five to seven year cycle, every household in the selected meshblock will have been invited to participate in the survey. Each selected household is randomly allocated two consecutive travel days on which each person is asked to maintain a travel diary. As such,

---

[18] Ministry of Transport (and NZ Transport Agency) reports using NZHTS data are cited in appendix 3.

[19] Details are available on the Ministry of Transport website, via this link: http://www.transport.govt.nz/research/travelsurvey-method. The confidentiality agreement is reproduced in appendix 2

surveying takes place on every day of the year including weekends (NZ Ministry of Transport, 2010). The NZHTS sampling method is illustrated in Figures 5.1a and 5.1b.

Figure 5.1a: Map of Wellington region showing households (identified by sample number) within clusters of meshblocks

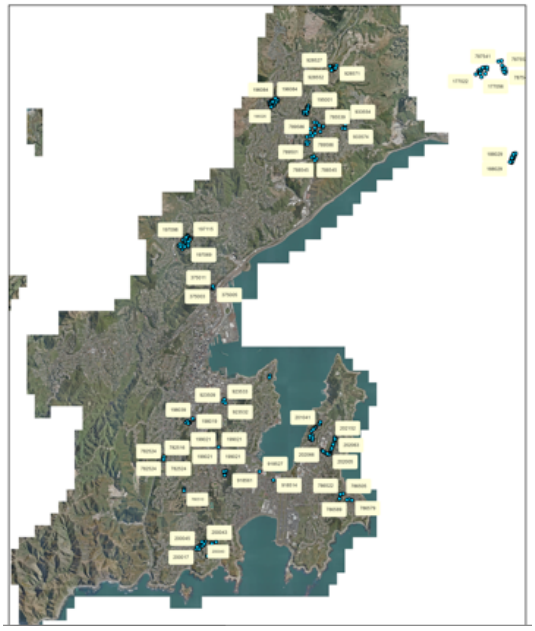
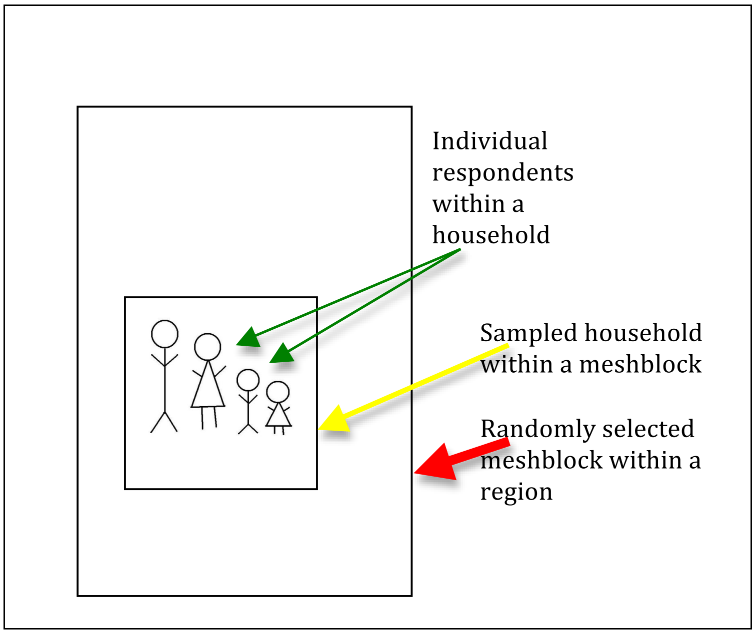


Figure 5.1b: Diagram to explain how NZHTS data is gathered from individuals from sampled households within meshblocks



Source: Law, 2011.

Data collection consists of a face-to-face interview with each eligible, willing member of the sampled household. Between 2003/04 and 2007/08 (inclusive), 2,200 households were invited to participate in the NZHTS each year. This paper uses NZHTS data from five different data collection periods: 2003/04, 2004/05, 2005/06, 2006/07 and 2007/08.[20]

[20] Additional information about the sampling design is found in appendix 4.

Units of analyses

The data obtained from the Ministry of Transport for the purposes of this analysis are in three separate files: household, person and trip files. The three files were supplied separately but due to the focus of my study only the trip file is utilised in detail. This is not as constraining as it may sound because a large number of variables from the others files were also carried across to this file as appropriate thus allowing the trip file to be analysed as a stand-alone.[21] Table 5.1 shows the NZHTS main data categories and descriptions.

Table 5.1. NZHTS Main data categories and descriptions

Main data category	Description
Household	Details about the household and its response to the survey
Person	Details about people in the household (information such as age, sex, driving/cycling experience, accident totals, occupation, income, driving, work and school locations)
Trip	Purpose, mode, destination, date, time, duration and distance of each trip leg, and vehicle information
Vehicle	Type, make, model, year, engine size and owner information for vehicles driven during the survey
Alcohol	Drinking session times and locations
Accident	Accident involvement over the last two years
Address	Text description of trip destinations
Accident locations	Text description of accident locations
Trip geocoding	Trip location (map references) and geocoded distance estimates

Source: Milne and Abley, 2011.

5.2 Conceptual and measurement issues

There are several conceptual and measurement decisions that have to be made in any survey, reflecting the environment in which they are constructed and the purpose to which their funder wishes to use them. Those made here reflect the monitoring, planning and research priorities of the Ministry of Transport and agencies they work closely with. One of the most important survey design decisions for the purposes of my study has to do with the way commuting trips are defined.

---

[21] Supplementary information regarding the nature of the three files is supplied in appendix 4.

The commute: trip legs and trip chains

As discussed in chapter 2, the commute has two distinct dimensions over and above the travelling to and from work. The first is the full one-way journey itself, the trip chain, and the second are the segments it is divided up into, the trip legs.[22] Since about 40 percent of all commuter trip chains are made up of more than one leg, the distinction between legs and chains is quite crucial in identifying both the presence of active commuting and the calculations of the total distance and time actually travelled.

Because of the confusion over terminology in the literature, I have been very careful to define active commuting according to how the mode is assigned to the trip itself (Ministry of Transport, 2009, based on the classification presented by O'Fallon and Sullivan, 2005). Trips are defined precisely as any movement on a public street, footpath, railway line, etc., of more than 100 metres.[23] Therefore, a commute trip chain as I use the term constitutes a series of one or more trip legs for the purposes of employment, where the starting point is home and the end point is the workplace. A new chain starts whenever the leg is the first one recorded in the respondent's travel diary, or the respondent has been at that location for more than 90 minutes.

O'Fallon and Sullivan provide a thorough analysis of what duration of time should be used to delineate the end of one trip chain and the start of another. They conclude that there is no one "stop duration" value that will mark out the main activity of a travel pattern for all individuals or that will capture how all people conceive of their travel behaviour. They decide in favour of the 90-minute criterion used by several previous authors (Rutherford et al, 1997; Wallace et al,

[22] Unfortunately the terminology is not standard and researchers vary in their use of the terms, conflating trip chains, tours, segments, trip legs and mode (Krizek, 2003; McGuckin and Murakami, 1999; O'Fallon and Sullivan, 2005).

[23] Walking legs less than 100 metres are included if a road is crossed or if there is a change of purpose from last leg (O'Fallon and Sullivan, 2005, p.2).

2000) as it "permits analysis of additional energy consumption and pollutant emissions due to cold starts" (O'Fallon and Sullivan, 2005, p.6).[24] The key point, therefore, is that the current trip chain ends when the person arrives at home or at their workplace, or when they stay at one location for longer than 90 minutes.

Travel mode

My analysis is based on trip legs. Other researchers have studied active transport on the basis of trip chains (e.g. Brockman and Fox, 2011; Milne and Abley, 2011). For those trip chains in which more than one mode is used, it is acknowledged that the main mode must be based on clear, predetermined rules. These could include the largest share of distance travel within a trip chain, the longest duration, or the highest speed (Axhausen, 2000). However, O'Fallon and Sullivan (2005) could find very few examples in the literature of such rules having been devised and applied, and they suggest defining the main mode of the chain being that used for the greatest distance travelled. For example, if a trip chain consisted of driving 1km and then walking 300m, the main mode would be "vehicle driver". (O'Fallon and Sullivan, 2005, p.10). O'Fallon and Sullivan adopt a 'hierarchy of purpose' ranked by priority, as introduced by Reichman (1976; in Krizek 2003, p.396).[25] Examples of purpose include, in order of hierarchy: subsistence (work or education), maintenance (personal business, social welfare, shopping), and discretionary (social and recreational), as well as several other minor categories that account for trip purposes that do not fit into the main three just listed.

This hierarchy means that a chain with any leg having the purpose "work", for example, is classified as such, regardless of the other purposes found within the chain.[26]

been selected by the respondent as the purpose of at least one leg in the trip chain.[27]

5.3 Variables

The central feature of any data set is the variables themselves. These are typically divided into dependent variables, those whose variation I am primarily interested in, and independent variables, those I have reason to believe might account for some of that variation. In addition, there are conditional variables, those whose values might condition the way my dependent variables co-vary with independent variables. For example undertaking an active trip leg for commuting (my main dependent variable) may be influenced by income (my main independent variable) in ways that are also highly conditional on settlement type (one of the main conditioning variables). Before introducing each of these variables in detail I must define an additional kind of variable called filters.

Filters

'Filters' refer to those general conditions I impose on the sample in order to gain as unambiguous a picture of active commuting as possible. For example, I filter out all the non-employed so only the employed are included in the analysis. In a further filter, any trip leg I analyse must be part of a trip chain whose purpose is employment. I also adopt the convention used by Ministry analysts of excluding professional drivers, given the unusual nature of their 'commute'. I also exclude those commuters who report their income as zero. Furthermore my analysis only includes travel from home to work (not work to home). The assumption, warranted in the bulk of cases, is these will be mirrored in the return journey from work to home. While this assumption does not alter the proportion actively commuting it will by definition only include half the total commuting distances.

Dependent variable

[27] I present an analysis of the average number of legs per trip chain across different settlement types in appendix 4.

The active commuting variable I use is based on the incidence of walking and cycling as defined in chapter 2. I code each occurrence as binary variable (active = 1, non-active = 0), based on a recoding of the travel mode response (*trmode*). Active commutes make up 18% of the total filtered sample.

As Table 5.3 illustrates, the rate of active commuting in New Zealand has changed over the survey years. Commuting by foot constituted around 16% of all (home to work) commuter trips over the survey period, having increased steadily by almost 4% over the five-year period. Cycle trips constituted only around two percent of all commuter trips and these have decreased slightly over the same period.

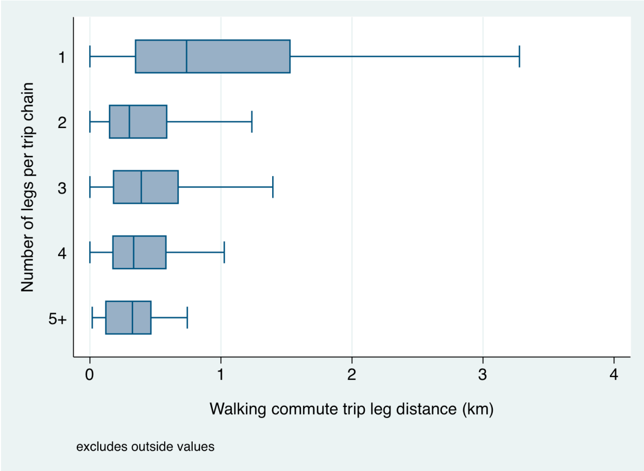
Table 5.2. Distribution of commuter trips taken by active modes (percentages) New Zealand 2003 to 2008

	year recoded					
travel mode	2003/04	2004/05	2005/06	2006/07	2007/08	Total
walk	14.71	15.57	15.85	16.12	18.52	16.11
bicycle	2.06	2.18	2.24	2.23	1.56	2.06
motorised transport	83.23	82.25	81.91	81.65	79.92	81.83
Total	100.00	100.00	100.00	100.00	100.00	100.00

Source: NZHTS Trip file

A second way the extent of active commuting can be measured is by distance travelled. The median distance commuters walk in New Zealand is about 400 metres. However the distributions are typically positive skewed resulting in a higher *mean* distance walked. Although my analysis is based on trip legs, it is important to record the way the length of these trip legs varies according to the number of segments in the trip chain (Figure 5.2). Not surprisingly perhaps, when people only walk to work, they walk longer distances than when they combine their walk with some other mode. Figure 5.2 also shows that walk-only commutes are considerably more variable in length than those attached to motorized transport.

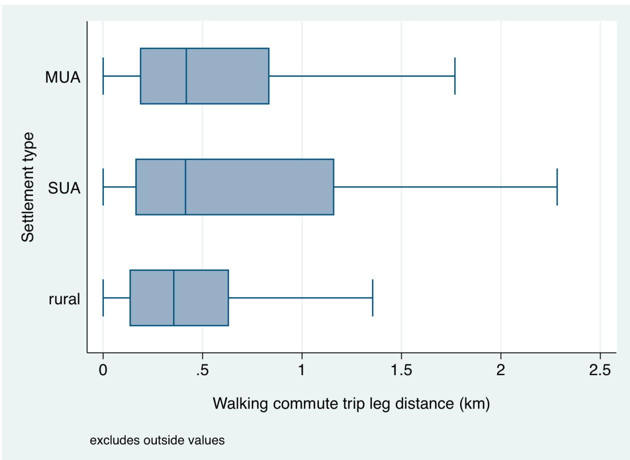
Figure 5.2. Distribution of walking commuters by distance (km) of trip according to number of legs per trip chain. New Zealand 2003-08



Source: NZHTS trip file

The distances are highly variable around similar medians as the comparison of distance walked in main, secondary and rural areas shows (fig. 5.3). The average distance a commuter walks is shortest in rural areas, about one third of a kilometre, and rises in main urban areas (MUAs) and secondary urban areas (SUAs), even though their median commute distances are practically identical (0.42 and 0.41 respectively).[28] The *mean* commute distance in secondary urban areas is elevated to 0.80 kilometres due to a skewed upper tail, signaling the scattered labour sheds that characterize many such smaller labour markets.

Figure 5.3. Distribution of walking commuters by distance (km) of trip in different settlement types. New Zealand 2003-08

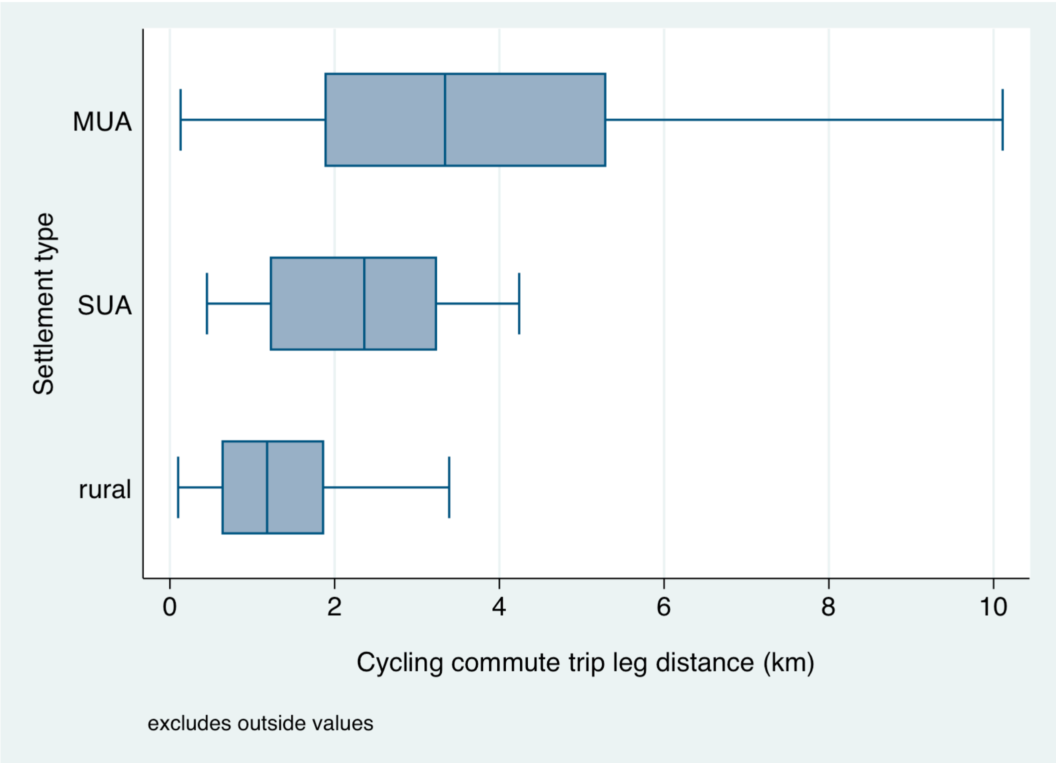


Source: NZHTS trip file

[28] Median distance walked in rural areas =0.36km, mean= 0.57km

The distribution of cycle commute distances across the different settlement types is shown in Figure 5.4. Somewhat surprisingly, cycle commutes in main urban areas tend to be further (median=3.3, mean=4.3), as well as being more dispersed in length than in either secondary urban areas (median=2.4, mean=2.5), or rural areas (median=1.9, mean=2.1).

Figure 5.4 Distribution of cycling commuters by distance (km) of trip in different settlement types. New Zealand 2003-08

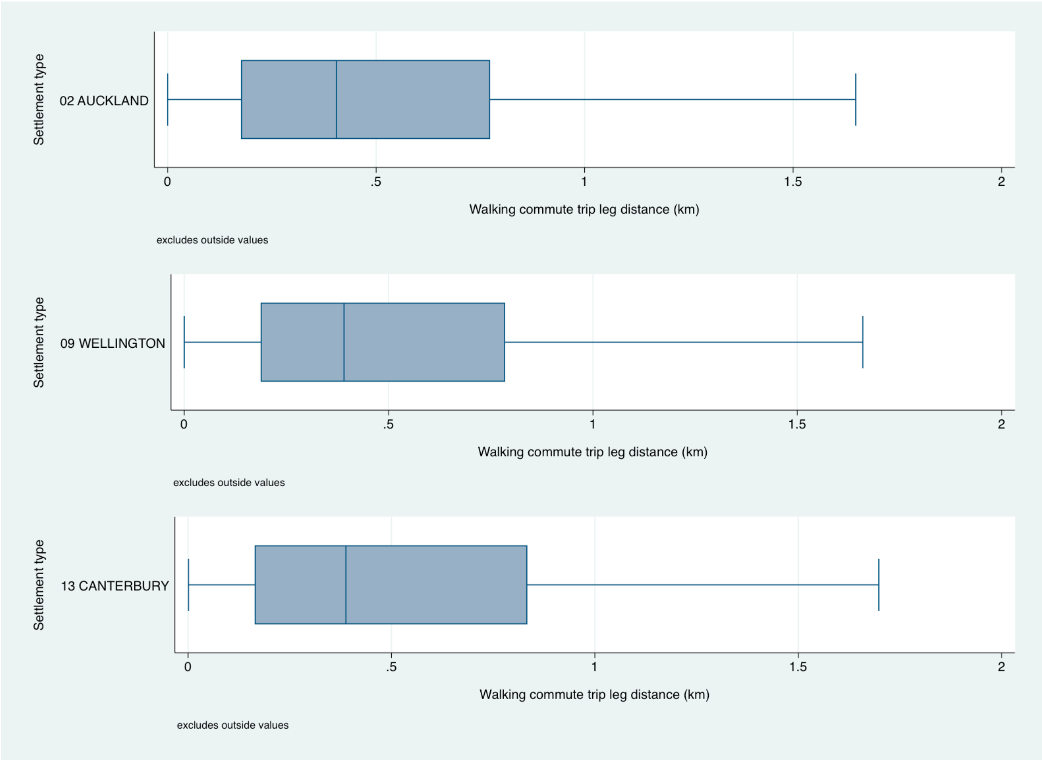


Source: NZHTS trip file

Figure 5.5 reveals that commuters in Auckland, Wellington and Canterbury have an almost identical average distance for the walking segments of their trip chains, with a median of about 0.39 kilometres.[29]

[29] The means are higher for all three regions, especially for Canterbury in which the 75% percentile is a comparatively higher 0.84km.

Figure 5.5. Distribution of walking commuters by distance (km) of trip in the three main regions. New Zealand 2003-08



Source: NZHTS trip file

In summary, when it comes to distances walked as part of the commute, well over half walk less than half a kilometre and then presumably do the same on the way home meaning less than one kilometre of walking per day. Considering commuting legs of under 100 metres are not included, the average walking distance is probably less than this, suggesting that only 16 percent of the employed population will exercise for up to one kilometre a day through commuting alone. This small amount of exercise, given the potential commuting offers as a form of daily physical activity, is one of the motivations for my thesis.

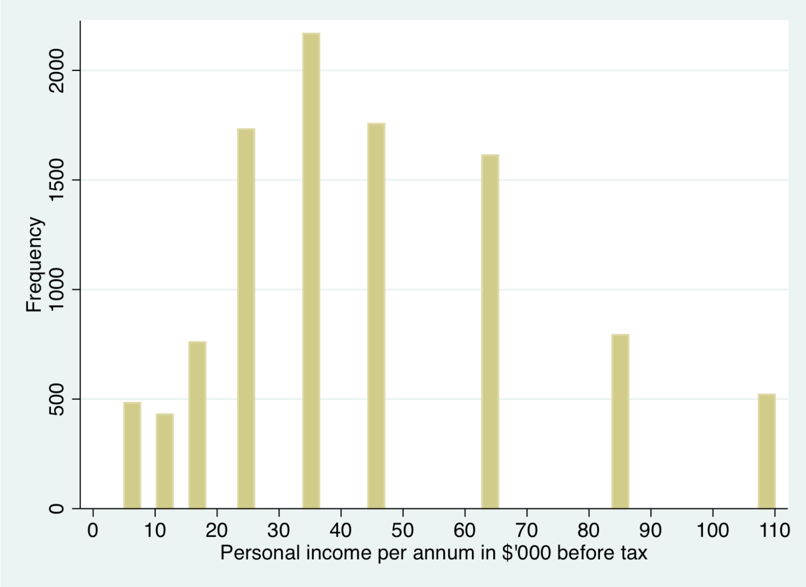
Independent variable

The attribute of commuters of special interest in this study is income.[30] As is commonly the case for income-related survey questions, there are a number of missing values, 8.89%, and these have been dropped from the analysis.[31]

---

[30] Survey respondents were asked to indicate their personal gross income by choosing one of fourteen different income codes, indicative of income brackets ranging from 'no income' to '$100,000+', as well as 'don't know' and 'object to state'.

Figure 5.6. Distribution of personal gross incomes of commuters in New Zealand 2003-08



Source: NZHTS person file

The most common income bracket for commuters in this sample was $30,000-$40,000 per year before tax (median=$35,000; mean=$44,000).

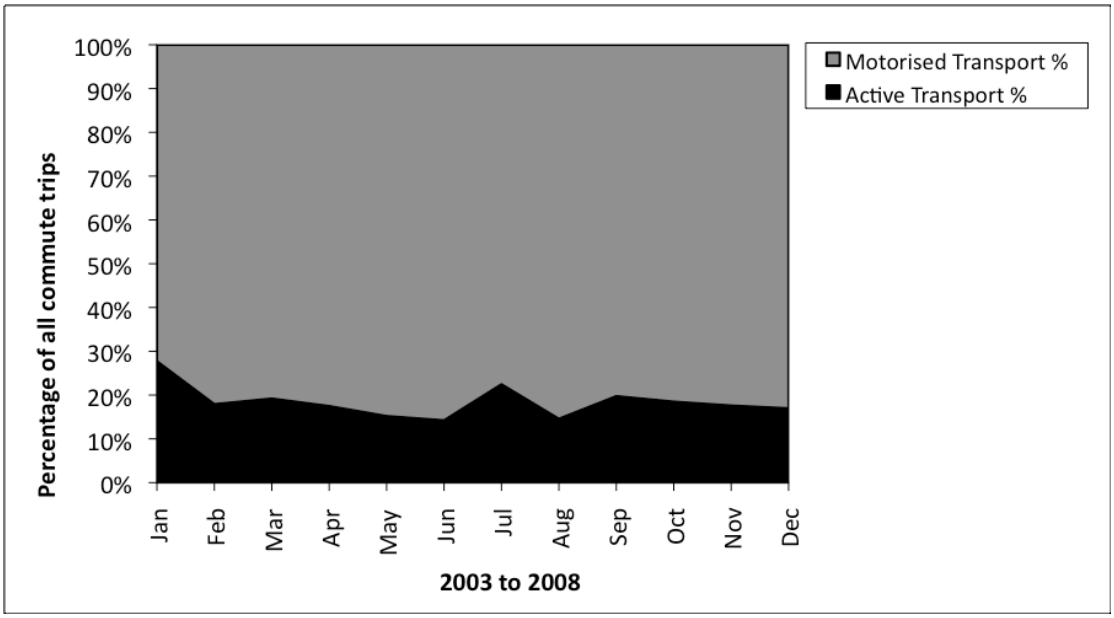
Contextual variables

I have classified my variables into four different types, dependent, independent, controls and contextual. The contextual variables are those whose presence might alter the relationship between the dependent and independent through either known or unknown mechanisms. The first of these I want to describe are those that cover temporal variation: seasonal, monthly, and daily.

Figure 5.7 shows that there is no clear increase or decrease in rates of active commuting according to season but rather that there are a number of fluctuations in the percentage share of active versus non-active modes over different months. Active commuting is highest in January (27.7% of commuter trips use active modes), as might be expected, but, curiously, July also sees a high number of active commuting trips (22.5%). Use of active transport for commuting is lowest in June (14.2%) and August (14.6%).

[31] In addition, I have filtered out those who returned an income of zero, a further 6.22 %.

Figure 5.7. The distribution (%) of active and motorized commutes across months of the year. New Zealand, 2003-08.



Source: NZHTS trip file

There is also some level of fluctuation in the proportion of commutes that are 'active' across different days of the week. Active commuting is least prevalent on weekends, comprising only a 10.3% share of commuter trips on a Saturday, and a 15.5% share of commuter trips on a Sunday, compared to between 17.9% and 20.6% on week days(see table 5.3).

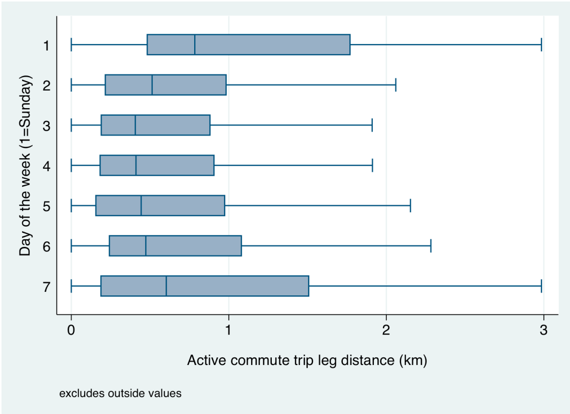
Table 5.3. The distribution (%) of active commutes across days of the week. New Zealand, 2003-08.

Day of week of this travel day (1=Sunday)	travel mode active	travel mode motorised	Total
1	15.54	84.46	100.00
2	20.59	79.41	100.00
3	19.05	80.95	100.00
4	18.00	82.00	100.00
5	17.94	82.06	100.00
6	18.72	81.28	100.00
7	10.26	89.74	100.00
Total	18.17	81.83	100.00

Source: NZHTS trip file

What is interesting is that, while commuters are less likely to use active modes on the weekend, it is active commutes undertaken on the weekend that tend to be longer in distance (see Figure 5.8). This may suggest that, without time and route constraints, people would be likely to walk or cycle further.

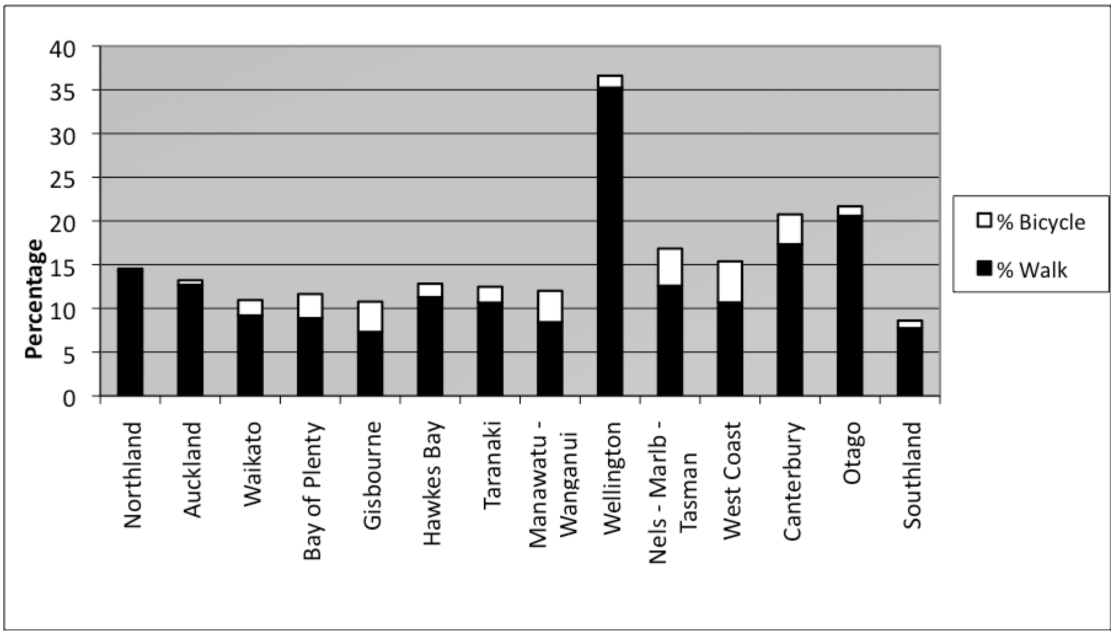
Figure 5.8. Average active commute trip leg distance by day of week. New Zealand, 2003-08.



Source: NZHTS trip file

The other, considerably more influential contextual variable is the regional context within which decisions to actively commute are made. In one of the striking features of New Zealand's travel patterns, Wellington is an instructive outlier; at over 35% the region exhibits considerably higher rates of walking to work than any of the other thirteen regions across the country. The lowest proportion of commuter walking trips occur in Gisborne and Southland, where fewer than 8% of all journeys were involved over the five year period.

Figure 5.9. The distribution (%) of walking and cycling commutes across regions. New Zealand, 2003-08.



Source: NZHTS trip file

As a means of getting to work, cycling has a very limited role. However, here again the nature of the settlement plays an important role. There are more cycle commuters in the Nelson-Marlborough-Tasman region and the West Coast for example than elsewhere. Still, cycle commutes only make up around 4% of commuter trips in both these regions compared to under 0.6% in Auckland and Northland.

Variable characteristics

In Table 5.4 I present the characteristics of all four sets of variables. These figures apply to the filtered population of interest: employed people, with an income greater than $0 who are travelling for the purposes of work and are not professional drivers. Note that the distinction between control and contextual variables is somewhat fuzzy. For instance, though I have categorised settlement type and region as contextual variables because they appear as contextual effects in my multilevel regression in chapter 8, they act as controls in the multivariate models I build in chapter 7.

Table 5.4. Summary distributions of different sub-groups of commuters in the NZHTS trip leg data set

Variable	Obs.	%	Mean	Std. Dev.	Min	Max
Dependent						
Active commuting	2045	18.17			0	1
Distance of active commute (km)			0.979	1.94	0	48.98
Independent						
Income (in $'000s) [32]	10258		43.76	25.77	5	110
Controls						
Sex						
Male	5071	45.06				
Female	6184	54.94				
Age	11255		40.73	13.35	8	88
Employment status						
Full time	9205	81.79				
Part time	1795	15.95				
Household type						
Single adults	1897	16.85				
Household with children	4732	42.04				
Family no children	4564	40.55				
Partnership						
Living with partner	7759	69.27				
Not living with partner	3423	30.56				
Holds car licence						
Yes	10622	94.59				
No	607	5.41				
Contextual						
Day of week						
Sunday	489	4.34				
Monday	1831	16.27				
Tuesday	2110	18.75				
Wednesday	2156	19.16				
Thursday	2062	18.32				
Friday	1944	17.27				
Saturday	663	5.89				
Season						
Summer	2618	23.26				
Autumn	2864	25.45				
Winter	2756	24.49				
Spring	3017	26.81				
Survey year						
2003/04	2379	21.14				
2004/05	2158	19.17				
2005/06	2498	22.19				
2006/07	2103	18.69				
2007/08	2117	18.81				
Region						
Northland	420	3.73				
Auckland	1742	15.48				
Waikato	1077	9.57				
Bay of Plenty	507	4.50				
Gisborne	260	2.31				
Hawkes Bay	390	3.47				
Taranaki	441	3.92				
Manawatu-Wanganui	641	5.70				
Wellington	1691	15.02				
Nelson-Marlb-Tasman	659	5.86				
West Coast	468	4.16				
Canterbury	1668	14.82				
Otago	826	7.34				
Southland	465	4.13				
Settlement type						
Main Urban Area	6865	61				
Secondary Urban Area	1289	11.45				
Rural Area	3101	27.55				

[32] Note: income is rendered continuous here and in the analysis by replacing each category with its mid-point. The open ended (highest) income has been set to $110,000.

5.4 Summary

National travel surveys are one of the most detailed sources of information about people's activity levels. My use of the NZHTS is one of the few I can discern undertaken by a graduate student and joins only a handful of investigations outside the Ministry's own research staff.

The first part of this fifth chapter introduced the NZHTS and outlined the sampling method utilized for collecting data. I highlighted the importance of clearly defining what is meant by active transport and described the meaning of commuting it was possible to derive from the survey. The difference between trip chain and trip leg was explained along with how the principal purpose of that trip was established, and how a particular transport mode could be deemed to be the dominant mode.

The second part of the chapter showed the distribution of values in the NZHTS for the main dependent variable (active commuting), and independent variables of interest in this study: income and those I use as controls such as age and sex. I then briefly examined seasonal and regional patterns of commuter walking and cycling and found that, while there is little variation in active commuting across different months of the year, commuter walking and cycling varies significantly across different regions of New Zealand. Wellington is notable for its considerably higher percentage of walking commutes compared to the rest of the country.

Against this base I now turn to the relationship between active commuting and income for various subgroups within New Zealand.

Chapter 6. Active Commuting and Income

The New Zealand Household Travel Survey outlined in chapter 5 offers a number of valuable opportunities to explore the way in which people's income levels affect their likelihood of using active transport for commuting. My central argument, outlined in chapter 4, is that in general people would tend to substitute easier, motorized forms of transport as their wage returns from the commute increased.[33] Certainly the historical evidence supports such a view with car ownership in general (and multiple car ownership in particular) rising steadily with income.[34] Whether this relationship holds in cross-section and at the level of the local labour market is one of the questions I want to explore here.

I begin by examining the national picture, drawing on commuting patterns over the last five years in New Zealand as a whole. The result is initially something of a surprise, given my earlier hypothesis, for the probability that active trip legs will occur within travel to work trip chains does not fall continuously with income at all. On the contrary, I am confronted with a paradox: active commuting does fall as incomes rise, but after about $50,000 per annum, the average probability of walking and cycling to work rises, and continues to do so as incomes continue to rise. In other words, in my cross-sectional survey data, active commuting is U-shaped in income.

In order to unpack this surprising result I reexamine the relationship for different subgroups within the commuting population beginning with gender and discover that quite a different relationship holds in the two cases. However, they depart again when I consider the way active commuting differs between young men and young women, middle age groups, and older commuters. Clearly, the way income impacts people's propensity to walk or cycle to work depends a great deal on their demographics.

---

[33] In other words, physically active commuting is an inferior good; both the probability of actively commuting *and* the distance commuted are expected to fall as people's incomes rise.

[34] Bearing in mind that increased car ownership with income does not imply that car use for commuting will necessarily increase. Car ownership could provide for discretionary use of a vehicle without everyday dependence on it for commuting.

One of the ways income affects the likelihood of active commuting is through car ownership. Car ownership is highly sensitive to income, first the initial car, then the second and even third. The most important influence however is that initial purchase, closely associated as it is with the obtaining of a car licence. Therefore I explore what happens to the way income affects active commuting before and after obtaining a licence.

It is difficult to transport heavy or delicate items when actively commuting. One might expect therefore that meeting the needs of children would have a profound effect on the propensity to walk or cycle to work. Again I was surprised at the result. I also explore whether living with a partner alters the relationship since it raises joint income but also opens up opportunity for sharing vehicles among other things.

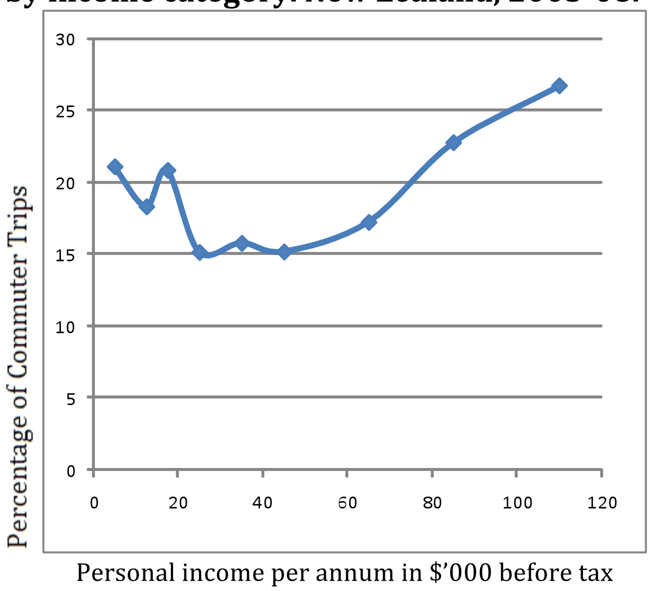
Instructive though the national picture as a whole is, there is one vital conditional effect missing, namely the nature of the local labour market within which these decisions are made. The national picture is in effect just the sum of a whole set of quite different local experiences each of which can modify, and sometimes radically change, the way active commuting is influenced by income. Therefore in the second half of this chapter I reconsider the income commuting relationship within three distinct settings, in main urban areas, secondary urban areas and rural areas. The results help resolve the unexpected results I obtained for income. With the problem relocated to the level of the local labour market I am now able to show that the reason active commuting *rises* with higher income is not necessarily because the switch to alternative forms of transport diminishes but rather because the nature of the transport and distance options change.

What happens, I discover, is that rising income alters people's settlement patterns. Higher income earners are more likely to move to the larger, denser labour markets in the main centres which in turn provides options for non-car travel but more importantly it allows many high income commuters (though not all) to locate closer to the workplace. With distance to the workplace diminished, the relative costs of motorised and non-motorised transport change in favour of active transport. As we have long known, compact settlements encourage more sustainable commuting. However, it is the *higher* income groups (who can locate centrally) that are able to avail themselves of this new opportunity set and this is primarily why the probability of active commuting rises among higher income groups. As further evidence for this argument I demonstrate that it is the *likelihood* of active commuting that rises with higher incomes rather than the *distance* actually walked or cycled. This is consistent with my income and location argument. With this overview, I turn now to the specific results.

6.1 Income and active commuting: the national picture

Contrary to the expectation outlined in chapter 4, active commuting *is most likely at the lower and higher ends of the income distribution*. The relationship is U-shaped, as shown in figure 6.1. Approximately 20% of all home to work trip chains among those earning under $30,000 (mid point of $25,000) involve walking or cycling over some of the distance. This falls to around 15 percent of all trips undertaken by those with gross earnings of $50,000 or less, after which the probability of commuting actively rises, to between 25 and 30 percent among the highest income groups.

Figure 6.1. The distribution (%) of active (walking and cycling) commutes by income category. New Zealand, 2003-08.



Source: NZHTS trip file

I can model the description in figure 6.2 by estimating in (1) the probability of active commuting as a quadratic function of income, that is:

(1) $p(AC)_{ij} = \alpha + \beta_1 \text{Income}_{ij} + \beta_2 \text{Income}_{ij}^2 + \varepsilon_{ij}$

where p(AC) is the probability of actively commuting (AC=1,0), Income is personal income before tax, and Income^2 is income squared. The subscript i = 1, 2, …, N refers to the sampled commuter trip chain, and j = 1, 2, …, K, identifies the position of the leg in each trip chain. An example observation might be ij = 43 where 4 is the fourth person in the sample whose active commute takes place as the third leg of that trip chain.[35]

I estimate the equation above as a logistic regression model (2). The parameters of this equation when applied to the odds of active commuting and estimated for New Zealand as a whole are:

(2) $p(AC) / 1\text{-}p(AC) = 0.275\ (-15.23)\ - 0.985\ (-4.22)\ \text{Income} + 1.00\ (5.56)\ \text{Income}^2$

The parameters for the quadratic show the odds of actively commuting fall (-0.985) then rise (+1.00) with income.[36]

However I am primarily interested in probabilities rather than odds ratios and I have therefore constructed Figure 6.2, which fits a median spline through the estimated probabilities of using active modes to commute as predicted from the equation (1) above.[37] These probabilities replicate the proportions shown in Figure 6.1 reasonably well.

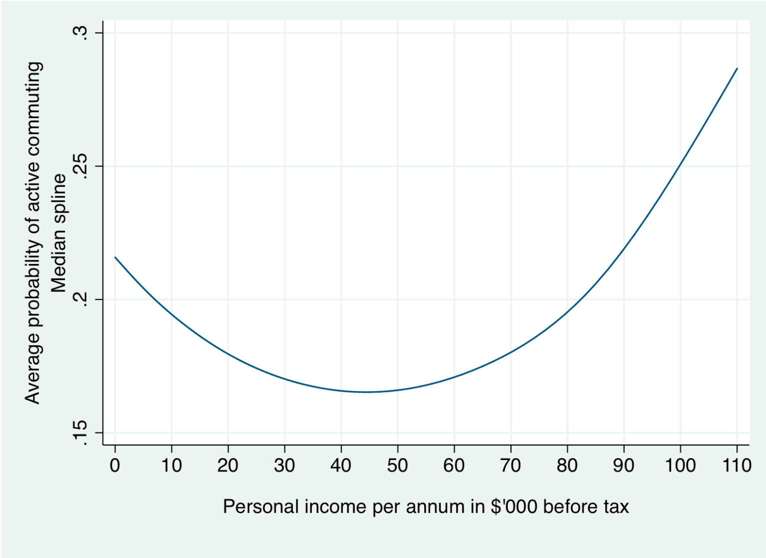
---

[35] Note that because it is trip legs that are used as the unit of analysis, this subscripting allows the same person to be counted more than once in the sample of active commutes. This could occur if the person walks to the bus stop, takes a bus then walks at the end, where both walks exceed 100 metres. This person will appear as the 'active commuter' in two of the three trip legs that make up this particular chain.

[36] The numbers in parentheses are z values.

[37] This graph is produced using a method available in Stata called median spline. This basically chops the scatterplot into vertical bands, calculates the bivariate medians for each and then interpolates the median points using cubic splines. (In mathematics a spline is a sufficiently

Figure 6.2. The probability of using active transport for commuting by personal gross income category. New Zealand 2003-08.



Source: NZHTS trip file

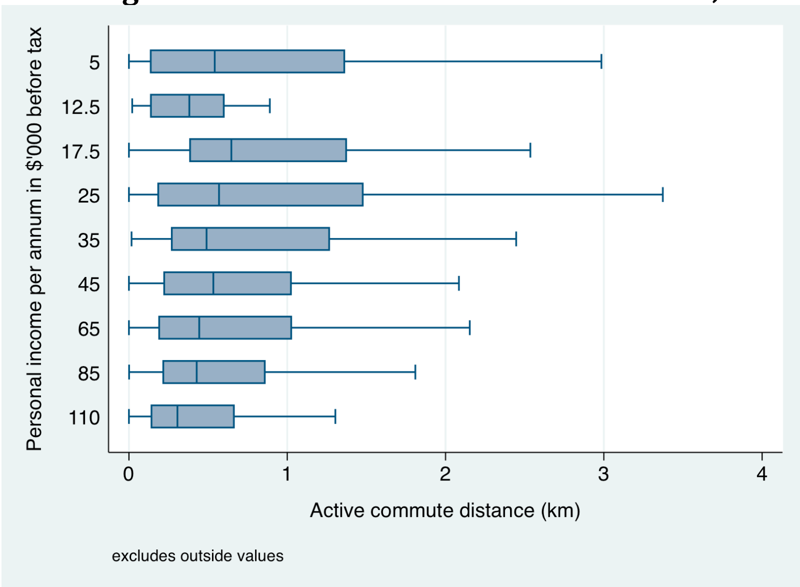
The probability of using active transport during the commute from home to work starts at around 0.22, drops to just over 0.15 at about $45,000 gross income then rises continuously with income to around 0.28 in the maximum income category. My explanation for this U-shaped pattern is that moving from a low to middle income enables access to the comfort and convenience of private vehicles (enabling a switch from active and public transport modes to the private car), but that moving from a middle to high income buys a residential location that is in closer proximity to the workplace (thus enabling the use of active modes for the commute). I can test this theory by checking whether active commuting distances actually do fall as incomes rise. The expectation is that commuting distances will be smallest for those with the highest predicted probability of actively commuting, which is commuters in the highest income brackets in main urban areas. Figure 6.3 shows that the evidence is consistent with such an argument.[38]

---

smooth piecewise polynomial function). The median spline is robust to outliers and therefore is a useful way of tracking the way average probabilities change as I do here.

[38] I acknowledge that significance testing could have been carried out here. However, it should be noted that the multivariate analyses in chapter 7 tackle the question of sampling errors.

Figure 6.3. Distribution of average active commuting distances by gross income categories in main urban areas New Zealand, 2003-08.



Source: NZHTS trip file

If higher income earners are able to outbid those on lower incomes in order to purchase more centrally-located residences, then it is likely that these higher income city-dwellers will also have superior access to public transport options. This may further enable opportunities for active commuting since public transport usually involves some degree of walking at either end. I can test this idea by exploring whether the instance of multi-leg trip chains increases with income.

Table 6.1. Number of trips legs per work trip chain by gross income category. New Zealand 2003-08

Income (in $'000)	Legs per trip chain 1	2	3	4	5+	Total
5	75.78	18.22	4.76	0.62	0.62	100.00
12.5	72.62	15.78	7.19	2.55	1.86	100.00
17.5	73.68	17.37	6.71	1.18	1.05	100.00
25	67.09	23.33	5.60	2.08	1.91	100.00
35	64.44	25.65	6.83	1.89	1.20	100.00
45	58.91	29.65	7.51	2.16	1.76	100.00
65	57.90	29.45	8.68	2.48	1.49	100.00
85	50.57	34.30	9.71	3.91	1.51	100.00
110	48.94	35.89	11.13	2.30	1.73	100.00
Total	62.61	26.35	7.38	2.15	1.50	100.00

Source: NZHTS trip file

This table is also consistent in showing that the commute becomes more complicated with income. Whereas about 3/4 of all commutes by low income workers involve a single leg chain i.e. one mode only, among the higher income groups this had dropped to about half, most of which involve two legs and over 10% involve three legs or more. I infer from this that there is a greater chance that an active commute leg (most likely walking) will appear among the trip legs of higher income commuters. In other words, it may not simply be that high income commuters can outbid others for central locations and thus reduce the travel to work time, but that higher income workers are exposed to greater opportunities for multi mode commutes and this alone increases the chance that at some point they will walk.

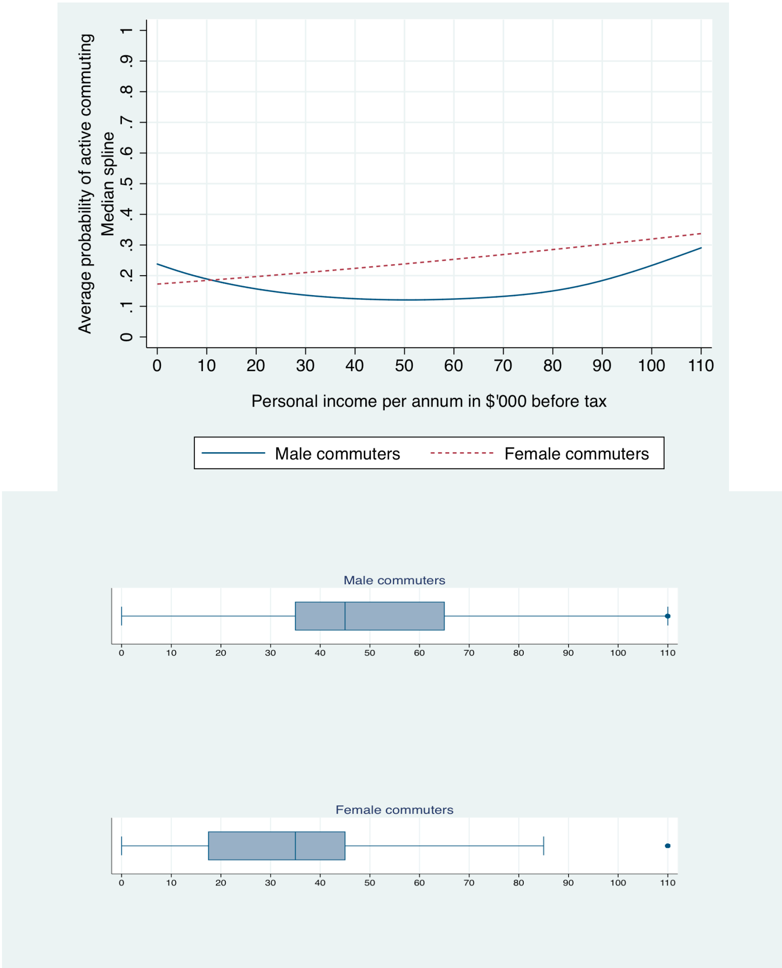
There is an additional reason (discussed in chapter 4) for why the likelihood of actively commuting is greater among higher income earners. This is the theory that, since higher income earners are typically also more highly educated, the higher use of active modes among these individuals reflects a greater concern for health, borne of a better awareness about the benefits of active transport for fitness and well-being. As I do not have any data relating to either individual's education levels or attitudes about health in the NZHTS data set, I am unable to test this empirically. However, other large data sets, such as the 2008 New Zealand General Social Survey, have revealed a strong positive relationship between education and income (Scott, 2010).

6.2 Individual characteristics:

Gender

When we look at the income-active commuting relationship for men and women separately in Figure 6.4, we can see that they differ substantially. Note that I have included box plots beneath the graph to show the difference in income distributions between male and female commuters. Male incomes are much more skewed towards the upper end of the income spectrum.

Figure 6.4. The probability of using active transport for commuting by personal income category: men & women. New Zealand 2003-08.



Source: NZHTS trip file

The estimated parameters of this equation for male commuters are

$p/1\text{-}p = 0.312\ (-8.64)\ - 0.979\ (-6.25)\ \text{Income} + 1.00\ (7.71)\ \text{Income}^2$

and for female commuters

$p/1\text{-}p = 0.208\ (-13.35)\ - 1.008\ (1.44)\ \text{Income} + 1.00\ (0.07)\ \text{Income}^2$ [39]

Table 6.2 below shows the number of male and female commuters at each income level in order to demonstrate that there are sufficient observations to obtain meaningful results.

---

[39] The relationship with income for female commuters is clearly a linear one, so henceforth I will drop the income^2 variable for all female regressions. The estimated parameters for the equation for female commuters in figure 6.4 now becomes:

$p/1\text{-}p = 0.208\ (-22.28)\ -+1.008\ (5.04)\ \text{Income}$

Table 6.2. Distribution of commuters by income. New Zealand 2003-08.

Male Commuters

Income $'000	Active Commuting N	Y	Total
5	145	41	186
	77.96	22.04	100.00
12.5	85	25	110
	77.27	22.73	100.00
17.5	222	52	274
	81.02	18.98	100.00
25	655	95	750
	87.33	12.67	100.00
35	979	145	1,124
	87.10	12.90	100.00
45	940	123	1,063
	88.43	11.57	100.00
65	942	131	1,073
	87.79	12.21	100.00
85	481	122	603
	79.77	20.23	100.00
110	332	122	454
	73.13	26.87	100.00
Total	4,781	856	5,637
	84.81	15.19	100.00

Female Commuters

Income $'000	Active Commuting N	Y	Total
5	234	63	297
	78.79	21.21	100.00
12.5	264	57	321
	82.24	17.76	100.00
17.5	377	109	486
	77.57	22.43	100.00
25	807	175	982
	82.18	17.82	100.00
35	828	216	1,044
	79.31	20.69	100.00
45	535	159	694
	77.09	22.91	100.00
65	382	158	540
	70.74	29.26	100.00
85	131	59	190
	68.95	31.05	100.00
110	50	17	67
	74.63	25.37	100.00
Total	3,608	1,013	4,621
	78.08	21.92	100.00

Source: NZHTS trip file

I will now test the significance of the above male income curve by creating dummy income variables and testing them against the base income ($35,000). The results show that the lowest three income levels and the highest two income levels are statistically significantly more likely to actively commute, compared to the base. Therefore we can have confidence in the U-shape above.

Table 6.3. Test of significance of the male income curve

Logistic regression — Number of obs = 5637; LR chi2(8) = 93.18; Prob > chi2 = 0.0000; Pseudo R2 = 0.0194

Log likelihood = -2354.2726

AT	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
5000	1.909108	.3780073	3.27	0.001	1.295063	2.814299
12500	1.985801	.4851321	2.81	0.005	1.230232	3.205418
17500	1.581485	.2813678	2.58	0.010	1.115898	2.241328
25000	.9792577	.1383876	-0.15	0.882	.7423456	1.291778
35000 = base						
45000	.8834703	.115569	-0.95	0.344	.6836662	1.141668
65000	.938934	.1210211	-0.49	0.625	.7293265	1.208783
85000	1.712496	.2309884	3.99	0.000	1.314667	2.230709
110000	2.481055	.3431289	6.57	0.000	1.891976	3.253548
_cons	.1481103	.0131793	-21.46	0.000	.1244064	.1763307

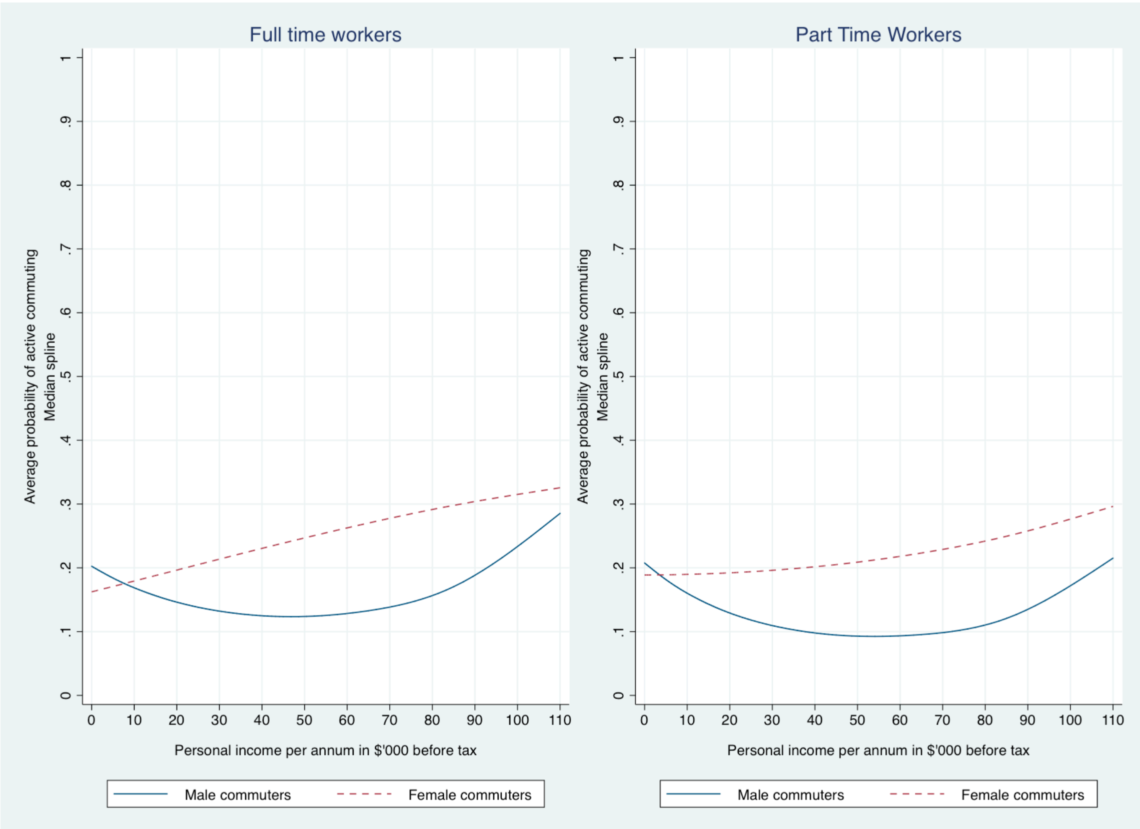
Source: NZHTS trip file

At virtually all incomes, female workers are more likely to walk or cycle to work than their male counterparts. It is only among the lowest income earners that men's probability of active commuting is higher than women's. Contrary to the hypothesis advanced in chapter 4, the propensity of women to walk or cycle rises continuously rather than falls with income. Men tend to substitute the car for active commuting as their income rises. It is only among the higher male earners that their probability of active commuting begins to approximate that of women.

Employment status

When we divide both male and female commuters into part time and full time workers as in Figure 6.5, we can see part timers' decision to actively commute is slightly less responsive to income than full timers'.

Figure 6.5. The probability of using active transport for commuting by personal income category: part time and full time workers. New Zealand 2003-08.



Source: NZHTS trip file

Men are considerably less likely to use active transport than women, regardless of employment status, except at the very lowest income levels. In the case of male part timers, the U-shape is more severe; those in the middle income brackets have a median probability of only about 0.05, compared to full time middle income men, whose probability is closer to 0.125. Among female active commuters, full timers are more responsive to rising income than part timers. A woman working full time and earning $20,000 per year has a probability of active commuting of 0.2, whereas a woman earning $70,000 more than this has a probability of over 0.3.

Table 6.4 shows that among men a higher percentage of part time workers walk or cycle to work than their full time counterparts (17.4% compared with 14.7% respectively). However for women the reverse is true: full timers are more likely to actively commute than part timers (22.6% versus 19.5%).

Table 6.4. Distribution of active commuters among full time and part time workers, New Zealand 2003-08

Male Commuters

Active Transport	Part time	Full time
N	365 82.58	4,796 85.28
Y	77 17.42	828 14.72
Total	442 100.00	5,624 100.00

Female Commuters

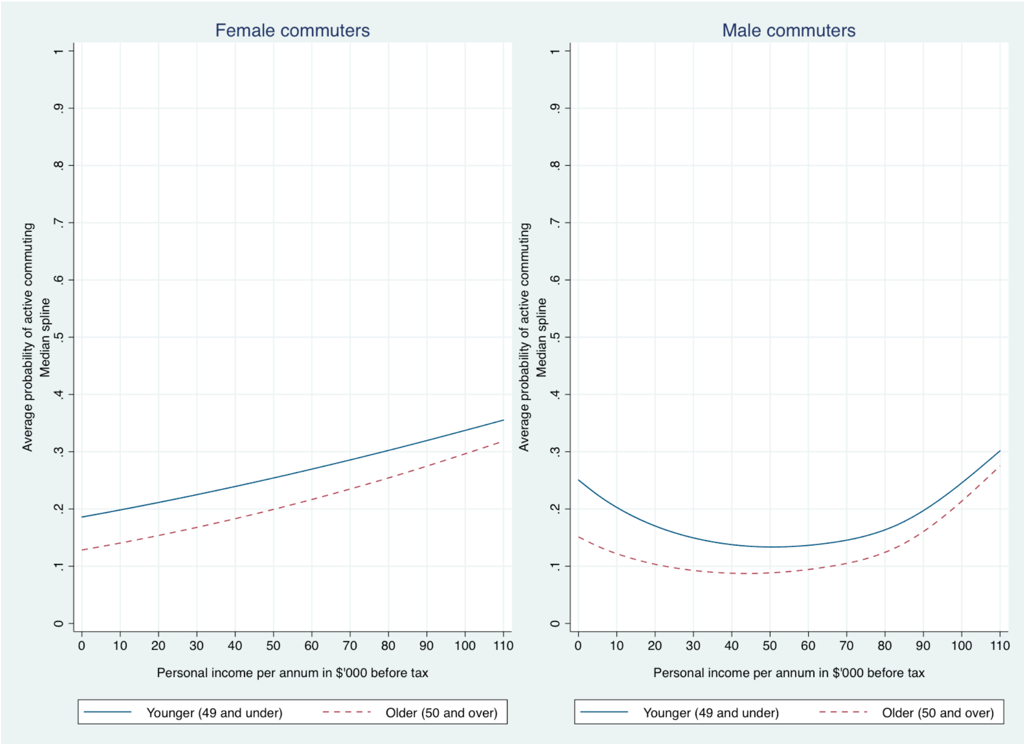
Active Transport	Part time	Full time
N	1,089 80.49	2,771 77.38
Y	264 19.51	810 22.62
Total	1,353 100.00	3,581 100.00

Source: NZHTS trip file

Age

In chapter 4 I argued that age was likely to have an important effect on the chances of workers actively commuting. My expectation that commuters would opt for non-active modes as they age seems to be confirmed by Figure 6.6 in which men and women are divided into broad “younger” and “older” categories.

Figure 6.6. The probability of using active transport for commuting by personal income. Younger and older commuters. New Zealand 2003-08.



Source: NZHTS trip file

The regression outputs for the two graphs in Figure 6.6 are [40]

Younger women-

Logistic regression

Number of obs	=	3353
LR chi2(1)	=	17.89
Prob > chi2	=	0.0000
Pseudo R2	=	0.0049

Log likelihood = -1811.0231

AT	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
peincnumrcx	1.00804	.0018893	4.27	0.000	1.004344	1.01175
_cons	.2283381	.0182077	-18.52	0.000	.1953006	.2669644

Older women-

Logistic regression

Number of obs	=	1268
LR chi2(1)	=	10.56
Prob > chi2	=	0.0012
Pseudo R2	=	0.0087

Log likelihood = -598.11247

AT	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
peincnumrcx	1.010556	.0032169	3.30	0.001	1.004271	1.016881
_cons	.1472137	.0222091	-12.70	0.000	.1095301	.1978624

40 For the remaining probability graphs in this chapter, I will only supply the estimating equations if there are any doubts that the median splines might not depict differences which are statistically significant.

Younger men-

Logistic regression — Number of obs = 4078; LR chi2(2) = 47.74; Prob > chi2 = 0.0000; Pseudo R2 = 0.0132

Log likelihood = -1788.0846

AT	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
peincnumrcx	.9700786	.0055795	-5.28	0.000	.9592044	.9810761
peincumrcx2	1.000297	.0000469	6.33	0.000	1.000205	1.000389
_cons	.3345582	.0490434	-7.47	0.000	.251011	.4459134

Older men-

Logistic regression — Number of obs = 1559; LR chi2(2) = 41.94; Prob > chi2 = 0.0000; Pseudo R2 = 0.0360

Log likelihood = -560.79376

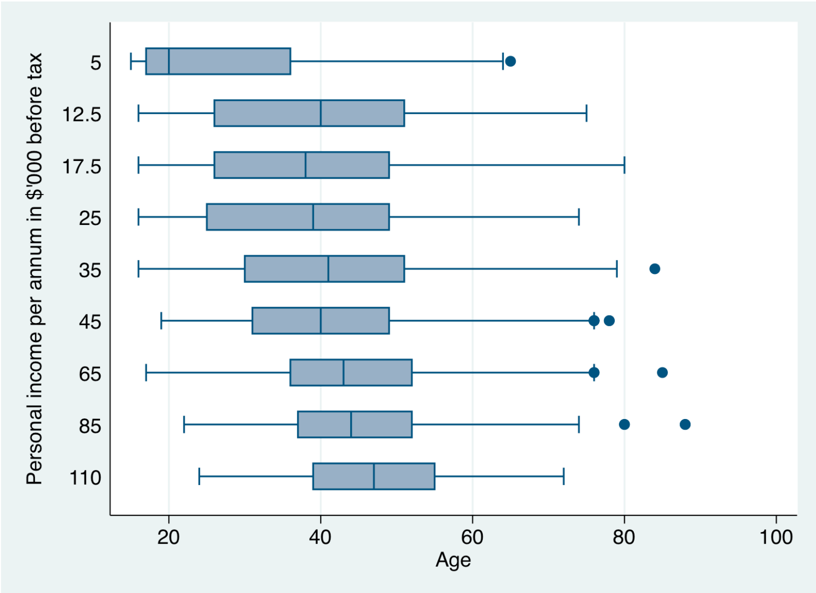
AT	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
peincnumrcx	.9722638	.0120561	-2.27	0.023	.9489191	.9961829
peincumrcx2	1.000318	.0000914	3.48	0.000	1.000139	1.000497
_cons	.1782142	.0635971	-4.83	0.000	.0885492	.3586744

We see that the response to income does not differ much between those who are under 50 and those who are over 50, but for both men and women, younger people are more likely to walk or cycle to work. Figure 6.6 also shows how the gap between younger and older people is most pronounced among low income earners. To illustrate, for men earning around $10,000 per year, the over 50s have a predicted probability of walking or cycling to work of about 0.11, whereas under 50s have a probability of closer to 0.2. In other words, there is almost a one percent difference. Contrast this to the much smaller discrepancy in probabilities between high income earning males, say those earning $100,000 per year, for whom those under 50 have a probability of about 0.24 and those over 50 have a probability of about 0.21.

The expectation that commuters will opt for non-active modes as they age, notwithstanding competing demands, is supported by the data that compares ‘older’ and ‘younger’ age groups. However age is closely linked with a number of other factors such as living with a partner and with earning a higher income, so it is quite difficult to disentangle these effects from the effects of age per se. Indeed,

Figure 6.7 reminds us that age and income are closely correlated, with average incomes tending to rise as people get older.[41]

Figure 6.7. Distribution of personal incomes according to age, New Zealand 2003-08.



Source: NZHTS trip file

Economic geography plays a role here too, as we know that there are a greater proportion of younger people living in urban areas, and for those living and working in the city, active commutes are much more feasible than for those living in the suburbs, who tend to be older.

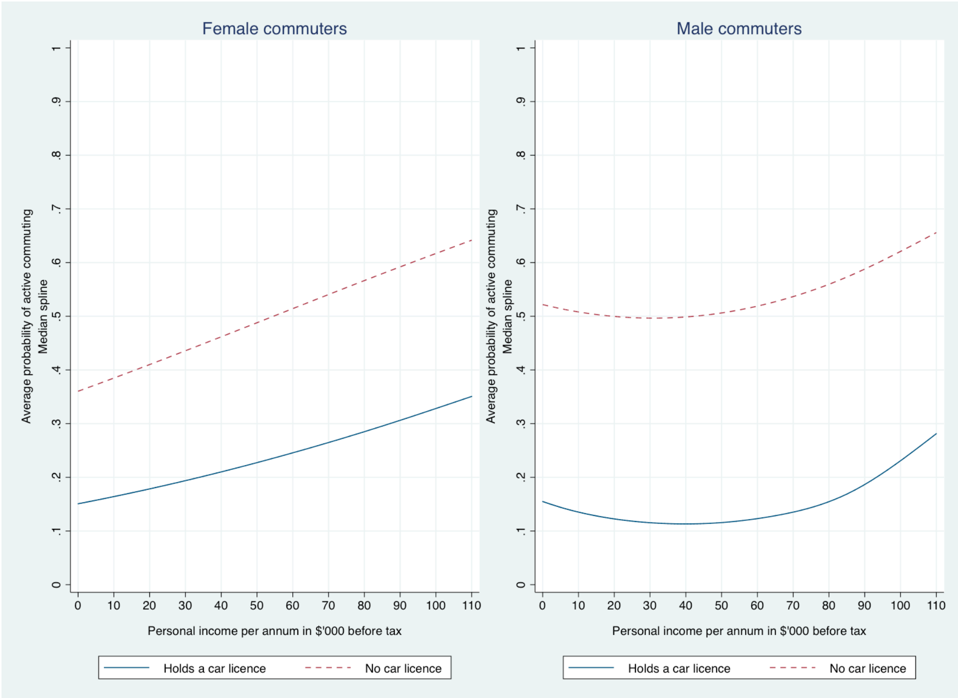
Holding a car licence

There is a well-established negative relationship between car ownership and active transport use (Adams, 2010; Keall, Chapman and Howden-Chapman, 2009; Merom et al, 2010). But how about the relationship between simply holding a driver's licence and using active modes? Figure 6.8 shows that holding a car license predicts significantly lower probabilities of using active modes for commuting, especially among male commuters.

---

[41] For further unpacking of the age variable in the context of the relationship between active commuting and income, see appendix 5.

Figure 6.8. The probability of using active transport for commuting by personal income category: licence holders. New Zealand 2003-08.

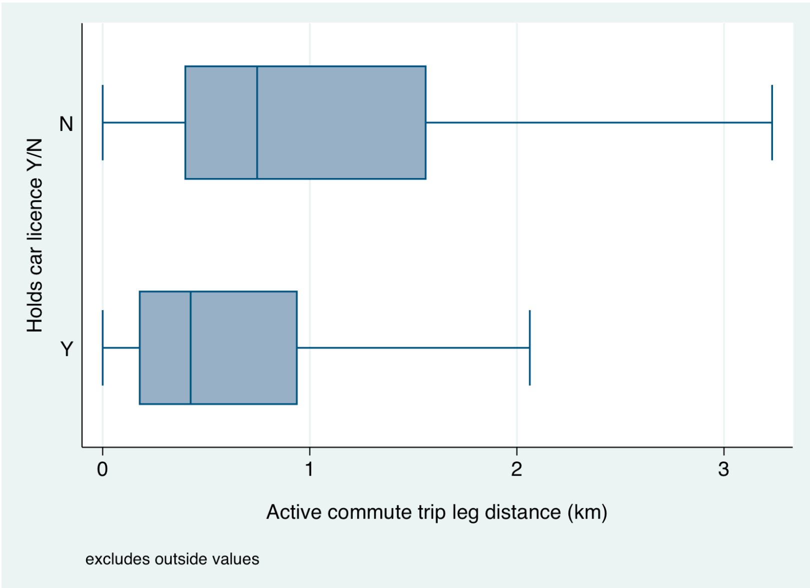


Source: NZHTS trip file

For men earning $40,000 per year, the probability of active commuting is about 0.125 for those who hold a driver's licence, compared to a much higher 0.5 for those who do not. For female commuters, the gap in probabilities between licence holders and non-licence holders is smaller (though still substantial), and it broadens somewhat as incomes rise due to the steeper slope of the non-licence holders estimated probability line. For men, the effect of income on the predicted probability of active commuting is near identical for licence holders and non-licence holders. However, the regression output for this graph shows that while the influence of income is highly statistically significant for both men and women who hold a car licence, income does not register as significant for non-licence holders of either gender. This may be due to the much smaller number of commuters who do not hold a licence (for men, n=201 and for women n=281) and their possible concentration at the lower end of the income distribution.

Interestingly, not only do those without a car licence have a higher likelihood of active commuting, they also commute longer distances in the active legs of their trip chains, as detailed in figure 6.9. The fact that more men than women hold car licences could be another reason why we see a greater prevalence of active commuting trips among women than men.

Figure 6.9. Average active commute trip leg distance by car licence. New Zealand, 2003-08



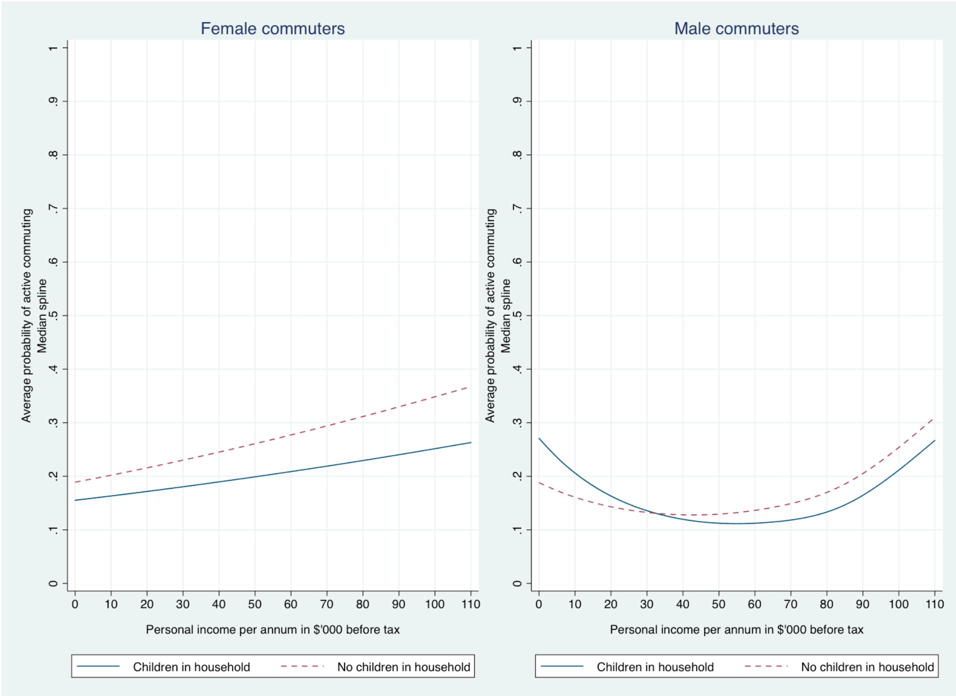
Source: NZHTS trip file

I have now explored several characteristics of individuals that affect the relationship between active commuting and rising income: sex, age, employment status and holding a driver's licence. I now turn to the characteristics of the household that may impact an individual's propensity to walk or cycle to work.

6.3 Household characteristics

I speculated that households containing children were likely to face more limited transport options that those without and, due to time, money and logistical constraints, may be less likely to commute by bike or foot. I test this empirically in Figure 6.10 by comparing the probability of using active transport modes by income in households with and without children.

Figure 6.10. The probability of using active transport for commuting by personal income category: households with/without children. New Zealand 2003-08.



Source: NZHTS trip file

For employed women living with children, the average probability of commuting using active modes is lower at all income levels compared to women living in households without children. This gap is less pronounced among lower income women with a probability of about 0.17 (with children) and 0.2 (without children) for women earning $10,000, but widens as both incomes and probabilities increase to about 0.25 (with children) and 0.35 (without children) for women earning $100,000.

For men the picture is slightly more complex. Men earning up to about $30,000 per year are actually more likely to walk or cycle to work if they live with children. Above $30,000, however, it is those men who do not live with children who are slightly more likely to use the active modes. We observe quite a striking difference between men and women living with children in the middle (and most common) income category. Whilst women with children earning a personal income of $50,000 before tax have a predicted probability of active commuting of 0.2, men with children earning the same income have a predicted probability of only about 0.12.

As expected, individuals in households with children are less likely to walk or cycle to work, and there are a number of good reasons for why this should be the case. Time is generally a scarcer resource for commuters with children, and therefore the opportunity cost of using active modes is greater. Coupled with that is the choice of residential location which, for people with children, is more likely to be outside the city centre, thus necessitating a longer commute distance.[42] The safety and logistics of walking or cycling with children is another constraint. There is also, as I have previously mentioned, the compounding effect between having children in a household and having more than one car. Children also impose financial constraints and, as we have seen, it is not until both men and women get into the higher income brackets that the probabilities of using active transport become quite high.[43]

Car ownership

Access to a motor vehicle and holding a driver's licence have been shown to be strong negative predictors of use of active modes for the work commute. Table 6.5 shows that households without children are significantly more likely not to have a car (8.25%) than those households with children (3.34%).

Table 6.5. Number of cars per household according to household type. New Zealand 2003-08.

Num.household cars	Other or Unknown	Household w/o children	Household w children	Total
No car	2 3.28	778 8.25	176 3.34	956 6.47
One car	20 32.79	4,063 43.06	1,606 30.46	5,689 38.52
Two cars	25 40.98	3,254 34.48	2,433 46.14	5,712 38.67
Three or more cars	14 22.95	1,341 14.21	1,058 20.06	2,413 16.34
Total	61 100.00	9,436 100.00	5,273 100.00	14,770 100.00

Source: NZHTS Household file

[42] Assuming that most commuters work within the central city.

[43] The logisitic regression outputs from which the above graphs were generated reveal that the results are all statistically significant. However, it is not the difference between having children or not having children in a household that is most significant, but rather the difference between being male or female. Being female has a significant positive efect on the probability of active commuting, regardless of household composition. Being male has a significant negative effect on active commuting and this effect is also indifferent to the presence of children in the household.

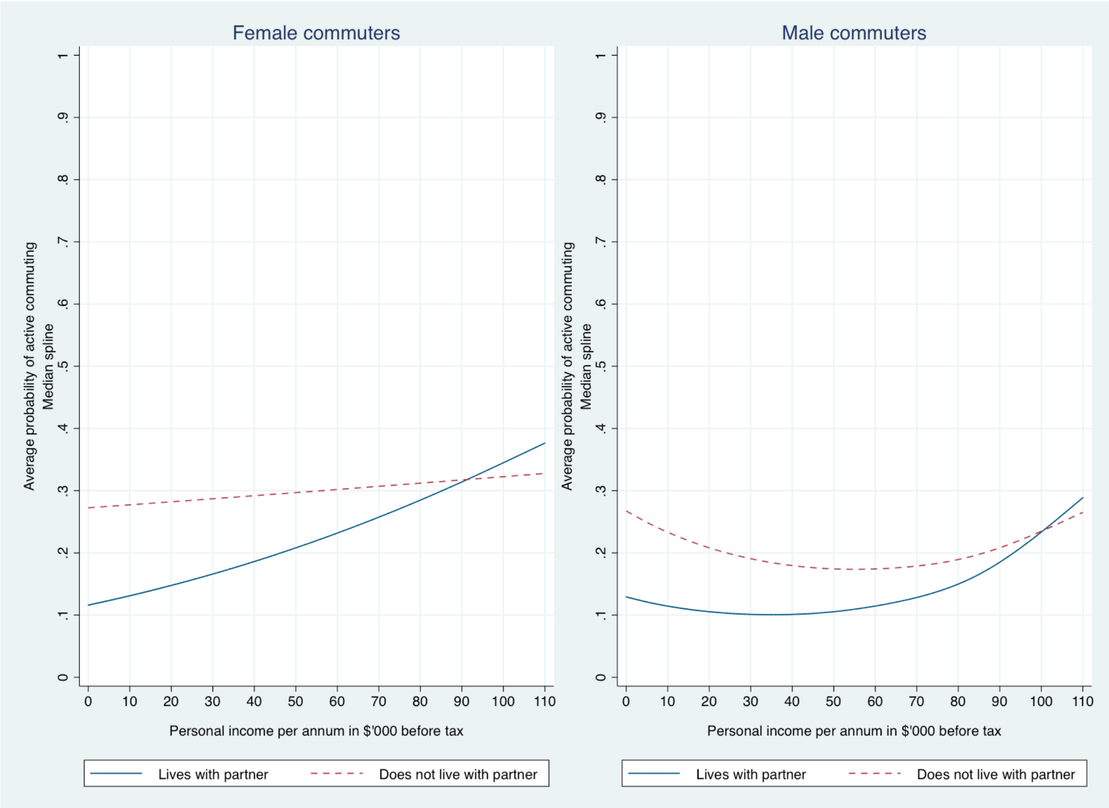
Equally, households with children tend to have more than one car per household (66.2%), whereas for households without children, one car per household is most common (43%). We therefore have a conflation effect whereby the presence of children in a household and the greater number of cars owned by such a household together result in a much lower probability of using active transport for the commute than would be the case otherwise.

Partnership

We can also investigate whether simply living with a partner or spouse affects the income-active commuting relationship and if it is different for men and women. My hypothesis on the basis of time series evidence was that in cross-section active commuting would decline with rising income. Therefore my expectation was that the greater combined income available to those living in a partership would mean that less active commuting will occur when couples are present in the household.

Figure 6.11 shows that for female commuters living with a partner, the probability of using active transport rises sharply with income from about 0.13 for women earning $20,000 per year, to about 0.3 for women earning $80,000 per year, and probabilities continue to rise steeply with income.

Figure 6.11. The probability of using active transport for commuting by personal income category: men and women living with/without a partner. New Zealand 2003-08.



Source: NZHTS trip file

For male commuters who live with a partner, the probability of walking or cycling does not start to increase until a man is earning over $50,000, after which predicted probabilities rise steeply from about 0.11 for a man earning $50,000, to 0.25 for a man earning $100,000. For both male and female commuters the predicted probabilities of using active transport are higher for those not living with a partner until the point where a person is earning $95,000 a year or more, and then it is those living with partners who are more likely to walk or cycle to work. Income does not register as being of statistical significance for either gender when regressed against commuters who do not live with a partner.

Regarding the negative effect of living with a partner on active commuting, one explanation could be that people who would otherwise not have access to a vehicle are able to switch from active modes to become vehicle drivers or passengers when living as a couple. Also, returning to the issue of economic geography, the proportion of people living with a partner is substantially higher in rural areas (73%) than in main urban areas (64.8%). This may suggest that household composition is not the most salient factor in this instance, but rather that settlement type is the more crucial variable. The role of residential location and other aspects of economic geography will therefore now be explored.

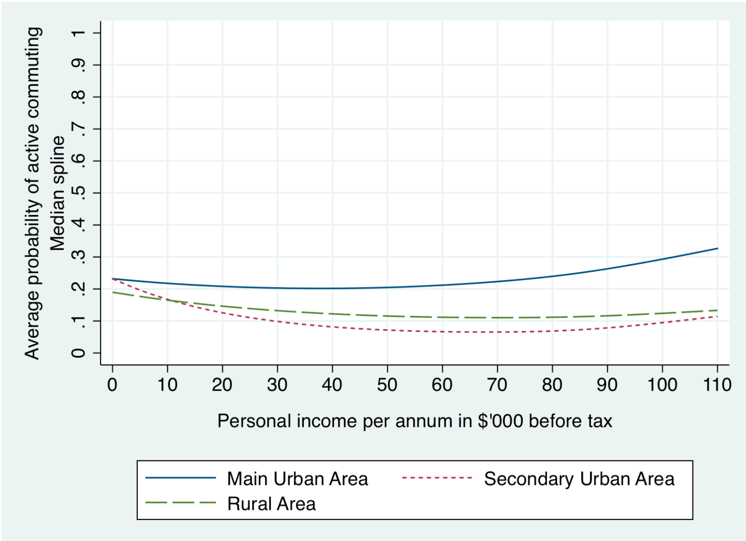
6.4 Locational characteristics

This section considers a final set of characteristics in relation to the impact of personal income on active commuting: those concerning an individual's location. There are two levels to explore with regard to geographical location and the first of these is settlement type; the type of local labour market the individual has access to- whether it is a major metropolitan centre, a medium sized town, or a small village in a largely rural area.

Settlement type

In chapter 4 I suggested that higher income individuals working in a large labour market would be able to outbid lower income individuals and gain access to downtown residential locations close to the workplace, enabling them the option of commuting by bike or on foot. Figure 6.12 shows that people living in main urban areas do have a higher probability of active commuting than those living in either secondary urban areas, or those living in rural areas and that this difference prevails at all income levels.

Figure 6.12. The probability of using active transport for commuting by personal income category across different settlement types. New Zealand 2003-08.



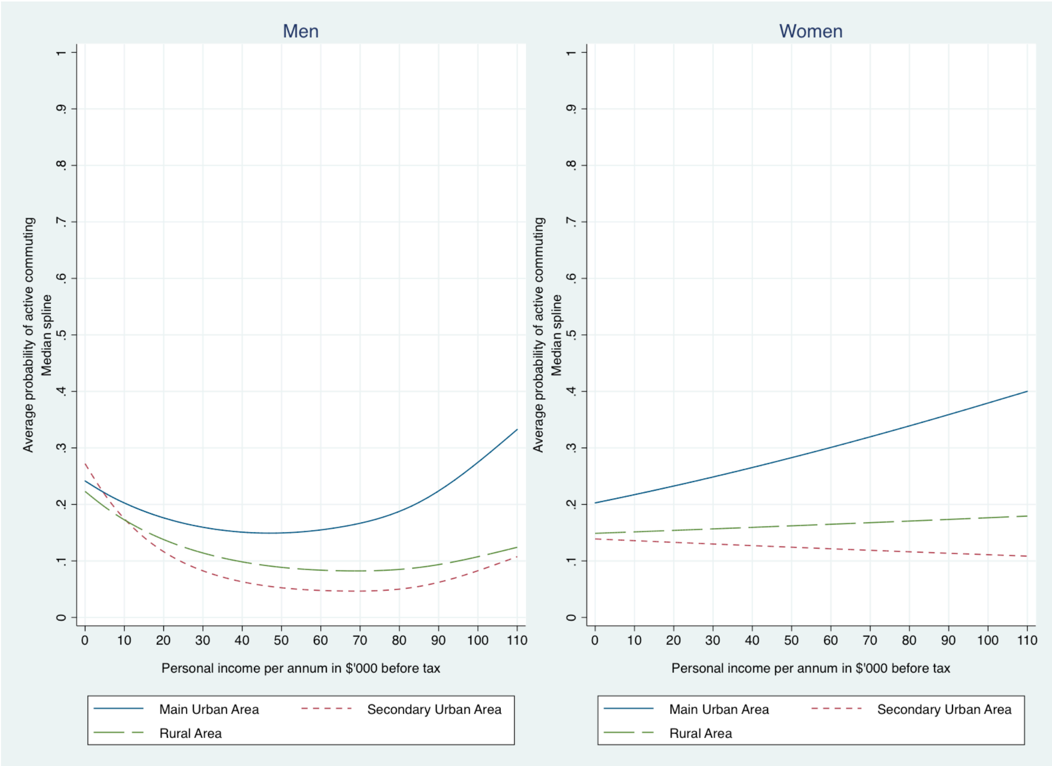
Source: NZHTS trip file

People in the main urban areas are the most responsive to rising income when it comes to the probability of walking or cycling to work. The predicted probability of active commuting for those residing in main urban areas rises from 0.2 for those earning anywhere between $20,000 and $60,000 per year, to above 0.3 for those earning upwards of $100,000 per year.

Conversely, for people living in either a secondary urban area or a rural area, the likelihood of using active modes is not only lower than for those living in the main urban areas but also drops slightly with income. Any commuter living in a secondary urban area and earning between $40,000 and $100,000 has a predicted probability of walking or cycling to work of less than 0.1. This is lower than for any other settlement type and any other income level.

In Figure 6.13, commuters in the three different settlement types are divided by gender. The probability patterns look very similar for men and women, notwithstanding the linear relationship experienced by women, and the U-shaped experienced by men.

Figure 6.13. The probability of using active transport for commuting by personal income category across different settlement types: Men and Women. New Zealand 2003-08.



Source: NZHTS trip file

For male commuters, it is only in the main urban areas that the probability of active commuting rises with income. In both secondary urban areas and rural areas, the probability of walking or cycling to work declines with income, only beginning to rise for men earning over $90,000 per annum. For female commuters, there is also a very clear increase in the probability of active commuting for big city dwellers, rising from 0.25 for women earning $30,000 per annum, to slightly under 0.4 for women earning $100,000 per annum. Female commuters living in the remaining two settlement types are far less responsive to income, with predicted probabilities declining slightly with income in secondary urban areas, and rising with income very subtly in rural areas.

The above exploration shows that settlement type does not do much to alter the relative contribution of men and women to the use of active transport for commuting. Men and women are both far more likely to use active modes if they live in a main urban area, than if they live in either a secondary urban area or a rural area. Living in a large city, therefore, predicts greater use of active transport among commuters. Why?

Opportunities to actively commute rises in cities due to the interactive effects of a number of factors such as greater land use mix, access to key destinations and because population density spatially stratifies income groups. The intensified competition for access to centralised jobs in dense settlements is accompanied by higher income workers outbidding lower income workers for the more accessible sites. More accessible sites, by definition, mean shorter commutes and therefore greater opportunities for active commuting. For these settlement based reasons we would expect the probability of active commuting to rise with income more steeply in heavily urbanised settings. High density, in turn, allows higher income commuters to move to 'superior' forms of transport, i.e. superior to motorised, which in the right climate and terrain means walking or cycling.

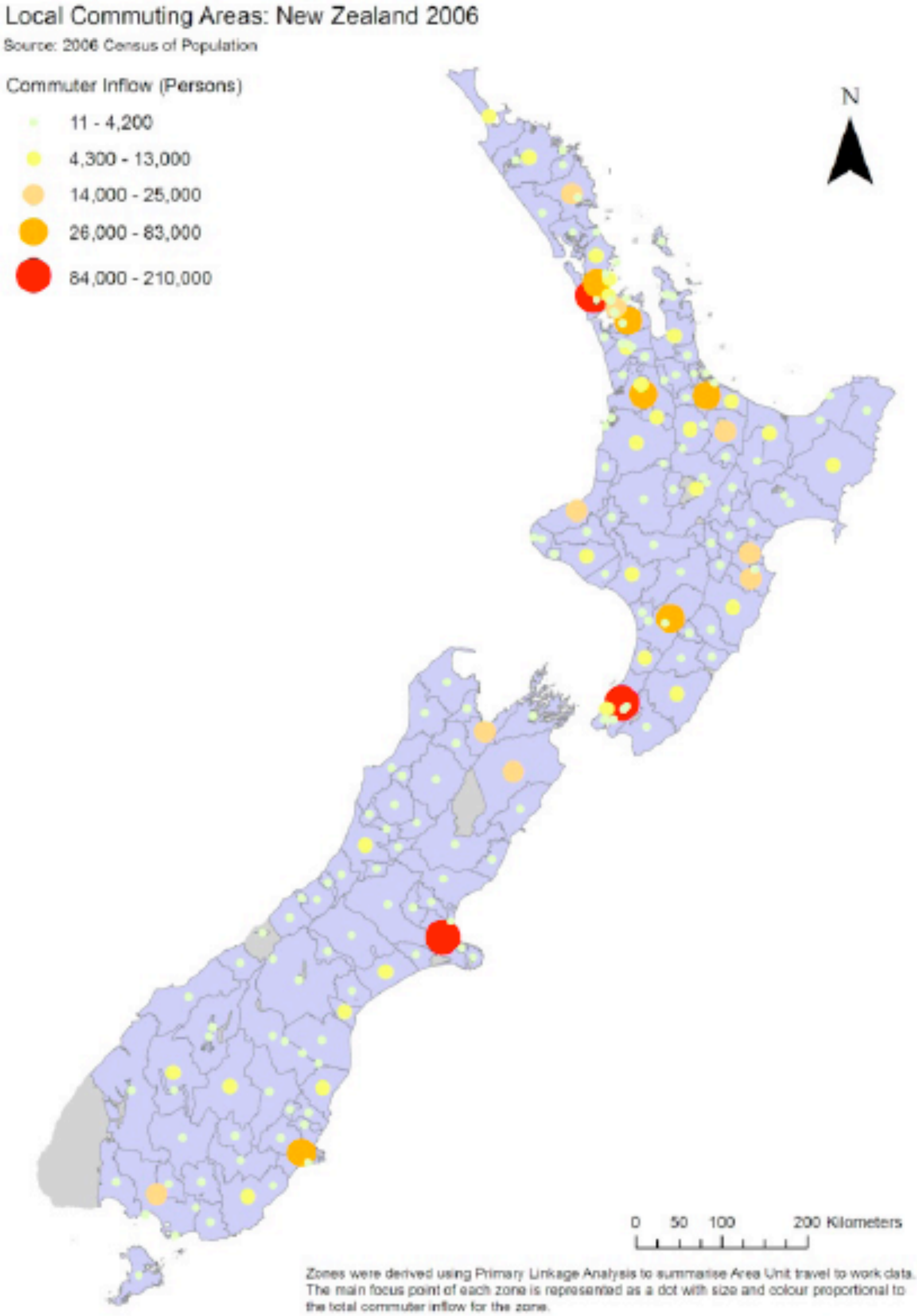
A second reason for higher rates of active commuting in big cities is that commuters are better served by public transport in urban areas, and this is likely to increase the number of 'active' legs in a trip chain (mainly walking trip legs), because use of public transport usually involves some degree of walking (e.g. in order to get from home to the initial bus stop or train station, and then from the final stop to the workplace). For example in Table 5.2 above we see that in main urban areas there is a greater proportion of walking and cycling commuter trips that are part of multi-leg trip chains than in either of the less densely populated settlement types.

Region

As most active commuting is done by people in big cities, it is relevant to know how the relationship between active transport use and income differs across New Zealand's three main regions, Auckland, Wellington and Canterbury. Auckland's four cities (North Shore, Auckland, Waitakere, and Manukau), Wellington's four cities (Porirua, Upper Hutt, Lower Hutt, and Wellington), and Christchurch city have the largest labour markets in New Zealand. Almost half of the working population in New Zealand work in these cities (New Zealand Census of Population, 2006).

Figure 6.14 depicts the greater inflow of commuters to these three areas compared with the rest of the country.

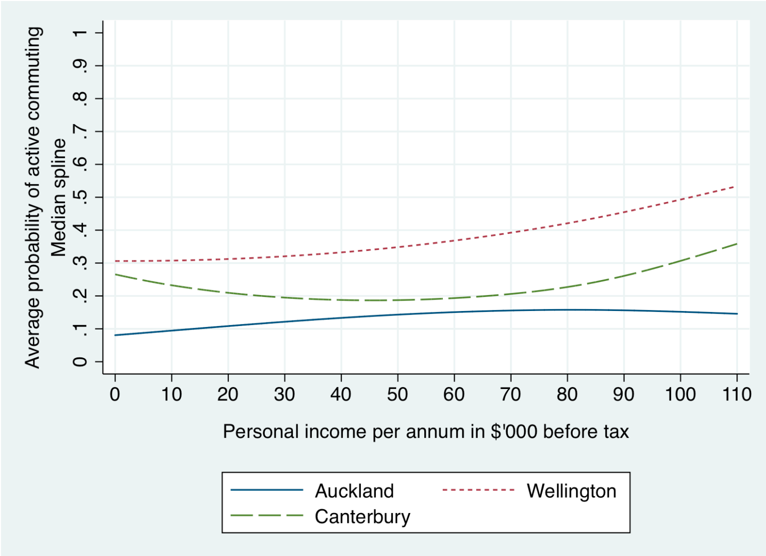
Figure 6.14. Local commuting area in New Zealand. 2006 Census.



Source: *Workforces on the move,* Statistics NZ, 2007.

Figure 6.15 reveals that the three largest labour markets in New Zealand do not only vary in their respective probabilities of active commuting, but also display different responses to rising income.

Figure 6.15. The probability of using active transport for commuting by personal income category across the three main regions. New Zealand 2003-08.



Source: NZHTS trip file

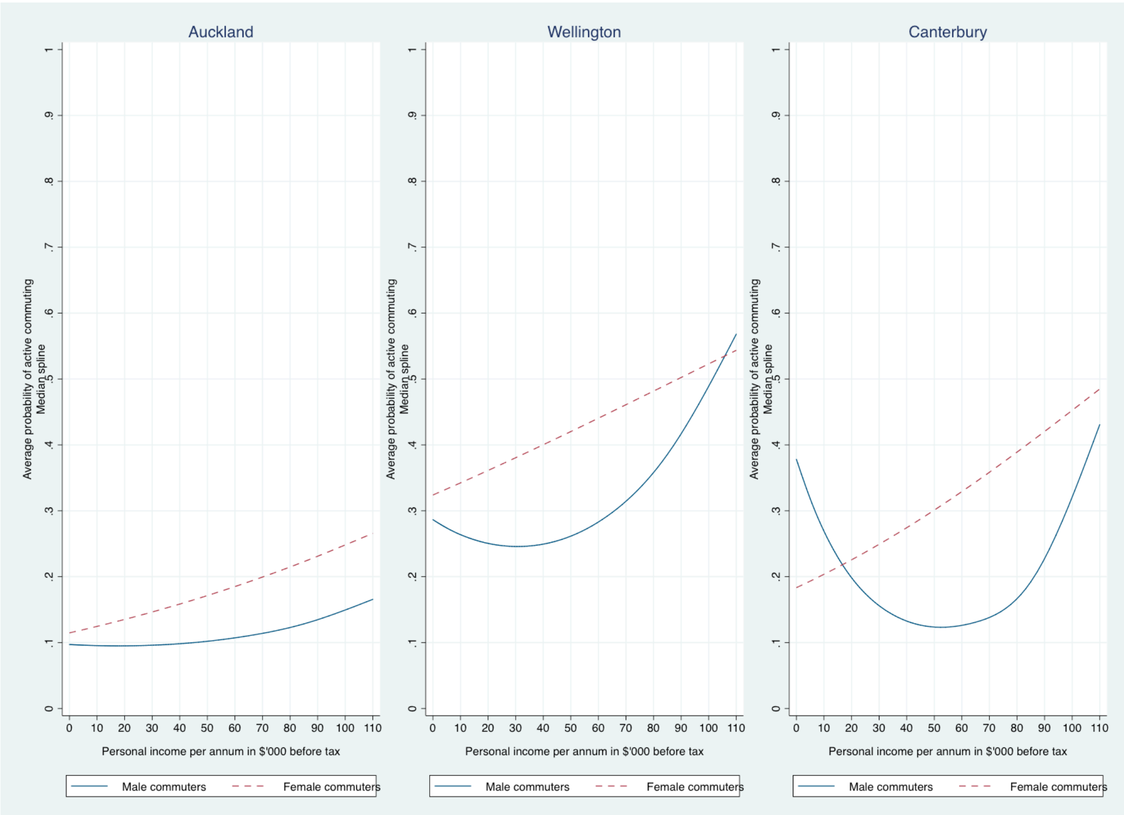
Commuters in the Auckland region are the least likely to actively commute, and the relationship with income exhibits no evidence of being U-shaped nor positively related to income. The predicted probability of walking or cycling to work appears to rise with income up to about $50,000, from which point it levels out at an average probability of 0.15 but none of the features are statistically significant.

Cantabrian commuters have higher predicted probabilities of active commuting than Aucklanders at all income levels and the relationship is statistically significant. The U-shaped relationship with a skew towards the upper end closely resembles the pattern for the country as a whole. Cantabrian commuters with the highest predicted probability of walking or cycling are those earning over $100,000 per year, where almost a third participate in active commuting.

Wellington commuters have substantially higher average probabilities of walking or cycling to work than commuters in either of the other two main regions at all income levels. The relationship with income is a fairly linear positive one, though it is not statistically significant. In Wellington, probabilities increase from a median probability of 0.3 for commuters earning $30,000 per year, to 0.5 for commuters earning $100,000.

As noted earlier in this chapter, the propensity for women's active commuting to rise with income is quite different to that of men's. However Figure 6.16 below shows that, for both male and female commuters, Aucklanders are the least responsive to income, Wellingtonians are slightly more responsive to income, and Cantabrians are by far the most responsive to income. For men the relationship with the likelihood of active commuting becomes successively more non-linear (U-shaped) as we move south.[44]

Figure 6.16. The probability of men and women using active transport for commuting by personal income category across the three main regions. New Zealand 2003-08.



Source: NZHTS trip file

[44] The much more non-linear income curve for Wellington and Canterbury men may reflect a greater level of income inequality in these two regions. This could be an interesting subject for future research.

For female commuters, the likelihood of actively commuting rises steadily with income in Auckland from 0.15 for a woman earning $30,000 per year, growing to 0.25 for a woman earning $100,000 per year. For women in Canterbury the rise in probability is much sharper: about 0.25 for a woman earning $30,000 per year, becoming 0.45 for a woman earning $100,000.

For male commuters, the U-shaped relationship with income becomes increasingly severe from north to south: Auckland men display no statistically significant relationship with income, while for men in Canterbury the relationship between active commuting and income is significant and highly non-linear. Probabilities of walking and cycling for Cantabrian men earning $40,000-$60,000 dip down to about 0.125, while those in the lowest and highest income groups have predicted probabilities of active commuting closer to 0.4. Wellington commuters have the greatest likelihood of walking or cycling regardless of gender and exhibit a higher degree of non-linearity than Auckland but less than Canterbury. Public transport may be a key factor here, as Wellingtonians are high users of public transport relative to other cities in New Zealand (Wellington City Council, 2011), and active modes are often used in combination with public transport as part of multi-modal trip chains.

The finding in chapter 5 that Auckland walkers do not face a longer walking commute on average than in Wellington or Christchurch is surprising. According to Tin Tn et al (2009), it is also not the case that Auckland commuters have a significantly longer average home-to-work trip distance overall. Average distance of home-to-work trips in Auckland is 10.9km, compared with 12.4km in Wellington, and 10.1km in Canterbury. So it seems that distance is not the most salient factor in prompting active transport use.

Different land use patterns and transport investment may be playing a more instrumental role. Regional strategies in Wellington have made considerable investments in active transport. Wellington has put forward an urban development strategy based on the idea of a "growth spine" (a strip of land along which more intensive urban development is encouraged), a bus lane programme, and school, workplace and community travel plans (Tin Tin et al, 2009). In comparison, Auckland's transport infrastructure investment has been largely centred on roading, and active transport opportunities are thus hampered by "an urban form designed around the private car" (Auckland Regional Land Strategy, 2010, p.40).[45]

6.5 Summary

The first part of this chapter used the cross-sectional evidence from the NZHTS data to tell an 'aspatial story' of the income -active commuting relationship. I observed that for women, active commuting rises with income, whereas it falls and then rises for men. The greater probability of active commuting among women compared with men was thought to be influenced by a number of factors including the greater number of men who hold a car licence, the higher average male income, and the safety, logistical and financial constraints associated with looking after children, which is primarily undertaken by women.

Age had a complex relationship with active commuting, as it is closely linked to a number of other factors such as living with a partner, earning a higher income and residential location. Overall, however, the pattern is for active commuting to decline with age.

The second part of the chapter told the 'spatial story', which further deepened my understanding of the relationship between income and active commuting. A key lesson to emerge was that both men and women are far more likely to actively commute if they live in a main urban area. I suggested that opportunities to actively commute rise with population density because density rises with land values (especially in the centre) and land values are likely to cause stratification of income groups. The intensified competition for access to centralised jobs in dense settlements is therefore accompanied by higher income workers outbidding lower income workers for the more accessible sites. More accessible

[45] Reflecting its dense urban core, Wellington City has the highest resident population (6.4 people) and employment densities (3.5 people) per hectare compared with Auckland or Christchurch. In addition, the four cities that make up the Wellington Urban Area collectively have a higher population (2.6 people per hectare) and employment (1.4 people per hectare) density than Christchurch City (Berl Economics, 2010, p.26).

sites, by definition, mean shorter commutes and therefore greater opportunities for using active modes.

The probability of active commuting, therefore, rises more steeply with income in densely populated areas because high density allows higher income commuters to shorten their commute to the point where they are more likely to be able to walk or cycle to work. However, trip chains also become more complicated at higher incomes and I have suggested that it may not simply be that high income commuters can outbid others for central locations and thus reduce their travel to work time, for higher income workers are also exposed to greater opportunities for multi-mode commutes and this, too, can increase their chances of active modes within the trip chain. This is primarily because commuters are better served by public transport in large urban areas, which is likely to increase the number of 'active' legs in a trip chain. Greater investment in active transport promotion and infrastructure in Wellington than in Auckland therefore helps explain to the discrepancy in the likelihood of active commuting between the two regions.

In chapter 7 I will retell the combined aspatial and spatial story that has emerged in this chapter, but in a multivariate framework with the appropriate controls.

Chapter 7. Multivariate Models

It became quite apparent in writing chapter 6 that there is still a great deal we do not know about active commuting in New Zealand. The NZHTS trip file offered a unique opportunity to explore who walked and cycled either all the way or some of the way to work over the 2003-2008 period.[46] Using this pooled sample I tested some basic hypotheses about the way I expected income to influence the decisions people make about the modes of transport they used to get to work.

I learned for example that, contrary to expectations, neither men nor women reduced their reliance on active commuting as their incomes rose (in cross section at least). On the contrary, as women with higher incomes were more likely to either walk or cycle some or all of the distance to work. Men's choices in this respect were only slightly different, with participation lower at moderate incomes and then rising with high incomes. Neither result accorded with what I expected based on historical, times series evidence, which showed a rise in absolute incomes to be accompanied by a shift to motorized transport, successively more cars per household and a commensurate decline in people walking and cycling to work.

The descriptive cross-sectional evidence in chapter 6 however was exploratory, for I just tracked the way the probability of active commuting differed by income, and how the sensitivity of active commuting to income varied according to age, household type, partnership status and with the legal right to drive. I then showed how strongly these trends were influenced by the size and density of local labour markets. All were bivariate graphical explorations with only limited statistical testing.

---

[46] While a number of parties have analysed the NZHTS to explore active transport use (see the annotated bibliography in appendix 3), I could not find any research to have conducted multivariate analysis, and certainly no application of the NZHTS data appears to have utilised the multilevel modeling techniques I explore in chapter 8.

There are at least two possible reasons for retaining some skepticism over the above patterns. The first is the fact that income, age, gender, household type and indeed location are interrelated. Until I control for a number of factors which might be related to income, such as age, I cannot be certain that the probability of active commuting does in fact vary with income in the way described in chapter 6. Therefore in this chapter I take a multivariate approach and formally model the odds of active commuting by income and then successively control for age and the other possible confounding factors. I also do the same for the distance traveled in the trip legs.[47]

The second reason for my ongoing skepticism about the patterns in the last chapter has to do with the profound effect which local context appeared to play in altering both the level of active commuting and the way context modified the influence of income on active commuting. There are more appropriate ways of modeling the role of local context than the conventional multivariate logit and OLS regression models adopted in this chapter, instructive though they are. Therefore in chapter 8 to follow, I retest some of the primary findings about the contextual effect of location by applying multilevel regression models.

7.1 Sequential model for male commuters

First, I build a male-only model, the results of which are reported in Table 7.1. I enter the variables into the model in stages so that I can see clearly what the relative strength of each variable is and how the sequential addition of each variable affects the central relationship between active commuting and income. I start by including only the income and income^2 variables (in their centered form) as model 1. Then, in the second stage of the model (model 2) I add the age and age^2 variables (also centered).[48] The third stage of the model (model 3)

[47] I will discuss the results from my models of trip distance in this chapter. The models themselves are reproduced in appendix 6.

[48] I have generated centered versions of the income and age variables in order to reduce collinearity. In order to 'center' the variables, I compute the difference between each value of the variable and its mean.

introduces dummy variables in order to control for employment status, household type, partnership, holding a car licence, season, day of the week, and survey year. The final two stages of the model introduce the locational variables. I first add settlement type (model 4) to test the effects of population density. I then ask whether location in a different region makes a difference, by introducing region (model 5).

Table 7.1. A sequential model of active commuting by men. New Zealand 2003-08

Variable	model1	model2	model3	model4	model5
Income					
Income	-.0111***	-.00606*	.00231	.00129	-.00081
Income2	.00032***	.00028***	.0002***	.00019***	.0002***
Age					
Agec		-.0221***	-.0149***	-.0128**	-.013**
Agec2		-.00023	-.00047	-.00041	-.0004
Employment Status					
Part Time			-.812**	-.922***	-.874**
Full Time = base					
Household Type					
Single Adults			.827***	.82***	.75***
HH with Children = base					
Family no Children			.0596	.0683	-.00615
Partnership					
Lives with Partner = base					
Not Living with partner			-.11	-.122	-.0884
Holds Car Licence Y/N					
No CarLicence			1.84***	1.79***	1.88***
Holds a Car Licence = base					
Season					
Summer			.166	.182	.0503
Autumn = base					
Winter			-.0975	-.113	-.0849
Spring			.0956	.186	.199
Day of Week					
Sunday			.137	.139	-.0938
Monday			.33*	.334*	.329*
Tuesday			.187	.195	.185
Wednesday			.0761	.0838	.0435
Thursday = base					
Friday			.22	.201	.195
Saturday			-.687**	-.698**	-.706**
Survey Year					
2003/04			-.0833	-.0515	-.0711
2004/05			-.0579	-.0687	-.0793
2005/06 = base					
2006/07			.148	.14	.23
2007/08			.108	.0979	.0591
Settlement Type					
Main Urban Area = base					
Secondary Urban Area				-.934***	-.982***
RuralArea				-.425***	-.371**
Region					
Northland					.716**
Auckland = base					
Waikato					.0792
BayofPlenty					.352
Gisborne					-.159
HawkesBay					.37
Taranaki					.593*
Manawatu					-.0314
Wellington					1.65***
NelsonTasman					.788***
WestCoast					.867**
Canterbury					.868***
Otago					1.07***
Southland					-.178
_cons	-1.89***	-1.85***	-1.45***	-1.23***	-1.93***
N	5637	5637	5619	5619	5619
r2_p	.0168	.0297	.0799	.0906	.14

chi2	80.4	143	383	434	670
df_m	2	4	24	26	39

legend: * p<0.05; ** p<0.01; *** p<0.001

Source: NZHTS trip file

The estimates in model 1 confirm the U-shaped relationship between active commuting and income that was observed in the previous chapter.[49] We see, however that the downward slope of the U becomes flatter and less significant as more controls are added, but that the upward slope (the income squared variable) remains highly significant, even when the influences of all the other variables are controlled for (model 5). This suggests that one of the reasons that active commuting falls initially with income is due to the way age is correlated with income. While people's income rises as they age they are also on average less likely to actively commute because of the physical demands it imposes. With income in this model, age has a small but highly significant negative effect on active commuting, and remains so when all remaining controls are added, but with diminishing impact. The age squared variable does not register as significant, which indicates that the propensity to actively commute declines linearly with age.

Working part time has a strong and statistically significant negative effect on active commuting for men, which persists even when the locational variables are accounted for. Male commuters have very strong and statistically significantly greater odds of active commuting if they live as a single person (as opposed to living in a household with children). However, living in a household with family but no children does not significantly affect the likelihood of actively commuting. This may reflect the influence of access to a motor vehicle, as people living with family are probably able to use a family member's car, whereas those living with non-family members may not have the same access. Also, partnership does not have a significant effect when other variables are present.

Not holding a car licence results in male commuters having over six times greater odds of using active transport relative to those holding a licence, and this

[49] Note that my interpretation of the models is in terms of the odds ratio (the exponent of b). This is because Stata, the statistical software programme used, does not allow odds ratios to be used in sequential tables. The odds ratio regression results to which I refer are reproduced in appendix 6.

strong effect holds even when temporal, seasonal and locational factors are controlled for.[50] Model 3 also includes several temporal factors such as day of the week and survey year. Few register as having any significant explanatory power apart from commuting on either a Monday or Saturday. For some reason Monday has a moderate positive effect on active commuting whereas Saturday, has a very strong and statistically significant negative effect on the use of active modes. Further investigation into this effect (outside my thesis) may be worthwhile.

The strong negative influence of living in less densely populated areas on active commuting that was revealed in chapter 6, is shown to persist in the multivariate case, even when controlling for a broad variety of other factors. Relative to men living in main urban areas, those in secondary urban areas have 63% lower odds of active commuting.

Lastly, region registers as having a strong impact on the likelihood of walking or cycling to work. Relative to Auckland, we observe significantly *greater* odds of active commuting in six of the remaining regions: Northland, Taranaki, Wellington, Nelson-Tasman, West Coast, Canterbury and Otago. Living in Wellington has an extremely strong positive influence on the odds of active commuting, with men in Wellington having over five times the odds of active commuting than those in Auckland, even with all the other controls in the model.

7.2 Sequential model for female commuters

Previous chapters have repeatedly demonstrated the different propensities of men and women to walk or cycle to work and how this responds to their income. For female commuters Table 7.2 shows that it is the linear effect of income (not the income squared) that significantly affects the chance of actively commuting. However, as in the male case, the upward slope flattens slightly as successive variables are added to the model, and the level of statistical significance reduces from $p<0.001$ to $p<0.05$.

[50] See the odds ratio model reproduced in Appendix 6.

Table 7.2. A sequential model of active commuting by women. New Zealand, 2003-08

Variable	modelf1	modelf2	modelf3	modelf4	modelf5
Income					
Income	.00799***	.0115***	.00988**	.00684*	.00654*
Income2	3.7e-06	-3.0e-05	-1.7e-05	8.2e-06	-4.0e-05
Age					
Agec		-.0181***	-.00851*	-.00684	-.00622
Agec2		.0003	-.00049*	-.00057*	-.00058*
Employment Status					
Part Time			.548*	.487	.379
Full Time = base					
Household Type					
Single Adults			.568***	.581***	.488***
HH with Children = base					
Family no Children			.295**	.322***	.273**
Partnership					
Lives with Partner = base					
Not Living With Partner			.4***	.355***	.35***
Holds Car Licence Y/N					
No CarLicence			1.17***	1.12***	1.28***
Holds Car Licence = base					
Season					
Summer			.163	.154	.0736
Autumn = base					
Winter			-.0321	-.0397	-.0581
Spring			.0533	.113	.113
Day of Week					
Sunday			-.748**	-.751**	-.725**
Monday			.0484	.0514	.0397
Tuesday			-.0816	-.0827	-.0877
Wednesday			-.0345	-.0532	-.0743
Thursday = base					
Friday			-.158	-.142	-.145
Saturday			-.638**	-.654**	-.629**
Survey Year					
2003/04			-.0354	-.0202	-.107
2004/05			.101	.126	.0837
2005/06 = base					
2006/07			-.0759	-.0175	-.00344
2007/08			.142	.171	.144
Settlement Type					
Main Urban Area = base					
Secondary Urban Area				-.818***	-.892***
RuralArea				-.529***	-.522***
Region					
Northland					.512*
Auckland = base					
Waikato					.194
BayofPlenty					.117
Gisborne					.272
HawkesBay					.0212
Taranaki					.265
Manawatu					.585**
Wellington					1.42***
NelsonTasman					.912***
WestCoast					1.14***
Canterbury					.949***
Otago					.921***
Southland					.11
_cons	-1.3***	-1.3***	-2.13***	-1.93***	-2.45***
N	4621	4621	4615	4615	4615
r2_p	.00511	.012	.0489	.061	.0999
chi2	24.8	58.1	238	297	485
df_m	2	4	25	27	40

legend: * p<0.05; ** p<0.01; *** p<0.001

Source: NZHTS trip file

The relationship with age is similar to that of men. Age has less of a negative influence and becomes less statistically significant as additional variables are controlled for. Unlike in the male case, however, the age squared variable *does* register as significant, suggesting that the use of active transport decreases more rapidly with age among female commuters. Note however that it is only significances that differ. The magnitude of the age^2 effect is similar for men and women.

Men and women do differ with respect to the effect of household type. In the case of female commuters, the positive effect on actively commuting of living in *any* household type without children is highly significant, and remains so even when other variables are added to the model. Female commuters living in childless households have over 1.3 times the odds of actively commuting relative to households with children. This is likely indicative of the greater amount of childcare responsibilities undertaken by women than men, since, as soon as children are taken out of the equation, a woman's probability of active commuting grows significantly.

The positive active commuting effect of not living with a partner is also much stronger for women than for men. Female commuters *not* living in a partnership arrangement have 1.4 times greater odds of actively commuting than those who are living with a partner. Even when controlling for other factors, this effect is highly statistically significant. This may suggest that living with a partner increases access to a motor vehicle. Given women's role as the primary care givers, due to safety and logistics, the woman may also be given preference in travel by car with the children, leaving the man to either accompany or use other modes to get to work.[51]

As was the case for men, seasonal and survey year effects are not strong but the day of the week is important. In the female case, however, it is only the weekend days that register as significant. Female commuters travelling on either a

[51] However, the effect of holding a car licence is only half as strong for women as for men (female commuters are 3.6 times more likely to actively commute if they don't hold a licence, compared with male commuters who are 6.6 times more likely). Perhaps this means that women are more likely to travel as a passenger in a partner's car.

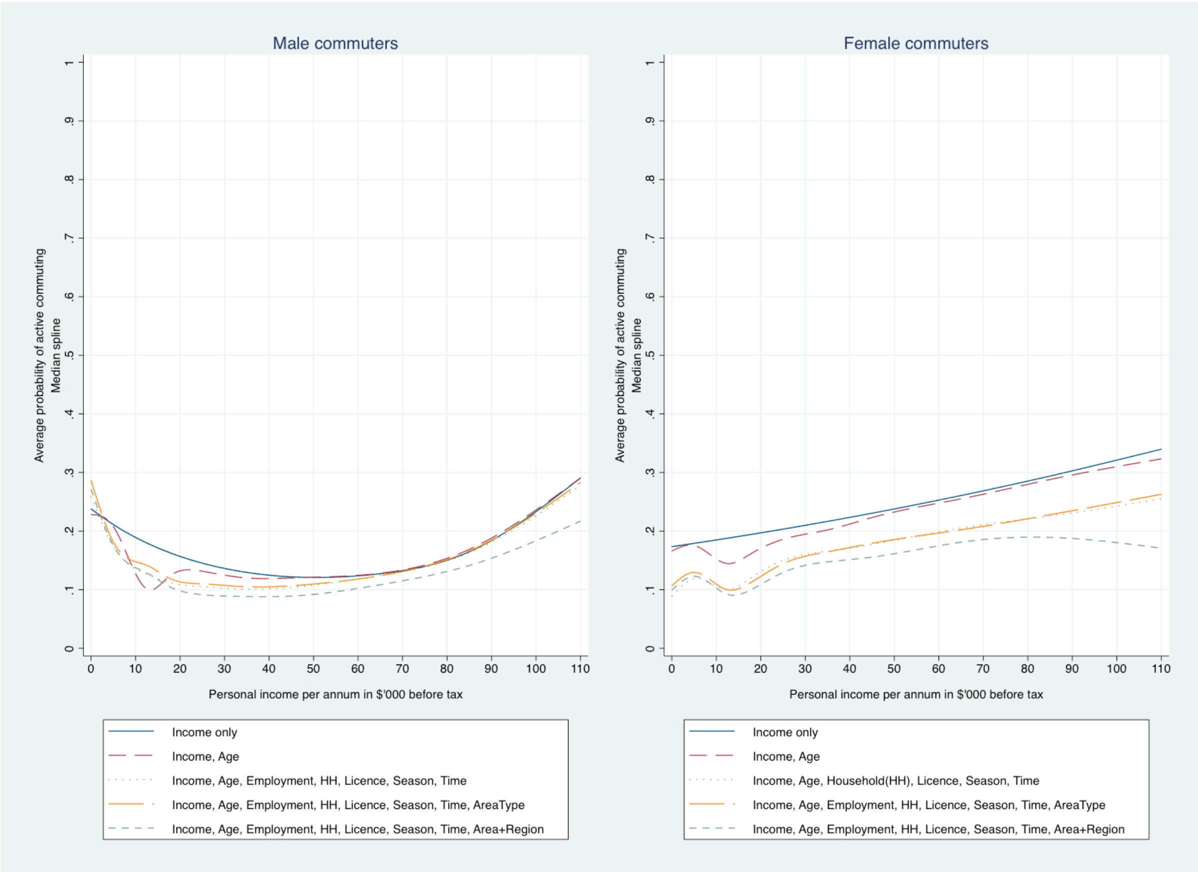
Saturday or a Sunday are half as likely to walk or cycle than the base (Thursday). Again, quite why this might be the case requires further investigation.

Those commuting in secondary urban areas are the least likely to actively commute (60% lower odds than those in main urban areas) and rural commuters are also much less likely to walk or cycle than those in the main urban areas, with 41% lower odds.

The regional effects are very similar for female and male commuters, though for women it is commuters in the Manawatu who become significantly more likely to actively commute (compared to Auckland), while living in the Taranaki fails to register as a significant positive influence as it did for men. The strong impact of region on the relationship between active commuting and income for both genders is indicative of the important role of place in constraining or enabling transport mode choices.

In figure 7.1 I present the predicted probability plots of active commuting for male and female commuters respectively. These serve to illustrate the little actual difference the controls make to the role of income in influencing the likelihood of active commuting for either gender. Only with the addition of the locational variables does the curve noticeably shift.

Figure 7.1. The probability of using active transport for commuting by personal income category when applying controls. New Zealand, 2003-08



Source: NZHTS trip file

Trip distance

The above discussion sought to account for the likelihood of active commuting among the employed. However, it is not simply the *mode* of commute that might vary. The *distances* travelled by active transport may also be affected by the same factors. I therefore reproduced the above models using trip leg *distance* as the dependent variable.[52] The results for both the male and female models (in appendix 6) showed that distance commuted by foot or bicycle is far less clearly associated with either income, age, or any of the sociodemographic variables seen to be influential in the likelihood of using active modes for at least one leg of

[52] And I applied OLS regression to this continuous distance variable.

the commute (as modeled above). Rural areas exhibited a significantly shorter average active commute relative to main urban areas, and there were a few differences across regions but, other than that, nothing else appeared particularly significant. This demonstrates that my ability to explain distance travelled by active commuting at the trip leg level is far lower than my ability to predict whether a trip will involve active commuting or not. The one thing that is clear, as was demonstrated in Figure 6.3, is that, in cities, active commute distances fall as incomes rise.

7.3 Summary

In this chapter I built two multivariate sequential models: one for male commuters and one for female commuters. The findings validate the conclusions I drew in chapter 6: the effect of income remains U-shaped for men and positive and linear for women, even after controlling for other factors. What the models also expose, however, is that the income effect is tempered by age for both genders but in different ways.

Locational factors have very strong effects on the propensity to actively commute by both genders. The settlement type effects are very powerful, providing further evidence that densely populated urban areas are the most conducive environments for active commuting. By and large, commuters living anywhere from the central North Island down to Otago are significantly more likely to actively commute than those in Auckland. In chapter 8 I will explore these locational factors further by building a nested multilevel model to represent the embedded nature of these two geographical 'levels'.

Chapter 8. Multilevel modeling

One of the most important conclusions to emerge from the previous chapter was the singular importance of the urban context within which the commuting decision is made. Far from simply being a local labour market within which people make travel decisions, the characteristics of the specific city they live in appears to have a greater quantitative effect on the probability that a given person will walk or cycle to work than any given attribute of the person concerned. In short, when it comes to the incidence of active commuting, it is not the person who matters so much as the place. Any person with a given suite of characteristics would behave quite differently in one urban setting compared to another. The policy implications of this result are quite profound but before attempting to draw those out I want to focus on context more explicitly. Specifically, in this chapter I want to try and estimate the relative importance of context using a method designed primarily for that purpose – multilevel modeling.

The differences I have identified between the level of active commuting in different settlements are examples of context effects, a term used to explain "the substantive consequences of nesting" (Bickel, 2007, p.xv). Nesting refers therefore to the fact that actors share a common physical and/or social environment and are thus exposed to opportunities and constraints that are not shared by others. Those others might be nested in places with different opportunity sets and different relative constraints. As a result of commuters being nested in different settlement types and regions, *where* one lives makes a big difference to the way one gets to work.

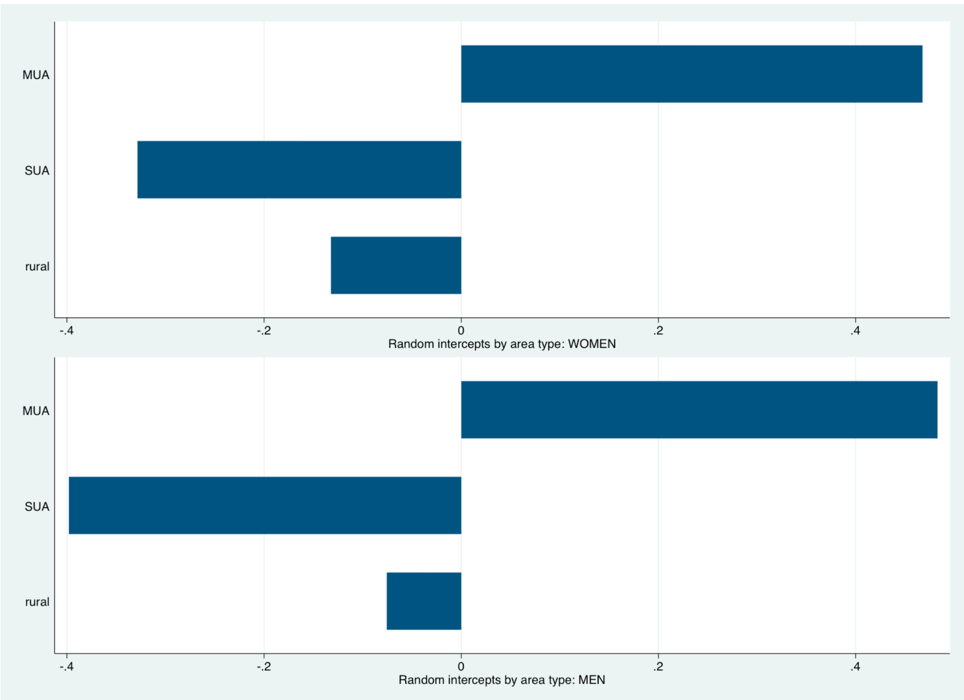
As Bickel observes, nesting poses both methodological problems and presents analytical opportunities that otherwise would be dealt with in less satisfactory fashion through ordinary regression (Ibid, p.1). Rather than repeat the technicalities however I'd like to illustrate the way multilevel modeling works and why this extension of regression is particularly suited to accounting for the wide variations I've observed in the likelihood of walking or cycling to work across the country. This will not be the first time multilevel modeling has been applied to questions about commuting (Antipova et al., 2011) nor is it the first to address the impact of the local environment on walking (Li et al., 2005). However as far as I know, it appears to be the first to address the geographical variation in levels of *active* commuting and certainly within the New Zealand context.

There are two types of clusters I am able to identify from the NZHTS trip file. The first is defined by population density and is the distinction between main, secondary urban areas and rural areas. The second is the region. In terms of the first, I will start by exploring the level of variability in the average probability of active commuting across settlement types.

8. 1 Variability between settlement types

Figure 8.1 tests whether the intercepts of the logistic regression vary with population density.

Figure 8.1. Deviations from the average estimated probabilities that male and female commuters will use active transport for commuting in different settlement types. New Zealand 2003-2008.



Source: NZHTS trip file

In keeping with the results in previous chapters, I find that there is a high level of variability in the average probability of active commuting across the three settlement types. For both men and women, living in a main urban area predicts a far greater probability of active commuting: well over 0.4 for both genders.[53] Conversely, the probability of using active modes if living in a secondary urban area is extremely low (relative to the New Zealand average), especially for men (approx -0.4, and for women approx -0.35). Living in a rural area also predicts a probability of active commuting much lower than the New Zealand average - about -0.15 for women and almost -0.1 for men.

In the mixed-effects logistic regression outputs for Figure 8.1, the standard error for female commuters (.15) is much smaller than the estimate (.35). Likewise, the standard error for male commuters (.17) is also much smaller than the estimate (.39). We therefore know that for both sexes there is considerable variation in the constant over the various settlement types.

8.2 Variability between regions

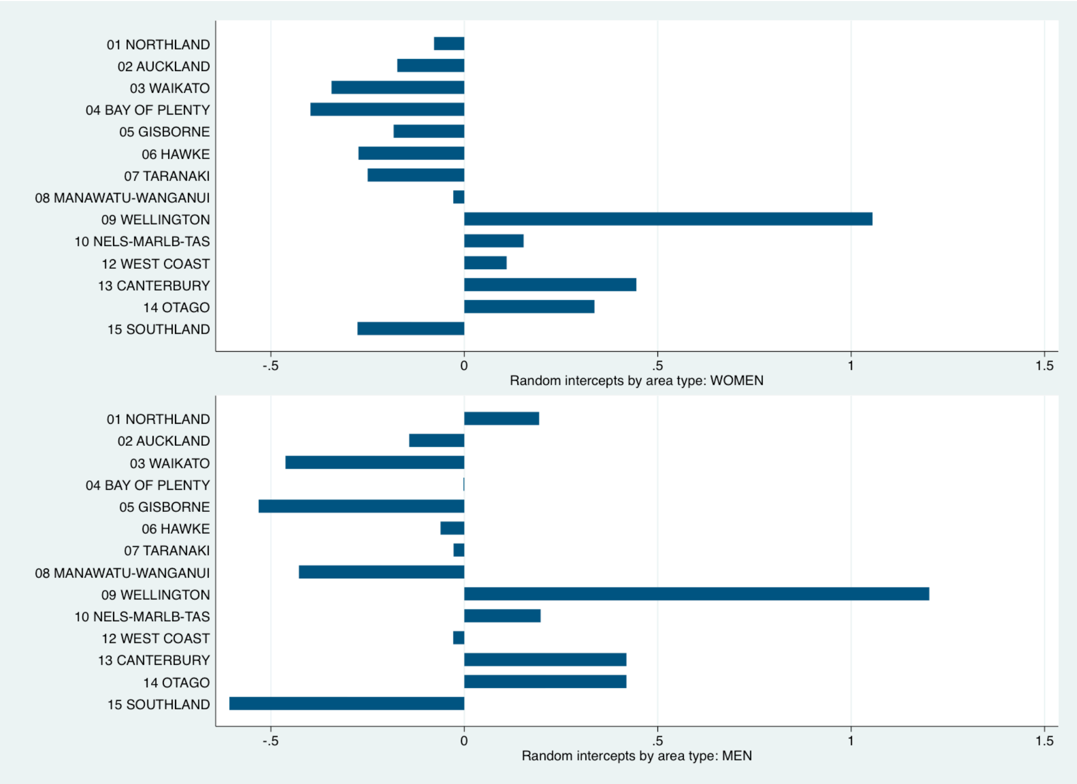
The propensity to walk or cycle to work is not simply a reaction to population density. There are also geographical effects. Figure 8.2 shows the high level of regional variation that is present. Broadly speaking, average predicted probabilities are negative north of Wellington and positive from Wellington southwards. This is especially the case for female commuters.[54] Of course, while I have grouped walking and cycling together under the banner of 'active commuting', environmental promoters may differ between the two (e.g. high levels of public transport in Wellington may favour walking rather than cycling).

---

[53] Probabilities are not the same as odds. It is probabilities that are reported in the multilevel modeling output.

[54] It is not clear why this should be the case. This deserves a study in itself. I will not investigate further here due to space limits.

Figure 8.2. Deviations from the average estimated probabilities that male and female commuters will use active transport for commuting in different regions. New Zealand 2003-2008.



Source: NZHTS trip file

One factor affecting differences across the regions may be the average distance of home to work trips. Tin Tin et al (2009, p.4) show that regions south of Wellington tend to have slightly shorter average commuting distances (with an average of 8.9km in the South Island, compared with 10.7km in the North Island). However, this explanation does not account for the considerably higher predicted probability in Wellington, which has the second to highest average commute distance (12.4 km for all transport modes) in the country, after the Waikato (14.8km). The public transport explanation is probably more compelling in the case of Wellington. As noted in chapter 6, Wellingtonians are high users of public transport (Wellington City Council, 2011), which is often used in conjunction with active transport modes.

Weather is another highly relevant factor and we can look at average sunshine hours, average rainfall and average air temperature for each region to see if they give any clues for unraveling the north to south pattern in probability of active commuting (see fig. 8.3).

Figure 8.3. Regional characteristics across New Zealand

Region	Population density (per km²)[1] 2006	Average distance of home-work trips (km)[2] (95% CI) 2003-2008	Average sunshine (hours)[3] 1971-2000	Average rainfall (mm)[3] 1971-2000	Average air temperature (°C)[3] 1971-2000
Northland	10.8	12.2 (7.0-17.4)	153	144	18.6
Auckland	215.3	10.9 (9.9-12.0)	180	82	18.7
Waikato	15.9	14.8 (11.1-18.5)	184	87	17.1
Bay of Plenty	21.0	9.5 (6.8-12.1)	197	132	18.3
Gisborne	5.3	8.3 (5.2-11.5)	185	99	17.4
Hawke's Bay	10.5	9.2 (6.4-12.1)	194	85	17.7
Taranaki	14.3	9.3 (5.1-13.6)	202	108	16.9
Manawatu-Wanganui	10.0	9.5 (7.4-11.6)	170	74	16.6
Wellington	55.2	12.4 (10.2-14.6)	191	92	16.6
Tasman	4.6	8.7 (6.4-11.1)*	212	75	16.3
Nelson	96.8	8.7 (6.4-11.1)*	212	77	16.1
Marlborough	3.9	8.7 (6.4-11.1)*	224	54	16.3
West Coast	1.3	6.7 (5.5-7.9)	161	171	15.7
Canterbury	11.7	10.1 (7.6-12.6)	183	56	15.1
Otago	6.2	9.3 (6.1-12.6)	139	70	13.7
Southland	2.8	9.9 (6.6-13.3)	136	94	12.5

Source: Tin Tin et al, 2009.

Average temperatures actually fall steadily as we move from north to south in New Zealand, which is counterintuitive to the active commuting pattern. However rain is perhaps a more significant concern for potential walkers and cyclists and average rainfall is in fact lower in the south (averaging 85.3mm cubed in the South Island compared with an average of 100.3mm cubed in the North Island), which makes it more conducive to using active travel modes (Tin Tin et al, 2009, p.4). Average sunshine hours for the North and South Islands are quite similar, with an average of 184 for the North and 181 for the South.

In the regression output for figure 8.2 above (reproduced in Appendix 7), the estimated probability of active commuting for women is 0.41 and the standard error is 0.09, while for men the estimate is 0.5 and the standard error is 0.11. The fact that the standard errors for both sexes are even smaller relative to the estimates than was the case for settlement types reveals that there is even greater variation in the average probability of active commuting across regions than across settlement types.[55]

8.3 A nested multilevel model

Now that settlement type and region have been examined independently, I have created a nested mixed-effects model that looks at the variations in random effects for active commuting when settlement types are nested within regions, thus explicitly recognising the embedded nature of these two geographical 'levels'.

In figure 8.4 I graph both the distributions and the means so that not only the averages can be observed, but also the ranges of deviations from the average within each region, including outliers. The outliers (in the case of every region in which there were any) are all from secondary urban areas and rural areas.

I have chosen not to divide the analysis between male and female commuters. The first reason for this is that we have already observed that settlement type does not do much to distort the relative contribution of men and women to active commuting. The second reason is to avoid the pitfall of having subgroups that contain <30 observations. Without the male/female stipulation, the smallest regional group in figure 8.4 contains 29 observations.

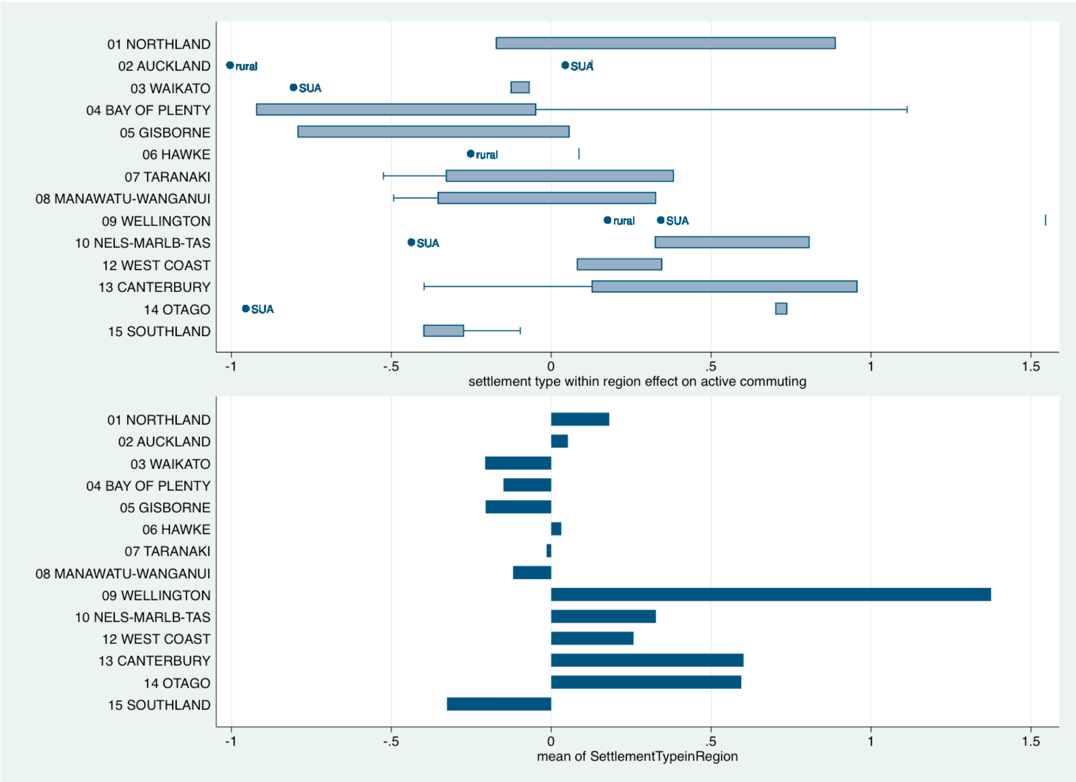
The random effects for settlement type within region appear significant, judging from the standard error (.09) in relation to the estimate (.65).[56] However, the random effects for region alone do not appear significant. Also, with the region, and settlement type within region effects in the individual level regression, personal income no longer registers as significant (P>|z|=0.304). This is interesting because it suggests that the primary reason *why* the probability of active commuting rises with income is because of the population density effects, which is what I suggested in chapter 4.

---

[55] There are ways of entering characteristics of regions as possible explanatory factors in such models but due to time constraints I was not able to develop this feature.

[56] The full statistical output for the nested multilevel model is reproduced in appendix 7.

Figure 8.4. Deviations from the average estimated probabilities. Distributions and means of area type within region variations for commuters using active transport. New Zealand 2003-2008.



Source: NZHTS trip file

The argument was that commuters' income rises with population density, population density reduces the distance to work, which in turn makes active transport more attractive. Without the ability to capture the advantage of population density there is no incentive for higher income commuters to switch to walking and cycling – mainly because they would not have the same public transport options that enable active transport components to be added to the trip chain. There is also considerably less pedestrian and cycling infrastructure outside of main urban areas, and speed limits for motorists are lower in the more densely populated settlements. Therefore it is possible that safety is also more of a concern for (potential) active commuters outside of cities.

We can corroborate this argument by testing the counter factual. If the above argument - about income working through population density to active commuting- is correct then we should not expect to find any positive relationship between commuters' income and their propensity to actively commute in *low* density areas (where there is little capacity for higher income commuters to capture the advantages of higher density). Figure 6.13 in chapter 6 confirms this result, illustrating that there is either a neutral or negative relationship between income and the probability of active commuting in the more sparsely populated secondary urban areas and rural areas.

8.4 Summary

There is a high level of variability in the average probability of active commuting across both settlement types and regions in New Zealand. The finding that commuters in main urban areas are significantly more likely to actively commute than those in less densely populated settlement types further confirms the influence of population density and mixed land use patterns that was established in chapters 6 and 7. The increased likelihood of active commuting in the southern regions of the country is an interesting result that may be influenced by environmental factors such as average rainfall and average commute distance, both of which are lower in the south.[57]

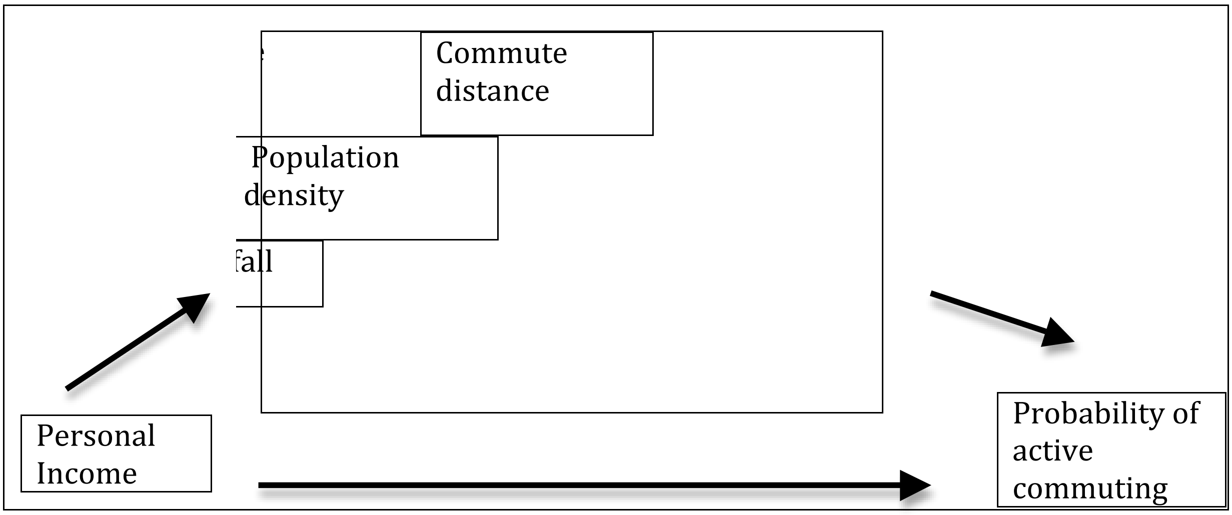
The nested multilevel model revealed that the impact of income on active commuting no longer registers as statistically significant once settlement type within region was controlled for. This implies that the main reason why the probability of active commuting rises with income is because of the close association between income and population density.[58] Density, like other factors such as land use mix, weather conditions, and commute distance, is an aspect of settlement type, as Table 8.1 illustrates.

---

[57] However, considerably more work is required to understand these regional patterns.

[58] The Auckland example seems rather an exception with regards to the argument that income boosts active commuting through population density. Parts of Auckland have high incomes and high population densities, but the lowest use of active transport of any metropolitan area of the country. Clearly other attributes of cities such as mixed land use, infrastructure and public transport provision play an important role here.

Table 8.1. Conceptualisation of the relationship between income and probability of active commuting in the context of various attributes of settlement type.



The other major finding from this chapter, which amplifies the results from the multivariate modeling in chapter 7, is that the Wellington region has considerably higher rates of active commuting than elsewhere in the country. The following chapter will present Wellington as a case study in active commuting. I will first attempt to better understand why Wellingtonians commute more actively than commuters in other regions. Then I will incorporate qualitative data collected during a Wellington regional active commuting programme to gain further insights.

Chapter 9. Wellington Case Study

Both the multivariate models in chapter 7 and the multilevel model in chapter 8 revealed that the likelihood of actively commuting is substantially greater in Wellington than in anywhere else in New Zealand. The aim of this chapter is to understand the reason for this and to explore the key themes that emerged from interviews conducted with participants in a Wellington regional active commuting programme.

9.1 Wellington, "the walking capital"

Relative to the national average, Wellingtonians earn higher incomes.[59] My previous analyses have shown that, for most subgroups, it is not until a person is earning over $50,000 per year that predicted probabilities of active commuting get quite high, therefore the higher level of affluence in Wellington may help to explain the greater use of active transport in the region.

Further, I find that there is a 3% difference in the proportion of Wellington commuters living in single adult households (19.6%) and the proportion living in this household type nationally (16.9%).

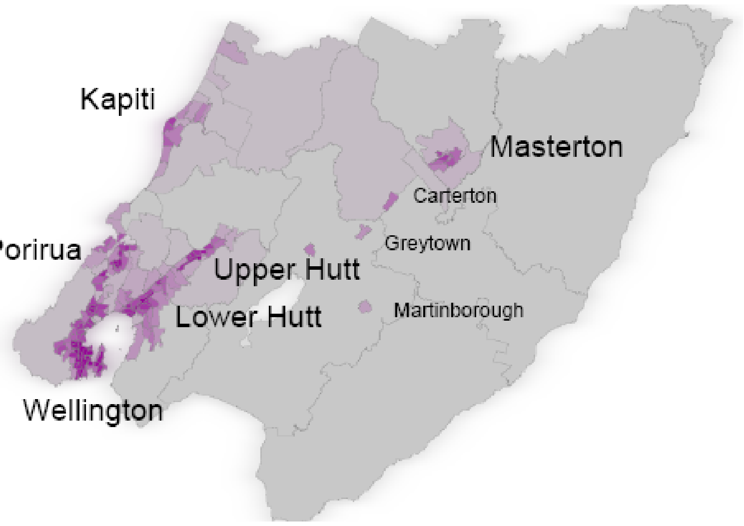
In addition, compared with the national proportion of 61%, a total of 86.9% of Wellington commuters live in main urban areas (see fig. 9.1).[60] This provides even greater evidence for the significance of population density in influencing the use of active modes of transport.

---

[59] The median personal income across all 14 regions of New Zealand in the survey period 2003-08 is $35,000 (mean=44k), while in Wellington it is $45,000 (mean=52k).

[60] These proportions are drawn from my NZHTS sample of commuters from 2003-08. As I commented in chapter 2, it has been reported elsewhere that the proportion of all New Zealanders (not limited to commuters, and not limited to "main" urban areas) living in urban areas (according to the UN) is 87%.

Figure 9.1. Population density. Average population per hectare across census area units of the Wellington Region, 2001. The darker the quantile, the higher the population density.



Source: Statistics New Zealand Table Builder via GeoViz Tookit, in Morrison, 2011.

The greater level of affluence concentrated in the Wellington region enables commuters to gain access to superior residential locations, leading to a much higher proportion of people living closer to their workplaces in main urban areas than is the case outside the capital. Commuters in these densely populated areas of Wellington are also more likely to be living in households without children, and living in this type of household has a positive effect on the propensity to use active modes.[61]

However, the NZHTS data cannot give us any deeper insight into what sorts of people actively commute in Wellington. For instance, what type of work they do, why they choose to walk or cycle, and what sorts of barriers they encounter in doing so. This is where the qualitative component of my study can help to 'put flesh on the bones' of the quantitative results.

---

61 As demonstrated in the multivariate models in chapter 7.

Active a2b was a health and wellbeing initiative run by the Sustainable Transport Team at Greater Wellington Regional Council for the second time from January to April 2011. The programme aimed to reduce congestion in urban areas through increasing travel to work by active modes. It offered participants personalised support and resources to encourage them to walk and cycle to work.

Analysis of the interview data collected during the 2011 Active a2b programme has enabled some additional observations to be made regarding the decision to actively commute. First I will outline how the Active a2b programme worked and who participated. Then I will discuss some of the main themes to emerge from the interviews.

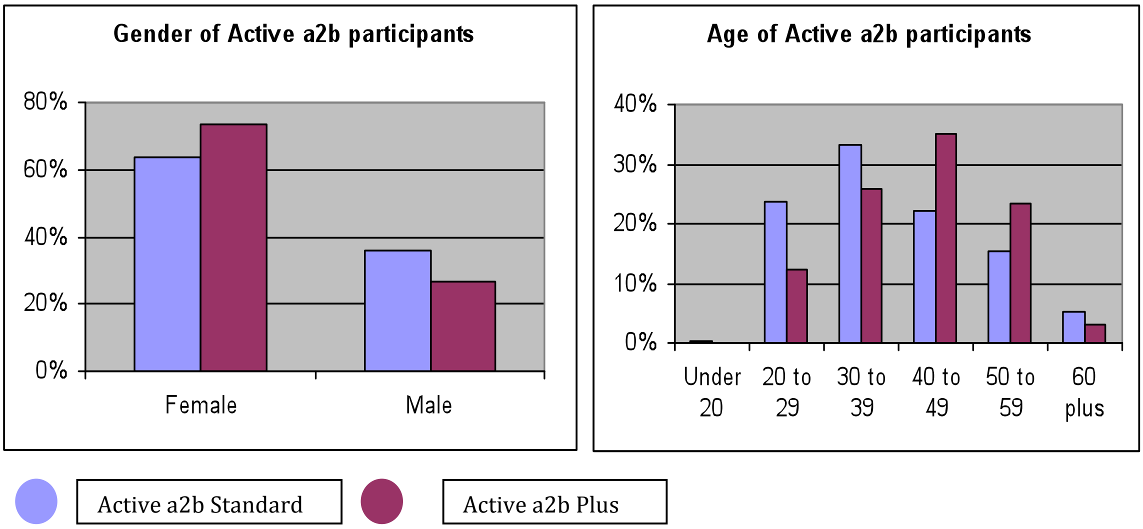
9.2 The Active a2b programme- structure and participation

Active a2b was developed in 2009 by the Sustainable Transport team at Greater Wellington Regional Council as part of their ongoing work to reach regional targets to increase the number of walking and cycling trips and reduce congestion in urban areas. In 2010, Active a2b was promoted at 54 workplaces in the CBD as a health and wellbeing programme designed to help employees incorporate walking or cycling into their commute. 890 people took part in the programme and by the end of May, a significant increase in active commuting (walking or cycling) had occurred.

In 2011, Active a2b was expanded beyond Wellington CBD to the wider region and 80 workplaces signed up, representing a total of approximately 45,000 employees. Nine hundred individuals registered for the programme, with 296 of these fulfilling the Active a2b Plus criteria (Active a2b Final Report, 2011, p.4).

Figure 9.2 shows the gender and age distributions of the both the Active a2b Standard and Plus group participants.

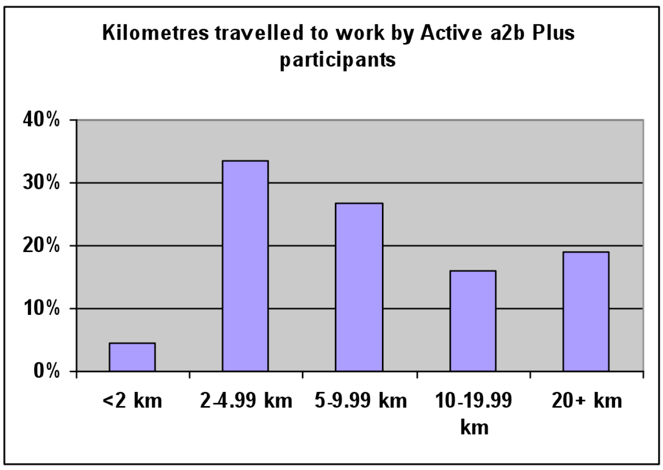
Figure 9.2. Demographics of Active a2b Standard and Plus participants



Source: Active a2b 2011 Final Report

Figure 9.3 shows, in percentages, the distances between work and home travelled by Active a2b Plus participants. Almost 40% of those who drove to work at least twice a week (Active a2b Plus group) were travelling under five kilometres to get there. 19% of the Plus group drove over 20 kilometres to get to work (Active a2b Final Report, 2011, p.10).

Figure 9.3. Distance travellled between work and home (kms) by Active a2b Plus participants



Source: Active a2b 2011 Final Report

The core target group for Active a2b were those participants who drove to work in a vehicle at least twice a week. These participants were part of the 'Active a2b Plus' group, and were given more personalised support than the standard participants, who did not drive to work more than once a week. The main point of difference for Active a2b Plus participants were the two personal phone calls they received to:

• discuss their situation
• brainstorm active transport goals and
• provide follow up encouragement.

I was the person responsible for making the calls and recording the information provided by the Active a2b Plus participants. During the telephone calls, the Active a2b Plus participants were also asked about what they considered to be the main benefits and the main barriers to walking or cycling to work.

Following the completion of the Active a2b programme, I decided the information described above, as well as demographic information obtained during the registration process and evaluation survey, could augment my research.

I believe the ecological validity of the Active a2b Plus data is retained in this thesis.[62] This assumption is based upon the fact that when collecting data for Active a2b, I was not considering this research and therefore had no incentive to influence the responses of participants in order to suit the purposes of this study. Furthermore, I have applied the Active a2b Plus data to this study with caution, attempting to ensure that any inferences made reflect the original sentiments of the programme participants.

---

[62] Ecological validity constitutes an acknowledgment of the fact that human action is situated within and highly contingent on contextual factors. The term refers to the degree to which the behaviours observed and recorded in a study reflect the behaviors that actually occur in natural settings. Studies with high ecological validity can be generalised beyond the setting they were carried out in, whereas studies low in ecological validity cannot.

9.3 Issues raised in interviews with Active a2b participants

Five main themes emerged from the interviews with regards to the feasibility and desirability of walking and cycling to work.[63] Below I outline each of these themes along with relevant quotes from participants and my own interpretations of how these issues might be addressed in order to help guide active commuting policy.

Fitness and weight-loss

Most Active a2b Plus participants saw the opportunity to increase fitness and lose weight as the main incentives for active commuting. For instance a scientist in his forties stated that his goal for the programme was to cycle to work every day, weather permitting. He commented that "I'm trying to slowly but surely get there with my weight loss goals… my aim is to lose ten kgs ultimately." Other participants expressed that they had not really considered using the commute as a way to get fit before joining the programme. A prison officer in her twenties remarked "I don't own a bike, nor have I thought of riding or walking to work before, but fitness was on the list as part of my new year's resolutions." Others noted that walking and cycling to work were cheaper options for getting active than many of the alternatives. A public sector worker in her thirties said "My doctor advised me that being more active will help reduce my cholesterol…I can't afford to go to the gym."

The fact that exercise was the primary reason that most interviewees registered for the Active a2b programme shows that the fitness and weight loss outcomes of active commuting are a large part of the appeal of walking and cycling to work. Therefore, presenting active commuting as a cheaper alternative to purchasing a gym membership is likely to be an effective way to entice people away from their cars for the commute. Chapters 6 and 7 showed that for men moving into the middle-income brackets, the probability of active commuting drops significantly and I have theorized that this is due to increased access to private vehicles. Due to the sedentary nature of many professions, getting an adequate level of

---

[63] A sixth theme, weather, could also be added here but due to space limitations and the problematic nature of assessing such a variable, I chose to omit it.

physical activity is likely to be of concern to many of these middle-income earners, especially if the time and financial constraints of family life make gym-going and other sources of exercise outside of work time unrealistic. For these reasons it may be possible to deter some of these middle income earners from commuting by car, by positioning active commuting as the most time and cost-effective way to get regular exercise.

Health and well-being

Female participants were more likely to recognise the benefits to mental health that stem from walking and cycling, such as stress-relief, relaxation, and feeling more connected to the world around them. A local government employee in her fifties said of active commuting, "It's good for mental health…gives me a chance to think about things." Similarly, another woman in the same age bracket commented that walking to work was "..a nice way to de-stress…and also to avoid having to find a car park" , and a third woman working at Parliament summed up the benefits for her by saying, "good for my mind, good for the environment." A male in the tertiary education sector mentioned that walking to work enabled him to "notice more of the world around me." Older people were more likely to mention health problems and mobility issues that imposed constraints on their ability to actively commute. This helps to expand on the results of my analysis in chapter 6 and the model in chapter 7, which showed that the propensity to actively commute declines with age.

Overall, the comments here suggest that the health and wellbeing benefits of walking and cycling to work should be emphasized by those seeking to promote active transport programmes, especially if the target group is older or female.

Motivation

Psychological factors such as being in the habit of driving a car and needing more motivation to establish a routine of walking or cycling were commonly identified by Active a2b Plus participants as being significant barriers to using active modes for commuting. A typical response when asked about what constituted the main barrier to active commuting was articulated by a woman in her fifties who blamed her own lack of motivation: "It's mainly psychological…making up excuses not to." Other participants said laziness, inertia, disorganization and the perception of not having enough time were the main culprits for their not having established an active daily routine.

This highlights the value of regional programmes and travel plans that offer support, encouragement and advice, and help foster a community of active commuters.

Safety and logistics

A number of participants described particular attributes of their commute route that made cycling feel unsafe, for instance the speed of cars, the narrowness of roads, or the inadequacy of provisions for cyclists. A woman in her thirties felt it was "a bit scary cycling in traffic sometimes" and a woman in her forties found it to be " stressful when people are rude in cars." A man in his forties said that "traffic conditions on the road from Wellington to Petone" made his cycle commute feel dangerous at times.

The fact that participants commented on safety issues around cycling, but not around walking, likely reflects both the efforts made by local government to establish Wellington as a walking city, and the significant challenges that cyclists in Wellington face in terms of the hilly terrain and narrow streets. Geographical hurdles notwithstanding, greater provision of cycling infrastructure including cycle lanes that are either off-road or separated from motorised traffic is likely needed in areas where it is possible in order to entice more would-be cyclists onto their bikes.

Time pressures and logistical constraints associated with having children were also mentioned in interviews, typically by working mothers. A woman in her thirties who worked in the tertiary education sector remarked "I don't think cycling is safe… there are also limitations with having a baby." Another woman in her thirties highlighted the time poverty often experienced by women with family responsibilities, as well as the notion that active commuting was outside cultural norms: "I have to get my family ready in the morning…also, we live in a very car-centric culture." Others mentioned having to take the car in order to drop children off at school or crèche. These comments reinforce the findings in chapters 6 and 7 that people with children, and particularly women with children, face a more constrained commute mode choice than those without. This emphasises the idea that parents will need additional help and incentives in order to make it feasible for them to switch to active transport modes.

However, it was not only having children that imposed logistical constraints. Many interviewees expressed views about the difficulty of using active modes when they had goods they needed to transport to work. A woman in her thirties said she needed to take the car "when I have too many things to carry." "Errands outside of work" was also cited as being a reason to commute by car. This indicates that cycling would be more feasible for many commuters if bike baskets and bike bags /panniers and bike trailers were more common or better publicized.

Convenience and efficiency

The advantage of not having to worry about car parking when walking or cycling to work was mentioned by a number of Active a2b Plus participants. A woman in her thirties said "My workplace car park has very limited parking so that's a huge demotivator for driving", and another in the same age group remarked that walking to work meant, "not having to worry about the hassle of a car…having to move the car every two hours [due to parking restrictions]." This suggests two things. From a policy perspective, decreasing the availability and increasing the cost of car parking is likely to encourage people to switch to active and public transport modes. Secondly, from an education and publicity perspective, the convenience aspect of walking and cycling should be emphasized by those designing active transport initiatives.

Male commuters were more likely to discuss the speed of the journey and that cycling to work, especially during peak congestion times, was often the quickest option. An engineer in his forties commented, "It's quicker to cycle…and I can stop by the pub on the way home and have a few drinks." Another man of a similar age working in the charity sector described his cycle commute as " a good start to the day and a good way to save money." This suggests that the ease and efficiency of commuting by bike should be emphasized when promoting active transport programmes to men.

9.4 Summary

The NZHTS data revealed that Wellington has a higher average income level and a higher proportion of residents living in main urban areas than is the case elsewhere in the country. These factors, in combination with the investment in active transport strategies and pedestrian infrastructure that the region has received, probably help explain the significantly higher use of walking as a commute mode in Wellington compared with other regions. Conversely, Wellington commuter cycling is no more prevalent in Wellington than other regions, which demonstrates that more can be done in the Wellington region to achieve higher rates of *both* walking *and* cycling.

In this chapter I have used qualitative data from Greater Wellington Regional Council's Active a2b programme to explore Wellington as a case study in active commuting. Data from interviews with Active a2b Plus participants revealed that there are a wide variety of other factors that affect commuters' willingness and ability to walk or cycle to work that are not captured in the NZHTS. Health and fitness were the main incentives for active commuting among this group.[64] Female commuters tended to enjoy the psychological and relaxation effects of walking, while male commuters tended to emphasise the speed, convenience and cost saving benefits of cycling. Some of the biggest deterrents to active commuting were safety (especially for cyclists and those with children) and a lack of motivation.

In the next (and final) chapter of my thesis I will discuss what has been learned from this research and how it relates to my prior expectations regarding the relationship between income and active commuting.

---

[64] It is possible that health and fitness concerns, or at least the propensity to translate these concerns into 'action', are likely to be positively associated with income.

Chapter 10. Conclusion

Active commuting bridges many concerns in the public health and transport sectors. The wide-ranging benefits of using active modes to get to work are now well documented, ranging from less air pollution and ambient noise, to reduced congestion and emissions, better work performance, well-being and community connectedness (Goodman and Tolley, 2003; Cavill et al., 2006 in Cole et al., 2010, p.497). Compared to driving, walking or cycling to work is economical, social, environmentally friendly and produces better physical and mental health outcomes. Better health outcomes reduce the financial burden on the health care system, resulting in better economic outcomes.

Despite this, the popularity of walking and cycling to work has greatly diminished over recent decades both in New Zealand and internationally. This has coincided with a steady rise in average incomes, associated with increasing economic activity. The New Zealand government has signaled that it is committed to sustaining economic growth and increasing the general affluence of the population (www.national.org.nz). What is unclear is what effect even greater affluence will have on the propensity to get physically active on the daily commute.

The historical evidence demonstrates a strong correlation between rising incomes and car ownership. The dominance of private vehicles in New Zealand has also been greatly facilitated by supportive public infrastructure. The net consequence has been a shift away from the use of active transport modes. What is unknown is whether the impact of income observed in the aggregate, also holds at the cross-sectional level. My aim in this research, therefore, was to track the influence of income on active commuting decisions in cross section using the New Zealand Household Travel Survey. My expectation was that active commuting would also decline with income in cross-section, since this is what the historical evidence suggests.

I initially explored this relationship in terms of commuters' individual and household characteristics. However, it became apparent that, while the study of people's behaviour is important, a critical aspect, and one the literature has not paid sufficient attention to, is context i.e. the opportunities and constraints imposed by the characteristics of the places in which people live. Since both locational variables included in the multivariate models were found to be highly influential in impacting active commuting, I then built a multilevel model in which settlement type was nested within region so that the embedded nature of these geographical 'levels' could be properly accounted for.

Next I focused in on Wellington- a region with an unusually high proportion of active commuters- as a case study. Qualitative data from a Wellington regional active commuting initiative was introduced so that I could paint a more complete picture of the experience of active commuting in this region.

10.1 What has been learned?

Across New Zealand as a whole only about 18% of workers walk or cycle to work. This figure varied significantly across the income spectrum. For example, among men and women in the highest income bracket, the proportion rises above 25%. However, for male commuters in the middle-income brackets (anywhere between about $25,000 to $65,000 per annum before tax) the figure is only about 12%. There were also large variations across different locations. In large cities over 20% of commutes involve active modes, whereas in smaller towns the proportion is less than 10%. Wellington constitutes an interesting outlier for commuter walking with over 35% of commutes involving walking; over double the national average of 16%.

Overall, I found that a conceptual position which argues for a negative relationship between active commuting and income cannot be sustained for most sub groups of female commuters, and is only true of male commuters up to a certain level of income, around $50,000-$60,000 per year before tax.

Female commuters

While the relationship between income and active commuting was a positive one for most types of female commuters, there were some circumstances in which this was not the case. For instance, women living in rural areas demonstrated very little elasticity in their propensity to actively commute at different income levels. Women living in secondary urban areas displayed a negative linear relationship between income and active commuting. I suggest that the overall positive relationship between active commuting and income is due to commuters' incomes rising with population density, which in turn reduces the distance to work, and increases opportunities for integrating active and public transport modes, which makes active transport more attractive.

But for commuters living in secondary and rural areas without the ability to capture the advantage of population density, there is no incentive for higher income commuters to switch to walking and cycling. Lower population density also means lower levels of public transport service, lesser provision of facilities for active modes and the lack of congestion as a disincentive to driving (Milne and Abley, 2011). However, female commuters residing in either a secondary urban area or a rural area comprise only 39% of the total female commuter population. The remaining 61% of female commuters live in main urban areas and for these women the relationship between active commuting and income is a strong positive linear one.

The conclusion therefore is that the concept of a negative relationship between active commuting and income for women only applies to quite a small subset of female commuters in New Zealand.

Male commuters

As for men, the effect of income on active commuting assumed a U-shape, skewed towards the upper end of the income scale.[65] This means that, on average, the probability of active commuting declined up to the point where a

[65] This U-shape may perhaps now be best characterized as a "J-shape" given the skew towards the upper end of the income scale.

man was earning up to about $60,000, and then the probability for most male sub-groups began to increase, with men earning upwards of $100,000 per year displaying the greatest likelihood of walking or cycling to work. There were some exceptions. For example, among male commuters living outside main urban areas, it was the lower income earners who had the highest probability of active commuting. This fits with the notion that income works through population density to active commuting.

Any conclusion regarding the propensity for men to walk and cycle in the face of rising incomes needs to take into account the distribution of incomes for male commuters. The median income for male commuters in New Zealand for the five-year period from 2003-2008 was $45,000, with 75% earning a gross yearly income of $65,000 or less. What this means is that the rise in the probability of active commuting that we see further up the income scale does not apply to the majority of male commuters.

We can say, therefore, that a position that argues for a negative relationship between rising income and active commuting can in fact be sustained for the majority of male commuters. It would require a large increase in incomes for most men before the positive effects of rising income could really be captured. I argue that this is because it is not until men are in the highest income brackets that they can afford to gain access to residential locations that enable walking and cycling to work to be feasible and desirable. Given that 'superior' residential locations are competitive and limited entities, their acquisition relies on the ability to outbid other (less affluent) workers, and therefore it is doubtful whether continuing to increase incomes will solve the problem of the J-shaped curve. The higher wage earners will always be able to outbid their lower wage-earning counterparts, making it necessary for some (less affluent) commuters to live in residential locations in which the scope for active commuting is limited.

In terms of stimulating greater active transport use, a more effective avenue than raising incomes may be to focus on urban design and mixed land use policies that permit the greatest number of commuters to live in compact areas in which the distance between residential locations and local labour markets is easily walkable and cycleable.[66] This is an idea I return to later in the chapter.

Additional factors

The multivariate models revealed that for both male and female commuters there were three key characteristics that constituted the most powerful determinants of whether a person would choose to use active modes of transport for the work commute. Each ultimately relates to prior longer term choices that predate the more immediate daily commute choice.

The most important individual characteristic in predicting the use of active transport was not holding a car licence. This suggests that a cultural shift from an emphasis on motorized mobility to an emphasis on muscle-powered mobility among young people approaching the age in which a driver's licence can be attained might be required in order to reconfigure life-long transport habits early on.

The critical temporal characteristic was commuting outside weekends. If an individual is employed in a position in which it is necessary to work on weekends, the choice of job is really the critical factor here and one that reflects an earlier decision that then constrains the daily commute mode choice. However, only about ten percent of commuter trips take place on a Saturday (5.9%) or Sunday (4.3%), and thus the problem of low probability of active transport use among commuters on weekends is probably not a high priority in policy terms, and it is probably wise to focus more energy on encouraging modal shifts on the weekdays when the vast majority of commuters are on the roads.

The key locational characteristic was settlement type; in other words, the level of population density in an individual's local labour market. This brings us to a major conclusion to be drawn from this exploration of the NZHTS data, which is that living in a main urban area is a strong predictor of greater use of active

[66] The compact areas would also need to be located near public transport nodes in order for the benefits to carry beyond the centrally-located 'elite'.

commute modes. This is one of the reasons why we see much higher use of active transport in Wellington than elsewhere in New Zealand. However, Auckland has an even higher proportion of commuters who live in main urban areas than Wellington (94% compared with 86.9%) and so there are clearly other factors that make conditions in Wellington more conducive to using active modes. A contributing factor is likely to be the steps that have been taken at a local government level to increase the use of active transport modes in the Wellington region.

The influence of income on active commuting became much less significant when the effects of settlement type and region were controlled for. Conversely, the strong effect of settlement type was sustained even when all other variables of interest were included in the model. This suggests that the positive effect of rising income I had initially observed was largely indicative of a higher proportion of more affluent workers being positioned in more densely populated local labour markets.[67]

The message, therefore, is that the positive effect of population density reflects a greater concentration of affluence and the associated option of a residential location close to the work place. This is really the most crucial factor in shaping transport mode choices for the work commute. This is an important finding. It signals that long term choices (such as the type of settlement and location within large settlements) that result in the wider context in which daily transport choices are made are absolutely fundamental to framing the decision of whether to actively commute or not.[68] While modal choice models are often very sophisticated in their identification of a broad set of inputs into the transport choice decision-making framework, they are not well-equipped to acknowledge

---

[67] It may also be that the educational component of higher incomes plays a part in the elevated probability of active commuting among the highest income earners, but I could not test this due to the absence of education-related data in the NZHTS.

[68] It should be borne in mind that not all workers have the luxury of considering the same suite of long term choices. For example, low or modest income earners often have very limited choices as to where they can afford to locate.

the fundamental importance of the long term choices that lead to the socio-economic and geographic context in which the more immediate, daily transport choices are made.

The characteristics of densely populated urban areas

It is not simply that greater population density equals greater use of active transport. The point is that living in the *most* densely populated metropolitan areas has a strong positive effect because it is in these large labour markets that a myriad of factors combine to make active commuting a more attractive option.

Firstly, the greater density in main urban areas applies not only to populations, but to mixed land-use, meaning that more amenities are within walking and cycling distance for inner-city residents. Also, the financial and time cost of car parking is higher in main urban centres, and better public transport provision enables heightened opportunities for integration with active modes. Pro-walking and cycling campaigns and community programmes are more prevalent in cities, and active transport infrastructure provision is more likely to be funded in densely populated areas in which agencies can be more confident that investments will provide better returns. In turn, better connectivity of pedestrian paths and cycle lanes in inner-city areas makes use of active transport modes both safer and more efficient.

Regional variances in commuter walking and cycling can partially be explained by the proportion of commuters living in main urban areas within each region, but also probably reflects varying levels of investment in active transport strategies and infrastructure across regions. Policies in the Wellington region that exemplify local government's commitment to walking are reflected in the high rates of commuter walking in the capital. Similarly, in the Nelson-Marlborough region, an integrative approach linking transport planning and urban development has seen the implementation of pedestrian, cycling and urban growth strategies in this area. This systematic investment in active transport modes would appear to have paid off given Nelson's comparatively high proportion of commuter cycle trips.[69]

10.2 Policy suggestions

The examples of the Wellington and Nelson-Marlborough regions suggest that investment in active and public transport does much to improve the viability of commuter walking and cycling, leading to an increase in the use of active modes.

However it is not just an issue of engineering, but of integration, meaning that integrated transport networks with links between active and public transport modes are likely to be instrumental in encouraging a shift away from private cars. In addition to this, the provision of showering and changing facilities at workplaces may help to improve the image and appeal of active commuting among potential walkers and cyclists.

Critical mass is a key component: the more people walk and cycle, the greater the perceived safety of using active commute modes will become, resulting in further increases in walking and cycling, and greater impetus to invest more in these modes. In order to start the cycle in motion, long-term strategies will be needed, with 'big picture' thinking and planning. This can and has been achieved through the development of partnerships between local and central government, with priority given to research and evaluation. Recent relevant examples are the North Island cities of Hastings and New Plymouth, both with populations of around 70,000. Central government funding, coupled with strong support and a clear vision at local government level, has resulted in these two localities becoming New Zealand's first 'Model Communities': "urban environments where walking or cycling is offered to the community as the easiest transport choice" (NZTA, 2012).

---

[69] 4.3%, compared with 0.5% in Auckland and 1.1% in Otago (see figure 5.9).

Strong leadership and commitment are necessary components, as previous international examples of cities that have received an active transport makeover, such as Portland, USA and London, UK, demonstrate. In these examples, the presence of at least one 'active transport champion' within local government has been critical in bringing active transport policies to fruition in a culture in which the motorcar still reigns supreme (Geller, 2012; Macpherson, 2012).

Building a culture of collaboration will help avoid the pitfall of 'reinventing the wheel' across different regions.[70] It is the sharing of information that will facilitate best practice, and the piloting and trialing of active transport schemes is a prudent way for local and national authorities to establish which approaches will best enable modal shifts.

10.3 Limitations

There were several limitations in the data that restricted the scope of the analysis and that therefore impose some limits on the conclusions that can be drawn. The first pertains to missing variables. No data collected in the NZHTS refers to respondents' level of education. Access to information on commuters' education would have enabled me to discern to what degree the effect of rising income on active commuting was actually an education effect.

Longitudinal data providing information on the commuting patterns and residential locations of the same individuals over time would have given us a more complete picture regarding the effects of long term decisions (chiefly the choice of region and settlement type within region) on the relationship between income and transport mode choices.

My study relied on cross-sectional time series data which meant that it was possible to examine patterns across time at an aggregate level, but not to discern how various factors impacted active commuting choices over time at an individual level. In the face of the issue of endogeneity or 'self-selection', and

[70] As one active transport commentator has noted "We are small enough to be a *national* model community" (Cheyne, 2012).

without data pertaining to the choices of the same individuals over time, it is difficult to confidently infer causality between the variables examined in this analysis and the use of active transport by commuters.

Finally, it must be remembered that my unit of analysis is the trip leg, and this has implications (and limitations) in terms of deriving meaning from the results. One issue here is that an individual can present multiple (on average about 2+) times in a particular trip chain using different modes. I estimated the probability that any given home-to-work trip leg (over 100m) will be walked or cycled (usually not differentiated but heavily weighted towards walking). This gives an indication of factors that affect the incidence of active commuting but not the proportion of the trip chain length nor the absolute distance travelled by active modes. The latter point is especially important in the context of active commuting's contribution to reducing obesity. In actual fact, the distances walked over a year via active commuting are uniformly very low and on average at least probably have relatively little impact: 18% of the population actively commute less than one kilometre per day. I'd conjecture that while this is a start, a real challenge is not only to get more than 18% of people walking and cycling to work, but to get people actively commuting longer distances.

10.4 Contributions of this research

This study provided an in-depth investigation into the relationship between active commuting and income based on a large national travel survey. As far I am aware, this study is the first to explore levels of active commuting according to income across the country and certainly within the New Zealand context.

It is also unique in its exploration of this relationship because it uses time-series data to capture not just one but a series of different points in time. Unlike many previous studies of active transport which have been of a purely descriptive nature, this study made use of both multivariate and multilevel nested modeling techniques.

It is rare for studies using national household travel survey data to incorporate a qualitative component. In my study, the inclusion of a regional case study using qualitative interview data enabled the study to encompass both breadth and depth in its inquiry into active commuting.

Previous studies in this area presented a confusing and sometimes contradictory picture of the relationship between income and active commuting and, at face value, my research complicates the picture even further. For instance, my finding that in New Zealand, largely due to economic geography, it is the most affluent commuters who have the greatest likelihood of walking or cycling conflicts with previous findings in both the UK (Adams, 2010), and the USA (Kruger et al., 2008), which found active transport use to be more prevalent among less affluent groups. However my findings are in partial agreement with studies in Australia (Merom et al., 2010), Germany (Buehler et al., 2011), and the UK (Brockman and Fox, 2011) which all found that cycling is more prevalent among the most affluent. The incongruous nature of the international literature is actually very telling and, taken altogether, it demonstrates the fundamental point of my study, that being the singular importance of context; the fact that actors in a particular place share a common physical and/or social environment and are thus exposed to opportunities and constraints that are not shared by others.

Appendices

Appendix 1: Letter of Ethics Approval

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON

Phone 0-4-463 5676

Fax 0-4-463 5209

Email Allison.kirkman@vuw.ac.nz

MEMORANDUM

TO	Laura McKim
COPY TO	Philip Morrison
FROM	Dr Allison Kirkman, Convener, Human Ethics Committee

DATE	8 July 2011
PAGES	1

SUBJECT	**Ethics Approval: 18518 - Working life conditions in New Zealand and their influence on active travel**

Thank you for your application for ethical approval, which has now been considered by the Standing Committee of the Human Ethics Committee.

Your application has been approved from the above date and this approval continues until 28 February 2012. If your data collection is not completed by this date you should apply to the Human Ethics Committee for an extension to this approval.

Best wishes with the research.

Allison Kirkman

Human Ethics Committee

Appendix 2: Ministry of Transport Confidentiality Agreement

Ministry of **Transport**
TE MANATŪ WAKA

HER MAJESTY THE QUEEN

[Name of other party]

CONFIDENTIALITY DEED

DEED dated

PARTIES

HER MAJESTY THE QUEEN, in right of the Government of New Zealand, acting by and through the Secretary for Transport (the **Ministry**)

(the **Other party**)

INTRODUCTION

A. (Description of the services comprising the **Purpose**).

B. The Ministry has agreed to make available Confidential Information to [] on the basis that the confidentiality of that information is at all times preserved in the manner, and otherwise on the terms and conditions, set out in this Deed.

IT IS AGREED

1. **CONFIDENTIALITY OBLIGATIONS**

1.1 In consideration of the Ministry providing the Confidential Information to the Contractor, the Contractor agrees as follows:

(a) she shall at all times treat the Confidential Information as confidential;

(b) she shall not, **except** as provided in **clause 2**:

(i) disclose any Confidential Information (or the fact that she has Confidential Information) to any person whatsoever;

(ii) use any Confidential Information for any purpose other than the Purpose, **except** with the Ministry's prior written consent; or

(iii) copy or store any Confidential Information without the prior written consent of the Ministry, **except** for the Purpose;

(c) the Confidential Information, and all intellectual property rights in the Confidential Information, is, and shall remain, at all times the property of the Ministry;

(d) she shall not copy or store any Confidential Information without the prior written consent of the Ministry, **except** for the Purpose;

(e) any consent of the Ministry requested under this **clause 1** may be withheld as the Ministry, in its absolute discretion, thinks fit;

(f) she shall keep the Confidential Information in a safe and secure place when it is not in use;

(g) she shall, upon demand by the Ministry, promptly return to the Ministry all Confidential Information.

2. **DISCLOSURE OF CONFIDENTIAL INFORMATION**

2.1 The Contractor shall not disclose or distribute or permit to be communicated orally or in writing, directly or indirectly, the Confidential Information (or any copies of the Confidential Information) to any third party at any time **except**:

(a) as provided in and permitted by this Deed; or

(b) as required by law.

3. **INDEMNITY AND REMEDIES**

3.1 The Contractor shall indemnify the Ministry against any losses, costs, damages, expenses, liabilities, proceedings or demands which the Ministry may directly or indirectly incur or suffer as a consequence of any breach of this Deed.

4. **MISCELLANEOUS**

4.1 If any part of this Deed is found to be void or unenforceable, the remaining parts of this Deed shall be binding on the Contractor and shall be enforced with the same effect as though the void and unenforceable portions were deleted.

4.2 This Deed shall be governed by, and construed in accordance with, the laws of New Zealand.

4.3 This Deed shall operate until such time as all of the Confidential Information has fallen into the public domain otherwise than as a result of any breach of this Deed.

5. **INTERPRETATION**

5.1 In this Deed, unless the context otherwise requries:

(a) **Confidential Information** includes:

(i) all information which the Ministry or any of its representatives discloses to the Contractor relating to the business of the Ministry as it related to the Purpose (whether orally, in writing or otherwise);

(ii) All information supplied to or for the benefit of the Contractor by or on behalf of the Ministry during the course of any meetings, presentations or discussion; and

(iii) Copies of any of the information described above or any material derived from that information,

but does not include any information which:

(iv) at the time it was disclosed, is generally availabe to, and known by, the public (other than as a result of a disclosure directly or indirectly by the Contractor or anyone associated with her); or

(v) was available to, and legally and properly obtained by, the Contractor on a non-confidential basis from a source other than the Ministry or its advisers, agents, officers or employees; or

(vi) has been independently acquired or developed by the Contractor without violating any of her obligations under this Deed or by law without the use of any Confidential Information;

(b) **Deed** means this deed;

(c) **Disclosed** includes made available;

(d) References to **clauses** and **Schedules** are to clauses of, and schedules to, this Deed.

EXECUTED AS A DEED

HER MAJESTY THE QUEEN, in right of the Government of New Zealand, acting by and through the Secretary for Transport:

Witness:
Name:
Address:
Occupation:

[Other party]

Witness:
Name:
Address:
Occupation:

Appendix 3: Previous publications to have used NZHTS data

The following is an annotated bibliography of some of the various research reports, articles, books and theses that have analysed data from the NZHTS.

Transport mode and travel pattern research

Three reports commissioned by the New Zealand Transport Agency (NZTA) use NZHTS data to investigate different aspects of New Zealanders' travel patterns over time. The first of these, by Abley et al (2008) is designed to make the large amount of information contained in the NZHTS more accessible to researchers and practitioners involved with transportation. This report was commissioned as part of a National Travel Profile research project to develop a 'Description of Daily Travel Patterns' based on data from the NZHTS between 2003 to 2006. In order to present the findings clearly, the report provides a wide range of tables and graphs relating to modes, purposes and trip legs for weekdays and weekend travel. The authors also make a number of recommendations with regards to the NZHTS, one being that the variables surveyed in the NZHTS be further assessed for use in the development of transportation models for future travel projection.

The second report by O'Fallon and Sullivan (2009) is an update of an earlier study of older people's travel patterns, which used the 1997/98 NZHTS (O'Fallon and Sullivan, 2003). This more recent report provides a comparative analysis using the 2004–07 ongoing NZHTS database (ONZHTS).

The third NZTA report describes the 2008/09 reformulation of the 2004–07 ongoing NZHTS trips database into trip chains and tours (O'Fallon and Sullivan, 2009, p.11). The reformulation required a re-creation of programming sequences for key elements of the new datasets (segments, trip chains, tours, main mode and main purpose, and three different tour classification schemes) based on previous reformulation of the 1997/98 NZHTS dataset. Having reformulated the datasets, the authors were then able to compare New Zealanders' travel patterns in 1997/98 and over 2004–07. They found that the mean number of trip chains per day (2.3) and the mean number of tours per day (1.3) were essentially unchanged.

The fourth and most recent report to examine NZHTS data in relation to transport mode was undertaken by Abley Transportation Consultants in 2011. This research project extended the work presented in NZ Transport Agency research report 353 'National travel profiles part A: description of daily travel patterns' (Abley et al 2008), which assessed the trip leg patterns associated with the 2003–06 NZHTS. A key output of the research was the production of a suite of models which can be used to test changes in travel behaviour where variables such as age, car ownership and household compositions change over time.

Active transport research

There are five recent publications that explicitly explore issues around *active* transport by analysing NZHTS data.

The first is another NZTA-commissioned report. The focus of the report is on valuing the health benefits of active transport (Genter et al, 2008). It seeks to provide a per-kilometre value for the health benefits of active transport modes that is compatible with the Land Transport New Zealand Economic Evaluation Manual Volume 2 (p.15). Annual estimates of the costs of inactivity are applied to the New Zealand adult population using a weighted sum to establish a per-kilometre value for each mode. The authors report that the lack of specific data reduces the methodological approaches available to value the health benefits of active transport modes.

The second publication to specifically study active modes of transport using these data looks at trends in commuting to work by foot or bike in New Zealand over a 15-year period (1991-2006). Tin Tin et al (2009) examine regional and individual differences and suggest future directions for successful interventions. New Zealand Census details the primary data set used to analyse self-reported information on the "main means of travel to work" from individuals aged 15 years and over. However NZHTS data for the years 2003-2008 are used to compute the average distance of home to work trips in each region.

A recent article in the *Australian and New Zealand Journal of Public Health* estimates the effects on health, air pollution and greenhouse gas emissions if short trips (≤7 km) were undertaken by bicycle rather than car (Lindsay et al, 2010). NZHTS data are used in conjunction with a number of other data sources. This is because morbidity, mortality, vehicle pollutant and greenhouse gas emission effects of changing trips from cars to bicycles are not comprehensively covered by a single modeling instrument (p.55). NZHTS data from 2003-2006 provides information on trip purpose, distance and average speeds. The authors restrict the analysis to people aged 18-64 years living in urban areas and undertaking only short trips (defined above). It is concluded that "there are potentially substantial co-benefits, both health and environmental, if the bicycle replaces the car for short trips in urban settings in New Zealand" (p.57).

A study examining the relationships between transport mode choice and city size over time uses NZHTS data from between 2002-2006 (Keall, Chapman and Howden-Chapman 2009). The authors obtain estimates by classifying the respondents in terms of age and by the size of the population centre where they live. For each survey, the percentage of time travelling is calculated across various modes (p.16). The key finding from this analysis is the observed shift away from active transport by New Zealand children. However, while it is clear that the changes in mode choice vary with city size, it cannot be assumed that urban form is causing these modal shifts.

The fifth publication to use NZHTS data to research active travel modes is another in the *NZ Transport Agency research report* series. This report mainly uses Sport and Recreation New Zealand's "Active New Zealand" survey to meet a number of health and transport-related objectives. However, this report also conducts an in depth analysis of whether the Active New Zealand survey and the NZHTS "deliver broadly comparable estimates of transport-related walking and cycling" (Sullivan and O'Fallon, 2011, p.15). The purpose of this is to decrease the risk of conflicting data (or misinterpretations of data) by clarifying to what extent results from the NZHTS and ANZS diverge, and elucidating reasons for major dissimilarities.

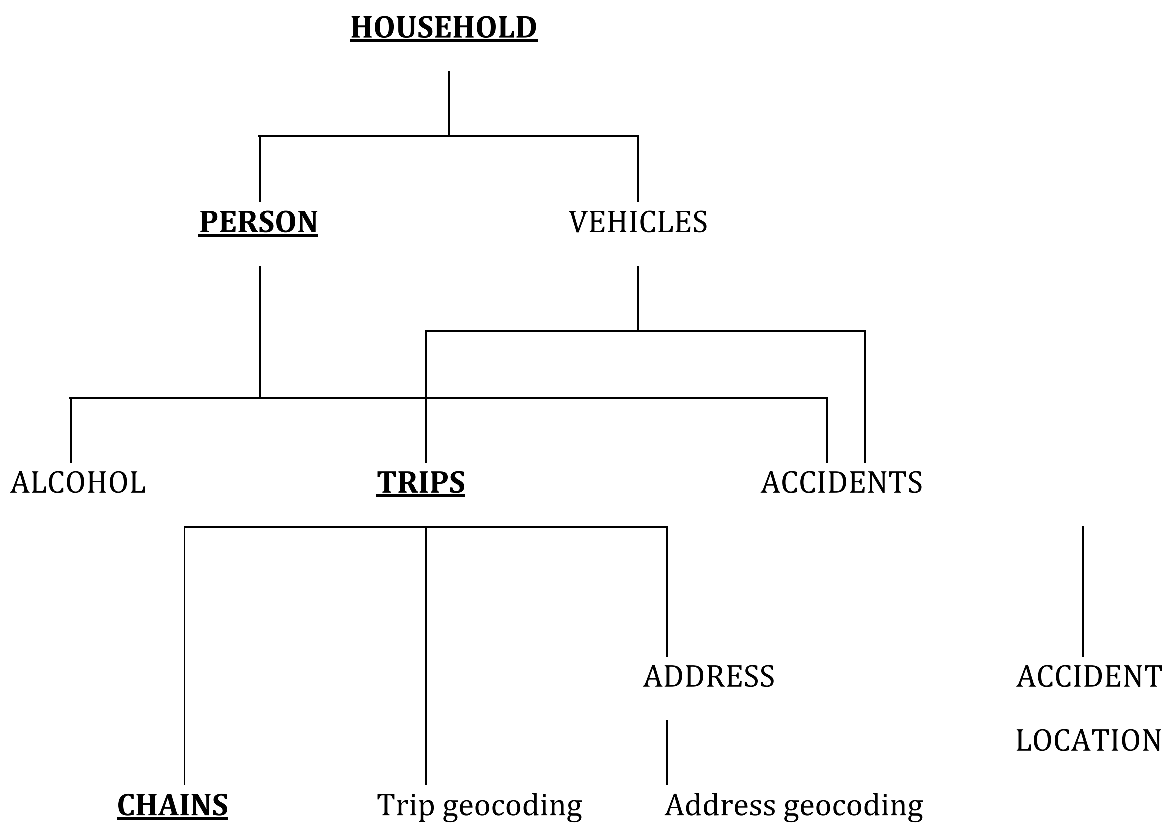
There are a few other publications that use NZHTS data, though these are of less direct relevance in terms of subject matter to the research at hand. These include a report inquiring into the question of whether SUV use has changed over time in New Zealand. NZHTS data from 1989-2006 was analysed and it was found that the proportion of SUVs to cars in the New Zealand vehicle fleet increased 7.3% over the 17-year period.

Also, a Master's thesis by a Victoria University student (Hulme-Moir, 2010) uses NZHTS data to explore issues of parking requirements in Porirua City Centre. The Porirua central business district case study is undertaken to investigate the use of Minimum Parking Requirements in a New Zealand context, and to assess their impacts on transport and land-use patterns (p.2). Hulme-Moir's research design does not include an analysis of NZHTS data. But his research is informed by information from the NZHTS on average trip length for the Wellington region, which he obtained from the Ministry of Transport.

Appendix 4: NZ Household Travel Survey Sampling Design

The survey applies a multistage sampling design (depicted below) to capture a representative set of households each year from throughout New Zealand. The data collected is organized into four main modules: household, person, trips and chains.

The structure of the Ministry of Transport Household Travel Survey



Details of the household are obtained from respondents.[71] Each person in the sampled household is then interviewed giving responses to questions on gender,

[71] The Household Questionnaire is available online at: http://www.transport.govt.nz/research/Documents/Household-form-versionF-April2008.pdf

age, employment, income, number of trips, ethnicity, and marital status.[72] Details of each trip made by sampled people on the travel days include trip purpose, mode (as driver/passenger/pedestrian/cyclist etc), date, time, origin and destination, age and gender of people in the vehicle, and which household vehicle was used.

Stratification

The sample strata and substrata are geographically based using Statistics NZ definitions for the 2001 Census of Population and Dwellings: the strata were the 14 Local Government Regions, further stratified into Main Urban Areas (at least 30,000 population), Secondary Urban Areas (population between 10,000 and 30,000) and rural (including Minor Urban Areas with population less than 10,000 and all other rural areas).

The sample sizes per Local Government Region are proportional to 2001Census populations except for the following: Less than proportional: Auckland, Canterbury, Wellington. More than proportional: Hawkes Bay, Nelson-Marlborough, Northland, Southland, Taranaki, Gisborne and the West Coast Regions.

The multistage stratified sample

The primary sampling unit (PSU) in the survey is the meshblock, a unit of about 100 households, which is the basic areal unit out of which all others in the Statistics New Zealand hierarchy of settlements are constructed.

In stage 1 of the design, meshblocks are sampled at random within each of 14 regions (and Main Urban Areas, Secondary urban areas and rural areas within them) across the country. Participating households are then systematically sampled from within each meshblock. Selected houses in the meshblock are sent a letter

---

[72] The Personal Interview Questionnaire is available online at: http://www.transport.govt.nz/research/Documents/Person-form-Version-F-April-08.pdf

describing the survey and advising that a surveyor will call. An interviewer visits the houses and invites people to take part. The people in the house note down their travel on two particular days. As soon as possible after the travel days the interviewer comes back and interviews each household member. Another set of households within the same meshblocks are sampled the following year, and so on until all households are captured after which a new meshblock is randomly selected. Therefore over a five to seven year cycle, every household in the selected meshblock will have been invited to participate in the survey.

Each selected household is randomly allocated two consecutive travel days on which each person is asked to maintain a travel diary. As such, surveying takes place on every day of the year, including weekends (NZ Ministry of Transport, 2010).

A trained interviewer visits each selected household and invites the members to complete a memory jogger to record all their travel over two days. The interviewer returns after the travel days to conduct a personal interview with each person in the household. The interview includes questions about the travel in the memory jogger. Data collection consisted of a face-to-face interview with each eligible, willing member of the sampled household. Between 2003/04 and 2007/08 (inclusive), 2,200 households were invited to participate each year.

Survey data are entered into an access database using a laptop computer, at the time of interview. Paper questionnaires are provided for situations where use of the computerised form is not practicable, and the results are entered into the database later by the interviewer. Data validation checks (including on the spot verification of street names) are incorporated into the database, giving rapid feedback and enabling early correction of errors.

Modules

The data in my analyses are gathered (or are derived from responses): For each Household the questionnaire collects Local government region of respondent's residence, urbanisation of respondent's residence, household structure, relationship of people in the household, number of people, number and type of household vehicles (car, motorcycle, van etc.), vehicle make and model, vehicle age, engine capacity and ownership, and response status of household.

For each person in the sampled household the person questionnaire collects - gender, age, employment, income, driving experience, number of road crashes, number of trips, ethnicity, marital status, whether they drank alcohol on travel days, and location of workplace/school.

For each trip made by sampled people on the travel days is documented over the two consecutive days. Collected are - trip purpose, mode (as driver/passenger/ pedestrian/cyclist etc), date, time, origin and destination, age and gender of people in the vehicle, and which household vehicle was used (linked to information on vehicle make and model, vehicle age, engine capacity, ownership).

Multi-leg trip chains

As I outlined in chapter 2, trip legs can occupy either the whole journey (chain) or part of it. Trip chains for the purposes of work may contain one or more walking or cycling trip legs but may also contain trip legs involving motorized modes i.e. public transport. Here I explore whether a greater proportion of commuter walking trips are part of multi mode trip chains for residents living in more densely populated areas (i.e. main urban areas) than in the less densely populated secondary urban areas and rural areas[73].

Number of legs per work trip chain by mode of travel. Total and by settlement type. New Zealand, 2003-08.

a. New Zealand

legs per trip chain	travel mode: walk	bicycle	motorised	Total
1	518	207	6,382	7,107
	28.57	89.22	69.29	63.15

legs per trip chain	walk	bicycle	motorised	Total
2	832	17	2,096	2,945
	45.89	7.33	22.76	26.17
3	346	4	455	805
	19.08	1.72	4.94	7.15
4	85	4	146	235
	4.69	1.72	1.59	2.09
5+	32	0	131	163
	1.77	0.00	1.42	1.45
Total	1,813	232	9,210	11,255
	100.00	100.00	100.00	100.00

b. Main urban areas

legs per trip chain	travel mode walk	bicycle	motorised	Total
1	290	134	3,670	4,094
	21.56	88.16	68.37	59.64
2	642	11	1,252	1,905
	47.73	7.24	23.32	27.75
3	317	3	276	596
	23.57	1.97	5.14	8.68
4	67	4	98	169
	4.98	2.63	1.83	2.46
5+	29	0	72	101
	2.16	0.00	1.34	1.47
Total	1,345	152	5,368	6,865
	100.00	100.00	100.00	100.00

c. Secondary Urban Areas

legs per trip chain	travel mode walk	bicycle	motorised	Total
1	37	28	826	891
	39.36	90.32	70.96	69.12
2	43	3	270	316
	45.74	9.68	23.20	24.52
3	9	0	45	54
	9.57	0.00	3.87	4.19
4	5	0	10	15
	5.32	0.00	0.86	1.16
5+	0	0	13	13
	0.00	0.00	1.12	1.01
Total	94	31	1,164	1,289
	100.00	100.00	100.00	100.00

d. Rural Areas

legs per trip chain	travel mode walk	bicycle	motorised	Total
1	191	45	1,886	2,122
	51.07	91.84	70.43	68.43
2	147	3	574	724
	39.30	6.12	21.43	23.35
3	20	1	134	155
	5.35	2.04	5.00	5.00
4	13	0	38	51
	3.48	0.00	1.42	1.64
5+	3	0	46	49
	0.80	0.00	1.72	1.58

Total	374	49	2,678	3,101
	100.00	100.00	100.00	100.00

Source: NZHTS trip file

For New Zealand as a whole, under 30% of commuter walking trips are single-leg trip chains. A greater number are part of two-leg trip chains (46%). In contrast, over 89% of commuter cycle trips are single-leg trip chains. These proportions are fairly similar to commutes in main urban areas only, reflecting the highly urbanised distribution of New Zealand's population.

A much higher percentage of walking trips are part of multi-part trip chains in main urban areas than in either secondary urban areas or rural areas[74]. In main urban areas, most walking commutes are part of a trip chain involving either two (47.7%) or three (23.6%) segments. In secondary urban areas, a similarly high proportion of walking commutes are part of a two-segment trip chain (45.7%), but a much larger proportion are single leg trips (39.4%) compared with in main urban areas (21.6%). In rural areas the majority of walking commutes are single leg trips (51.1%), while a significant proportion are part of two-segment trip chains (39.3%).

There is also an increase in the number of cycling trip legs that are single-leg commutes from the densely populated main urban areas (88.2%), to less densely populated secondary urban areas (90.3%), through to the least populous settlement type: rural areas (91.8%).

What the above tells me is that the use of trip legs as the unit of analysis is more representative of overall trip chains in some settlement types than others.

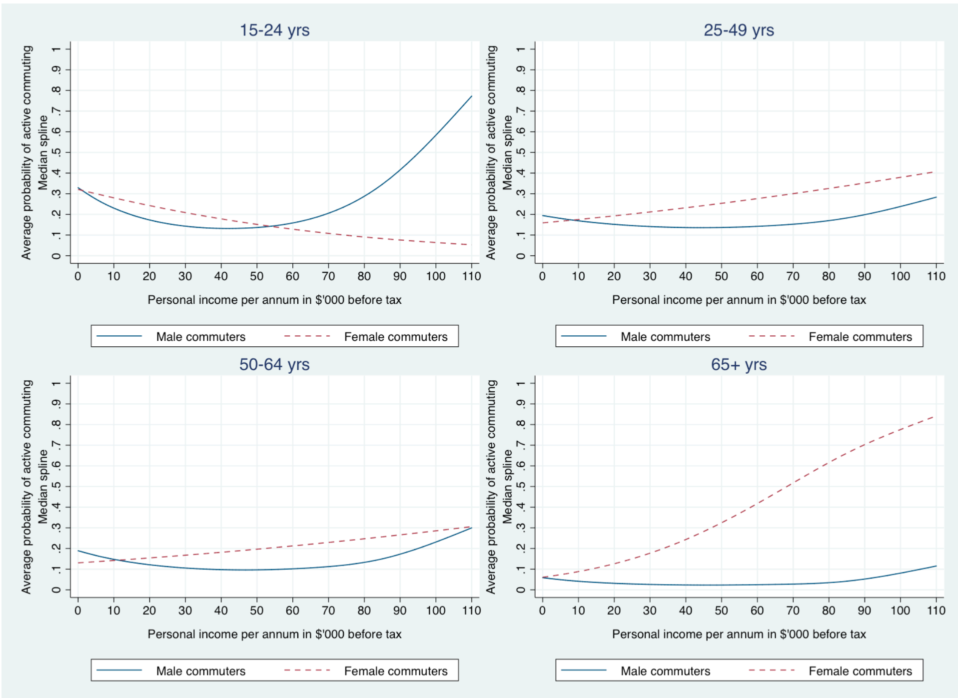
---

[74] According to the Ministry of Transport, main urban areas have population densities of over 30,000; secondary urban areas have populations of between 10,000-29,999; and rural areas have population densities of 9,999 or less.

Appendix 5: Additional analysis of age in relation to the impact of income on active commuting

I can further unpack the 'younger' and 'older' age categories used in chapter 6 in order to see whether we are able to get a more detailed picture of how the income-active commuting relationship itself changes with age. The probability graph below shows that there are substantial differences in the way active commuting changes with income across four different age groups.

The probability of using active transport for commuting by personal income category: different age groups. New Zealand 2003-08.



Source: NZHTS trip file

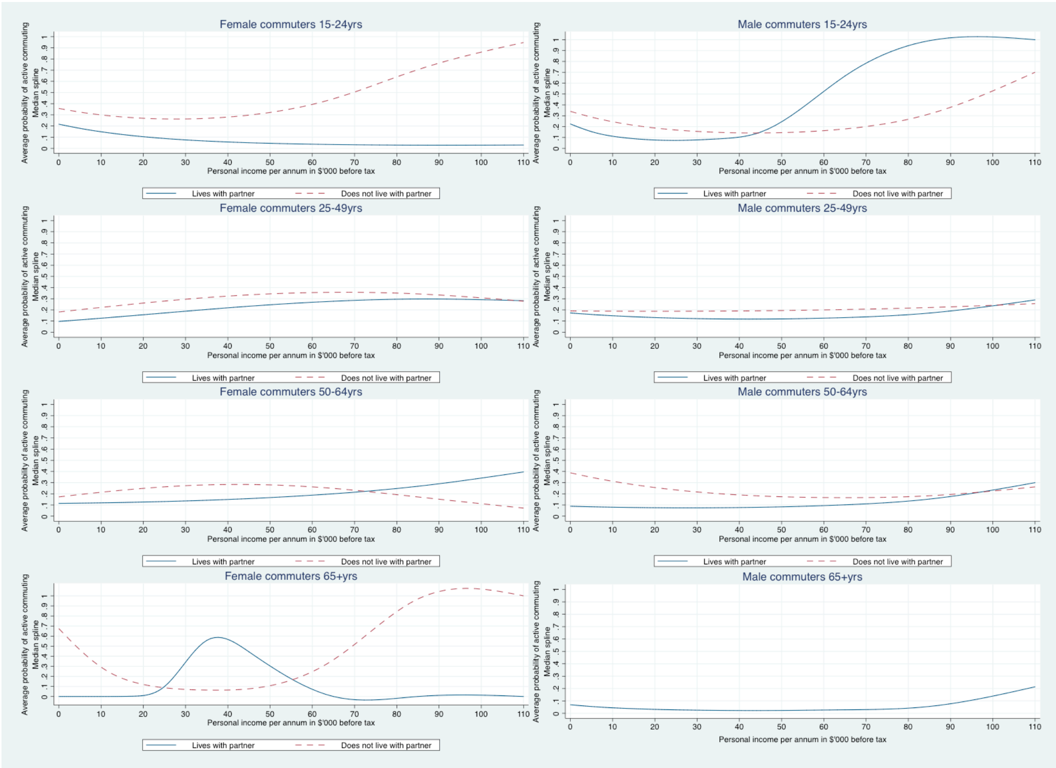
For women, the fairly linear positive relationship between rising income and rising active commuting use is still observed, albeit to varying degrees, for the three age categories containing female commuters aged 25 years and above. However, this trend is not so for younger women – those aged between 15-24 years (n=648)- for whom the probability of active commuting starts at slightly over 0.3 and steadily decreases with income down to less than 0.1 for young women earning $110,000 or more per year. This group is the only one to behave as expected conceptually.

In stark contrast, female commuters in the 65+ age bracket (n=77) are highly positively responsive to rising income, with a predicted probability of less that 0.1 for older women in the lowest income brackets, rising right up to over 0.8 for older women earning $110,000+. Women in the 50-64 year age group (n=1191) are the least responsive to income: though their predicted probability of active commuting does rise gradually with age, it stays at around 0.2 across all but the highest and lowest income brackets.

For male commuters, the predicted probability of using active transport is highest among those aged 15-24 (n=768) and lowest among those aged 65+ (n=202). For male commuters in the two middle age groups – 25-49 (n=3310) and 50-64 (n=1357) years – the pattern across incomes is almost identical, with a weak U-shape showing the probability starting at 0.2 for the lowest income earners, dipping down to 0.15 for those earning $45,000, and peaking at about 0.3 for 25-64 year old men earning $110,000+. Men aged 15-24 years show the most severe U-shape in the income relationship, with the probability of active commuting rising significantly to 0.8 for men earning $110,000+, compared with a probability of 0.3 for young male commuters on the lowest incomes. In contrast with female commuters in the 65+ group, male commuters over 65 are highly unresponsive to rising income, with very low probabilities of using active transport modes (about 0.05) across all income categories up until the $100,000 a year mark, at which point the probability sees a marginal rise to 0.1.

We have seen that age has a negative effect on the probability of using active modes for the commute. How does this relationship change when the effect of living with a partner or spouse is factored in? In the next graph, I lplot the differences between those living with versus those not living with a partner, as well as differences between male and female commuters.

The probability of using active transport for commuting by personal income category: men and women of different ages living with/without a partner. New Zealand 2003-08.



Source: NZHTS trip file

The picture above is quite complex. Among females, the effect of income on active commuting follows very different trajectories for those living with a partner than for those not living wit a partner in the youngest and oldest age brackets. For both 15-24 year old and 65+ female commuters not living with a partner, the likelihood of active commuting rises with income after about $40,000 before tax per annum. Contrastingly, for female commuters under 24 or over 65 years of age and living with a partner, the probability of active commuting declines to about 0 above $60,000 before tax per annum. For female commuters in the two middle age brackets, the difference in the likelihood of active commuting is not so pronounced between those living with and those not living with a partner, though on the whole not living with a partner predicts a greater likelihood of active commuting than the alternative up until a woman is earning around $70,000.

For male commuters in the two middle age brackets, the negative impact of living with a partner is also quite slight. The exception is lower income 50-64 year old men, for whom the likelihood of active commuting is much higher among those not living with a partner than among those living with a partner (0.3 for those not living with a partner and earning $10,000 versus 0.1 for those living with a partner earning the same). Male commuters aged between 25-49 years who do not live with a partner display total inelasticity in response to income; the probability of active commuting for this age group is 0.2 across all income brackets.

Among male commuters it is those aged between 15-24 years, earning over $60,000 per year and living with a partner that are the most likely to actively commute (predicted probability of over 0.5). Figure--- reminds us, however, that age and income are closely correlated and actually it is a small minority of commuters in the 15-24 year age group who earn over $50,000, so the very high predicted probabilities of active commuting that we see for some commuters within this age bracket applies to a rather small number of individuals (n=31).

Note that for the 65+ male commuter group the effect of partnership could not be tested. This is because there were no observations in the sample that registered as 'not living with a partner' once all the filters (being employed, travelling for the purposes of work, earning more than 0 and not working as a professional driver) were applied.

Appendix 6: Multivariate modeling – Additional material

Regression output of the odds of active commuting among male commuters

Logistic regression	Number of obs	=	5619
	LR chi2(39)	=	670.37
	Prob > chi2	=	0.0000
Log likelihood = -2060.9884	Pseudo R2	=	0.1399

AT	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Income						
Income	.9991945	.0035406	-0.23	0.820	.992279	1.006158
Income2	1.000195	.0000503	3.88	0.000	1.000097	1.000294
Age						
Agec	.9870665	.0042613	-3.02	0.003	.9787497	.9954539
Agec2	.9996002	.0002505	-1.60	0.111	.9991093	1.000091
Employment Status						
Part Time	.4172435	.1166404	-3.13	0.002	.2412327	.7216772
Full Time	.4219197	.1046858	-3.48	0.001	.2594368	.6861643
Household Type						
HHType: Single Adults	2.117838	.2973264	5.35	0.000	1.60839	2.788651
HH with children = base						
HHType:FamilyNoChildren	.9938663	.099533	-0.06	0.951	.8167375	1.20941
Partnership						
Lives with Partner = base						
NotLivingwPartner	.9153644	.1219395	-0.66	0.507	.7050209	1.188464
Holds Car Licence Y/N						
NoCarLicence	6.554795	1.12506	10.95	0.000	4.682303	9.176112
Holds Car Licence = base						
Season						
Summer	1.051546	.1250056	0.42	0.672	.8329888	1.327447
Autumn = base						
Winter	.9186066	.1097806	-0.71	0.477	.7267824	1.16106
Spring	1.219572	.1406955	1.72	0.085	.9727672	1.528995
Day of Week						
Sunday	.9104717	.1998854	-0.43	0.669	.5920975	1.400037
Monday	1.389755	.1893205	2.42	0.016	1.0641	1.815072
Tuesday	1.203235	.1592967	1.40	0.162	.9282382	1.559701
Wednesday	1.044477	.1374824	0.33	0.741	.8069689	1.351888
Friday	1.214763	.1637437	1.44	0.149	.9327257	1.582082
Saturday	.4934284	.1250139	-2.79	0.005	.300307	.8107421
Survey Year						
year200304	.9313695	.1178046	-0.56	0.574	.7268712	1.193401
year200405	.9237318	.1189676	-0.62	0.538	.7176612	1.188974
year200506 = base						
year200607	1.25826	.1582705	1.83	0.068	.9833354	1.610048
year200708	1.060856	.1324937	0.47	0.636	.8305147	1.355083
Region						
Northland	2.047174	.5109932	2.87	0.004	1.255126	3.339046
Auckland = base						
Waikato	1.082416	.226412	0.38	0.705	.7183663	1.630957
BayofPlenty	1.421301	.3433425	1.46	0.146	.8852416	2.281971
Gisborne	.8527196	.3773352	-0.36	0.719	.3582142	2.029877
HawkesBay	1.447947	.372568	1.44	0.150	.8744434	2.397581
Taranaki	1.808525	.4408869	2.43	0.015	1.121545	2.916303
Manawatu	.969052	.2380894	-0.13	0.898	.5987048	1.568489
Wellington	5.228264	.7255132	11.92	0.000	3.983257	6.86241
NelsonTasman	2.198708	.4598418	3.77	0.000	1.459304	3.312755
WestCoast	2.380515	.6622147	3.12	0.002	1.380012	4.106382
Canterbury	2.382421	.3561378	5.81	0.000	1.777363	3.193456
Otago	2.902382	.5853674	5.28	0.000	1.954699	4.309524
Southland	.8370224	.2414479	-0.62	0.537	.4755531	1.473246
Settlement Type						
Main Urban Area = base						
SecondaryUrbanArea	.3746796	.0630087	-5.84	0.000	.2694735	.5209596
RuralArea	.6899183	.08004	-3.20	0.001	.5495998	.8660615

_cons	.1447832	.044095	-6.35	0.000	.0797035	.263002

Regression output of the odds of active commuting among female commuters

```
Logistic regression                               Number of obs   =       4615
                                                  LR chi2(40)     =     485.29
                                                  Prob > chi2     =     0.0000
Log likelihood = -2186.1217                       Pseudo R2       =     0.0999
```

AT	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Income						
Income	1.00656	.0032028	2.05	0.040	1.000302	1.012857
Income2	.9999599	.0000625	-0.64	0.521	.9998374	1.000082
Age						
Agec	.9937962	.0036294	-1.70	0.088	.986708	1.000935
Agec2	.9994235	.0002561	-2.25	0.024	.9989217	.9999255
Employment Status						
Part Time	1.46086	.3816194	1.45	0.147	.875487	2.437628
Full Time	1.520386	.4063704	1.57	0.117	.9004171	2.567225
Household Type						
HHType: Single Adults	1.629806	.1947065	4.09	0.000	1.289574	2.059803
HH with Children = base						
HHType:FamilyNoChildren	1.314038	.1239418	2.90	0.004	1.092248	1.580863
Partnership						
Lives with Partner = base						
Not Living w Partner	1.418824	.1406674	3.53	0.000	1.168254	1.723137
Holds Car Licence Y/N						
NoCarLicence	3.602479	.5132513	9.00	0.000	2.724767	4.762923
Holds Car Licence = base						
Season						
Summer	1.076324	.1181438	0.67	0.503	.8679811	1.334677
Autumn = base						
Winter	.9435648	.1055122	-0.52	0.603	.7578581	1.174777
Spring	1.120182	.1207538	1.05	0.292	.90684	1.383716
Day of week						
Sunday	.4845325	.1256802	-2.79	0.005	.2914301	.8055851
Monday	1.04047	.1309218	0.32	0.753	.8130611	1.331483
Tuesday	.9160537	.1118959	-0.72	0.473	.7210191	1.163845
Wednesday	.9283947	.114504	-0.60	0.547	.7290365	1.182268
Thursday = base						
Friday	.8652816	.1089955	-1.15	0.251	.6759826	1.107591
Saturday	.5329599	.111604	-3.01	0.003	.3535488	.8034146
Survey Year						
year200304	.898314	.1072867	-0.90	0.369	.7108339	1.135241
year200405	1.087304	.1290716	0.71	0.481	.8616019	1.37213
year200506 = base						
year200607	.9965615	.1223414	-0.03	0.978	.7834433	1.267654
year200708	1.155347	.1385588	1.20	0.229	.9133335	1.461489
Region						
Northland	1.669382	.4081456	2.10	0.036	1.033823	2.69566
Auckland = base						
Waikato	1.214266	.2244359	1.05	0.294	.8452477	1.74439
BayofPlenty	1.124317	.2778635	0.47	0.635	.6926642	1.824965
Gisborne	1.312029	.3974873	0.90	0.370	.724547	2.375856
HawkesBay	1.021474	.2669882	0.08	0.935	.6119898	1.704946
Taranaki	1.303948	.3187991	1.09	0.278	.8075175	2.105564
Manawatu	1.794283	.3671319	2.86	0.004	1.201503	2.67952
Wellington	4.122336	.5634454	10.36	0.000	3.153554	5.388732
NelsonTasman	2.488898	.548502	4.14	0.000	1.615919	3.833491
WestCoast	3.128632	.7863857	4.54	0.000	1.911631	5.120414
Canterbury	2.583401	.3836851	6.39	0.000	1.930954	3.456302
Otago	2.510758	.44453	5.20	0.000	1.774596	3.552305
Southland	1.116079	.2977881	0.41	0.681	.6615771	1.882822

Settlement Type						
Main Urban Area = base						
Secondary Urban Area	.4099492	.0652977	-5.60	0.000	.300019	.5601591
Rural Area	.5931842	.0622635	-4.98	0.000	.4828846	.7286782
_cons	.0863174	.0272917	-7.75	0.000	.046448	.1604095

Regression output for the active commuting distance travelled by men

Source	SS	df	MS
Model	653.938415	39	16.7676517
Residual	5747.57351	815	7.05223744
Total	6401.51192	854	7.4959156

Number of obs =	855
F(39, 815) =	2.38
Prob > F =	0.0000
R-squared =	0.1022
Adj R-squared =	0.0592
Root MSE =	2.6556

bestdist	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Income	-.0059893	.0089372	-0.67	0.503	-.023532	.0115534
Income2	-.0000364	.000121	-0.30	0.764	-.0002738	.000201
Agec	.0118663	.0107045	1.11	0.268	-.0091453	.0328779
Agec2	-.0000616	.000698	-0.09	0.930	-.0014318	.0013085
maleR	0	(omitted)				
PartTime	.3376589	.6264592	0.54	0.590	-.8920047	1.567323
FullTime	.2493648	.5688792	0.44	0.661	-.8672763	1.366006
HHTypeOtherorUnknown	-1.735186	.8646683	-2.01	0.045	-3.432426	-.0379469
HHTypeSingleAdults	-.5427013	.3354748	-1.62	0.106	-1.201198	.1157951
HHTypeFamilyNoChildren	-.2382964	.2426646	-0.98	0.326	-.7146176	.2380248
PartnerStatusUnknown	0	(omitted)				
NotLivingwPartner	.2180794	.3552565	0.61	0.539	-.4792462	.9154051
NoCarLicence	.0684003	.3287428	0.21	0.835	-.576882	.7136826
Summer	-.3790938	.2825308	-1.34	0.180	-.9336676	.1754799
Winter	.082723	.2802269	0.30	0.768	-.4673285	.6327744
Spring	-.1952568	.2704889	-0.72	0.471	-.7261937	.3356801
Sunday	1.373682	.4997053	2.75	0.006	.3928211	2.354543
Monday	.1160997	.3180856	0.36	0.715	-.5082639	.7404632
Tuesday	-.0883714	.3089489	-0.29	0.775	-.6948007	.5180578
Wednesday	.0321201	.3078805	0.10	0.917	-.5722121	.6364522
Friday	.1614877	.3133313	0.52	0.606	-.4535438	.7765192
Saturday	1.072108	.6184746	1.73	0.083	-.141883	2.286099
year200304	-.4407116	.304729	-1.45	0.148	-1.038858	.1574346
year200405	-.4511704	.3076125	-1.47	0.143	-1.054977	.1526359
year200607	-.7102488	.2921253	-2.43	0.015	-1.283655	-.1368423
year200708	-.2687801	.2909361	-0.92	0.356	-.8398526	.3022923
Northland	-.2881095	.587586	-0.49	0.624	-1.44147	.8652507
Waikato	.4636236	.5534385	0.84	0.402	-.6227092	1.549956
BayofPlenty	3.410933	.6107478	5.58	0.000	2.212109	4.609757
Gisborne	1.302855	1.141607	1.14	0.254	-.9379811	3.543692
HawkesBay	-.3319954	.6336183	-0.52	0.600	-1.575712	.9117207
Taranaki	.4239701	.6003351	0.71	0.480	-.7544151	1.602355
Manawatu	.5899326	.6106317	0.97	0.334	-.6086635	1.788529
Wellington	-.2510536	.3233016	-0.78	0.438	-.8856555	.3835483
NelsonTasman	1.331554	.532881	2.50	0.013	.2855734	2.377535
WestCoast	.4700742	.682659	0.69	0.491	-.8699029	1.810051
Canterbury	.7748333	.3593934	2.16	0.031	.0693876	1.480279
Otago	.7775991	.5012095	1.55	0.121	-.2062144	1.761413
Southland	-.2735463	.7365745	-0.37	0.710	-1.719353	1.17226
SecondaryUrbanArea	-.6712728	.4301924	-1.56	0.119	-1.515689	.1731428
RuralArea	-1.11511	.3065749	-3.64	0.000	-1.71688	-.5133407
_cons	1.642403	.7025369	2.34	0.020	.2634077	3.021398

Regression output for the active commuting distance travelled by women

Source	SS	df	MS
Model	98.2330946	40	2.45582736
Residual	860.662862	972	.88545562
Total	958.895957	1012	.947525649

Number of obs =	1013
F(40, 972) =	2.77
Prob > F =	0.0000
R-squared =	0.1024
Adj R-squared =	0.0655
Root MSE =	.94099

bestdist	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Income	.0033556	.0026169	1.28	0.200	-.0017799	.0084911
Income2	8.47e-07	.0000514	0.02	0.987	-.0001001	.0001018
Agec	-.0053761	.0030267	-1.78	0.076	-.0113158	.0005635
Agec2	-.0000291	.0002067	-0.14	0.888	-.0004348	.0003766
maleR	0	(omitted)				
PartTime	.1983126	.2252592	0.88	0.379	-.2437378	.6403631
FullTime	.2468698	.2333374	1.06	0.290	-.2110332	.7047729
HHTypeOtherorUnknown	1.081019	.7176579	1.51	0.132	-.3273186	2.489356
HHTypeSingleAdults	.0853642	.0933274	0.91	0.361	-.0977821	.2685106
HHTypeFamilyNoChildren	.0132398	.0790381	0.17	0.867	-.1418652	.1683449
PartnerStatusUnknown	.8763656	.9598468	0.91	0.361	-1.007245	2.759976
NotLivingwPartner	.0848316	.0835465	1.02	0.310	-.0791207	.248784
NoCarLicence	.1859027	.0998469	1.86	0.063	-.0100376	.381843
Summer	.1156453	.0906385	1.28	0.202	-.0622244	.2935151
Winter	-.1211184	.0936407	-1.29	0.196	-.3048796	.0626429
Spring	.0084943	.0867981	0.10	0.922	-.161839	.1788276
Sunday	.2015874	.2206867	0.91	0.361	-.2314899	.6346647
Monday	.0689941	.0979917	0.70	0.482	-.1233056	.2612937
Tuesday	.0579803	.0957848	0.61	0.545	-.1299884	.2459491
Wednesday	-.001139	.0975484	-0.01	0.991	-.1925687	.1902908
Friday	.0638517	.0999934	0.64	0.523	-.1323762	.2600795
Saturday	.0346278	.1813788	0.19	0.849	-.3213113	.3905669
year200304	.0319805	.0984344	0.32	0.745	-.1611879	.2251489
year200405	-.0606297	.0967579	-0.63	0.531	-.2505083	.1292488
year200607	.1626531	.1010756	1.61	0.108	-.0356983	.3610045
year200708	-.0740029	.0960628	-0.77	0.441	-.2625173	.1145115
Northland	-.0227545	.2043686	-0.11	0.911	-.4238091	.3783001
Waikato	.5154193	.1612069	3.20	0.001	.1990657	.8317728
BayofPlenty	-.0551886	.2299784	-0.24	0.810	-.5065	.3961227
Gisborne	.4286322	.2627847	1.63	0.103	-.0870586	.944323
HawkesBay	-.0571194	.2247002	-0.25	0.799	-.4980726	.3838339
Taranaki	-.0491999	.2107456	-0.23	0.815	-.4627686	.3643688
Manawatu	.3907661	.1753938	2.23	0.026	.0465719	.7349602
Wellington	-.0430289	.1088456	-0.40	0.693	-.2566284	.1705706
NelsonTasman	.0615944	.1877476	0.33	0.743	-.306843	.4300317
WestCoast	-.0219293	.2214445	-0.10	0.921	-.4564936	.412635
Canterbury	.2423899	.1222155	1.98	0.048	.0025533	.4822265
Otago	.4383958	.1468235	2.99	0.003	.1502683	.7265233
Southland	.3784912	.2324802	1.63	0.104	-.0777297	.8347122
SecondaryUrbanArea	.0919141	.1461773	0.63	0.530	-.1949454	.3787735
RuralArea	-.4554066	.0920636	-4.95	0.000	-.6360729	-.2747404
_cons	.3097595	.2767444	1.12	0.263	-.2333259	.8528449

Appendix 7: Multilevel modeling logistic outputs

Multilevel (or mixed effects) modeling is basically just regression analysis allowing two kinds of effects: fixed effects, meaning intercepts and slopes which describe the population as a whole, and random effects, meaning intercepts and slopes that can vary across subgroups of the sample (Hamilton, 2009, p. 413).

Continuing the practice of the earlier chapters I analyse male and female commuting separately. One of the important results of the multivariate analysis in chapter 7 was the stability of the income effect on active commuting. Despite a range of controls and even after estimating settlement and region fixed effects the probability of actively commuting continued to rise with income, linearly in the case of female commuters and U shaped for males (at least until settlement and regional fixed effects were entered after which the relationship resorted to being linear). These results mean that I can focus, with some confidence, just on how settlement type and region influences the level and the degree to which the probability of active commuting changes with income.

In this appendix I test explicitly for the context effects of settlement, that is whether working a rural, secondary or main urban area alters the probability of actively commuting firstly for women commuters then male commuters.

The impact of including random intercept effects for settlement on the way in which female active commuting rises with income. New Zealand, 2003-2007

```
Mixed-effects logistic regression               Number of obs      =      4621
Group variable: areatype2                       Number of groups   =         3

                                                Obs per group: min =       465
                                                               avg =    1540.3
                                                               max =      2842

Integration points =   7                        Wald chi2(1)       =     17.74
Log likelihood = -2385.0012                     Prob > chi2        =    0.0000

------------------------------------------------------------------------------
          AT | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  peincnumrcx |  1.006884   .0016401     4.21   0.000     1.003675    1.010104

       _cons |  .1704143   .0372176    -8.10   0.000     .1110729    .2614591
------------------------------------------------------------------------------

------------------------------------------------------------------------------
  Random-effects Parameters  |   Estimate   Std. Err.     [95% Conf. Interval]
-----------------------------+------------------------------------------------
areatype2: Identity          |
                   sd(_cons) |   .3517085    .152401      .1504331    .8222846
------------------------------------------------------------------------------
```

```
LR test vs. logistic regression: chibar2(01) =    65.67 Prob>=chibar2 = 0.0000
```

Source: NZHTS trip file

As expected active commuting rises with income. The last line in the output indicates that allowing the constant to vary across settlements definitely improves the model. The degree of variation is considerable as shown by the estimated standard deviation in the constant and it comes with a relatively low standard error. The random effects themselves are plotting in the chapter.

Applying the same model to male case confirms firstly the significant quadratic nature of the commuting –income relationship. In addition it shows a slightly higher standard deviation of random effects across the three settlement types as well as the fact that allowing these to vary improves the fit of the model.

The impact of including random intercept effects for settlement on the way in which male active commuting rises with income. New Zealand, 2003-2007

```
Mixed-effects logistic regression               Number of obs      =      5637
Group variable: areatype2                       Number of groups   =         3

                                                Obs per group: min =       668
                                                               avg =    1879.0
                                                               max =      3505

Integration points =   7                        Wald chi2(2)       =     68.78
Log likelihood = -2331.3847                     Prob > chi2        =    0.0000

------------------------------------------------------------------------------
          AT | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  peincnumrcx |   .9693811   .0050067    -6.02   0.000     .9596177    .9792439
  peincumrcx2 |   1.000296   .0000411     7.21   0.000     1.000216    1.000377

       _cons |   .2398065   .0624371    -5.48   0.000     .1439588    .3994694
------------------------------------------------------------------------------

------------------------------------------------------------------------------
  Random-effects Parameters  |   Estimate   Std. Err.     [95% Conf. Interval]
-----------------------------+------------------------------------------------
areatype2: Identity          |
                   sd(_cons) |   .3782138   .1650727      .1607784    .8897073
------------------------------------------------------------------------------
LR test vs. logistic regression: chibar2(01) =    58.52 Prob>=chibar2 = 0.0000
```

Source: NZHTS trip file

I also noted in the multivariate chapter that it was not simply population density that mattered when it came to understanding the variation in active commuting across the country, but that the commuters location also played a role. Therefore the following two tables check to see whether allowing for the 14 region random effects also improves the model. What is interesting is the fact that the standard deviation across the 14 regions is actually greater than encountered in the 3 settlement types, 41.5, and the standard error is smaller, 0.086.

The impact of including random intercept effects for region on the way in which female active commuting rises with income. New Zealand, 2003-2008

```
Mixed-effects logistic regression               Number of obs      =      4621
Group variable: region_NS                       Number of groups   =        14

                                                Obs per group: min =       112
                                                               avg =     330.1
                                                               max =       786

Integration points =   7                        Wald chi2(1)       =     11.71
Log likelihood = -2328.8893                     Prob > chi2        =    0.0006

------------------------------------------------------------------------------
          AT | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 peincnumrcx |   1.005755   .0016864     3.42   0.001     1.002455    1.009066

       _cons |    .180412   .0243288   -12.70   0.000     .1385096     .234991
------------------------------------------------------------------------------

------------------------------------------------------------------------------
  Random-effects Parameters  |   Estimate   Std. Err.     [95% Conf. Interval]
-----------------------------+------------------------------------------------
region_NS: Identity          |
                   sd(_cons) |   .4149256   .0864706      .2757908    .6242532
------------------------------------------------------------------------------
LR test vs. logistic regression: chibar2(01) =   177.89 Prob>=chibar2 = 0.0000

Source:  NZHTS trip file
```

A similar result holds for the male case as well but once again, spatial variation in the male case is even greater, at 0.496.

The impact of including random intercept effects for region on the way in which male active commuting rises with income. New Zealand, 2003-2008

```
Mixed-effects logistic regression               Number of obs      =      5637
Group variable: region_NS                       Number of groups   =        14

                                                Obs per group: min =       118
                                                               avg =     402.6
                                                               max =       903

Integration points =   7                        Wald chi2(2)       =     58.04
Log likelihood = -2257.4199                     Prob > chi2        =    0.0000

------------------------------------------------------------------------------
          AT | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 peincnumrcx |   .9682453   .0050889    -6.14   0.000     .9583223    .9782709
 peincumrcx2 |   1.000297    .000042     7.06   0.000     1.000214    1.000379

       _cons |   .2596853   .0502786    -6.96   0.000     .1776819    .3795347
------------------------------------------------------------------------------

------------------------------------------------------------------------------
```

Random-effects Parameters	Estimate	Std. Err.	[95% Conf. Interval]	
region_NS: Identity				
sd(_cons)	.4962322	.1055642	.3270451	.7529433

LR test vs. logistic regression: chibar2(01) = 206.45 Prob>=chibar2 = 0.0000

Source: NZHTS trip file

Mixed-effects models can include more than one nested level. Not only is commuting nested within local labour markets of different density and size (as reflected in settlement type), but these settlements are also nested within the 14 regions of New Zealand. The question I want to ask here therefore is whether there exist random effects not only at the level of the settlement but also at the level of the region in which they are situated. The result is a hierarchical model in which both male and female have been included.

The impact of nesting settlement type within regions on the random intercept effects of active commuting (male and female) given income. New Zealand, 2003-2007

Mixed-effects logistic regression Number of obs = 10258

Group Variable	No. of Groups	Observations per Group Minimum	Average	Maximum	Integration Points
region_NS	14	230	732.7	1618	7
areatype2	38	29	269.9	1461	7

Wald chi2(1) = 1.06
Log likelihood = -4556.3759 Prob > chi2 = 0.3036

AT	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
peincnumrcx	.0010498	.0010204	1.03	0.304	-.0009503	.0030498
_cons	-2.015838	.1242617	-16.22	0.000	-2.259387	-1.77229

Random-effects Parameters	Estimate	Std. Err.	[95% Conf. Interval]	
region_NS: Identity				
sd(_cons)	.000052	.1127734	0	.
areatype2: Identity				
sd(_cons)	.6528924	.094257	.4919886	.8664193

LR test vs. logistic regression: chi2(2) = 610.12 Prob > chi2 = 0.0000

References

Abley, S., Chou, M.1, Douglass, M.2 (2008). National travel profiling part A: description of daily travel patterns. *NZ Transport Agency Research Report 353* (p. 150 pp.): NZ Transport Agency.

Abley Transportation Engineers. (2008). Walkability Research Tools-Summary Report *NZ Transport Agency Research Reports* (Vol. 356).

Adams, J. (2010). Prevalence and socio-demographic correlates of "active transport" in the UK: Analysis of the UK time use survey 2005. *Preventive Medicine, 50*(4), 199-203. doi: 10.1016/j.ypmed.2010.01.006

Antipova, A., Wang, F., Wilmot, C. . (2011). Urban land uses, socio-demographic attributes and commuting: a multilevel modeling approach. . *Applied Geography 31*, 1010-1018. doi: 10.1016/j.apgeog.2011.02.001

Auckland Regional Council. (2010). Auckland Regional Land Transport Strategy 2010-2040. Auckland.

Axhausen, K. W. (2000). Definition of movement and activity for transport modelling. . In D. A. Hensher, K. Button. (Ed.), *Handbooks in Transport: Transport Modelling*. Oxford: Elsevier.

Bassett, J., David, R., Pucher, John., Buehler, Ralph.,, & Thompson, D. L., Crouter, Scott. E. (2008). Walking, Cycling, and Obesity Rates in Europe, North America, and Australia. *Journal of Physical Activity and Health, 5*, 795-814.

Baxter, R. T., Rees, R. (1972). *The Penguin Dictionary of Economics*. Hammondsworth: Penguin Books.

Berl Economics. (2010). The economic benefits of early UFB roll-out in Wellington (pp. 1-38). Wellington: Grow Wellington and Greater Wellington Regional Council.

Bianco, M., Lawson, C (1998). Trip-chaining, childcare, and personal safety – critical issues in women's travel behaviour. In Proceedings: Second National Conference on Women's Travel Issues October 1996 *Report FHWA-PL-97-024* (pp. 123-143): US Department of Transportation.

Bickel, R. (2007). *Multilevel Analysis for Applied Research: It's Just Regression!* . New York: The Guilford Press.

Boone-Heinonen, J., Gordon-Larsen, P., Guilkey, D. K., Jacobs Jr, D. R., & Popkin, B. M. (2011). Environment and physical activity dynamics: The role of residential self-selection. *Psychology of Sport and Exercise, 12*(1), 54-60. doi: 10.1016/j.psychsport.2009.09.003

Bowman, J. L., & Ben-Akiva, M. E. (2001). Activity-based disaggregate travel demand model system with activity schedules. *Transportation Research Part A: Policy and Practice, 35*(1), 1-28. doi: 10.1016/s0965-8564(99)00043-9

Brandenburg, C., Matzarakis, A., & Arnberger, A. (2007). Weather and cycling--a first approach to the effects of weather conditions on cycling. *Meteorological Applications, 14*, 61-67.

Brockman, R., & Fox, K. R. (2011). Physical activity by stealth? The potential health benefits of a workplace transport plan. *Public Health, 125*(4), 210-216. doi: 10.1016/j.puhe.2011.01.005

Bronfenbrenner, U. (1989). Ecological system theory. . *Annals of Child Development 6*, 187-249.

Bronfenbrenner, U. a. C., S. J. (1994). Nature-nurture reconceptualized in developmental perspective: A bioecological model. *Psychological Review* (101), 568-586.

Buehler, R. (2010). Transport policies, automobile use, and sustainable transport: A comparison of Germany and the United States. [peer-reviewed]. *Journal of Planning Education and Research, 30*(1), 76-93.
Buehler, R. (2011). Determinants of transport mode choice: a comparison of Germany and the USA. *Journal of Transport Geography, 19*(4), 644-657. doi: 10.1016/j.jtrangeo.2010.07.005
Buehler, R., Pucher, J., Merom, D., & Bauman, A. (2011). Active Travel in Germany and the U.S.: Contributions of Daily Walking and Cycling to Physical Activity. *American Journal of Preventive Medicine, 41*(3), 241-250. doi: 10.1016/j.amepre.2011.04.012
Cavill, N., Kahlmeier, S., Racioppi, F (2006). Physical Activity and Health in Europe: Evidence for action: World Health Organisation.
Cerin, E., Leslie, E., & Owen, N. (2009). Explaining socio-economic status differences in walking for transport: An ecological analysis of individual, social and environmental factors. *Social Science & Medicine, 68*(6), 1013-1020. doi: 10.1016/j.socscimed.2009.01.008
Cheyne, C. (2012). *Mainstreaming model walking and cycling communities*. Paper presented at the 2 Walk and Cycle Conference, Hastings, New Zealand.
Cirillo, C., Axhausen, K W (2002). Mode choice in complex tours: A panel analysis. In A. V.-u. Raumplanung (Ed.). Zürich: Institut für Verkehrsplanung und Transportsysteme (IVT).
Cole, R., Burke, M., Leslie, E., Donald, M., & Owen, N. (2010). Perceptions of representatives of public, private, and community sector institutions of the barriers and enablers for physically active transport. *Transport Policy, 17*(6), 496-504. doi: 10.1016/j.tranpol.2010.05.003
Conder, T. (2009). Development and application of New Zealand car ownership and traffic. *NZ Transport Agency research report 394* (pp. 1-166): Booz and co (New Zealand) Ltd.
Creswell, J. W., Plano Clark, Vicki L. (2007). *Designing and Conducting Mixed Methods Research*. Thousand Oaks, California: Sage Publications.
Dargay, J., & Hanly, M. (2007). Volatility of car ownership, commuting mode and time in the UK. *Transportation Research Part A: Policy and Practice, 41*(10), 934-948. doi: 10.1016/j.tra.2007.05.003
Dargay, J. M. (2001). The effect of income on car ownership: evidence of asymmetry. *Transportation Research Part A: Policy and Practice, 35*(9), 807-821. doi: 10.1016/s0965-8564(00)00018-5
de Bruijn, G.-J., Kremers, S. P. J., Singh, A., van den Putte, B., & van Mechelen, W. (2009). Adult Active Transportation: Adding Habit Strength to the Theory of Planned Behavior. *American Journal of Preventive Medicine, 36*(3), 189-194. doi: 10.1016/j.amepre.2008.10.019
Department of Economic and Social Affairs Population Division, U. N. (2004). World Urbanization Prospects: The 2003 Revision. New York: United Nations.
Department of Internal Affairs. (2008). *Building Sustainable Urban Communities*. Wellington: New Zealand Department of Internal Affairs Retrieved from http://www.dia.govt.nz/diawebsite.nsf/wpg_URL/Resource-material-Building-Sustainable-Urban-Communities-Index?OpenDocument.
Diana, M. (2010). From mode choice to modal diversion: A new behavioural paradigm and an application to the study of the demand for innovative transport services. *Technological Forecasting and Social Change, 77*(3), 429-441. doi: 10.1016/j.techfore.2009.10.005

Dunlap, R. E., & Mertig, A. G. (1995). Global concern for the environment: Is affluence a prerequisite? *Journal of Social Issues, 51*, 121–137.
Duroy, Q. M. H. (2008). Testing the Affluence Hypothesis: A cross-cultural analysis of the determinants of environmental action. *The Social Science Journal, 45*, 419-439.
Eriksson, L., & Forward, S. E. (2011). Is the intention to travel in a pro-environmental manner and the intention to use the car determined by different factors? *Transportation Research Part D: Transport and Environment, 16*(5), 372-376. doi: 10.1016/j.trd.2011.02.003
Escobar, A. (2006). An ecology of difference: Equality and conflict in a globalized world. *Focaal–European Journal of Anthropology*, 120–137.
Garrard, J. (2009). Active Transport: Adults. An overview of recent evidence. Melbourne: Vichealth.
Geller, R. (2012). *How and Why American Cities are Succeeding at Bicycle Transportation*. Paper presented at the 2 Walk and Cycle Conference, Hastings, New Zealand.
Genter, J., S Donovan, B Petrenas and H Badland (2008). Valuing the health benefits of active transport modes. *NZ Transport Agency research report no.359.*: NZ Transport Agency.
Giles-Corti, B., Foster, S., Shilton, T., Falconer, R. (2010). The co-benefits for health of investing in active transportation. *NSW Public Health Bulletin 21*(5-6), 122-127.
Goodman, R., Tolley, R. (2003). The decline of everyday walking in the UK: explanations and policy implications. In R. Tolley (Ed.), *Sustainable Transport: Planning for walking and cycling in urban environments.* Cambridge, UK.: Woodhead Pty Ltd.
Greenland, S. (1999). Causal diagrams for epidemiological research. *Epidemiology, 10*(1), 37-48.
Hall, S. (2010). *The Declining Work Week*. Paper presented at the Fourteenth Conference on Labour, Employment and Work, Victoria University of Wellington. http://www.victoria.ac.nz/vms/researchcentres/LEW_Papers/I8_Hall_S_LEW14_Final.pdf
Hamilton, L. C. (2009). *Statistics with Stata. Updated for Version 10*, Toronto: Thomson/Brooks/Cole.
Hardin, G. (1968). The Tragedy of the Commons. *Science, 162*(3859), 1243-1248.
Hastings District Council. (2007). Flaxmere Town Centre Urban Design Framework.
Haworth, J. T., Veal, A.J. (2004). *Work and Leisure*. London: Routledge.
Hensher, D. A. (2008). Empirical approaches to combining revealed and stated preference data: Some recent developments with reference to urban mode choice. *Research in Transportation Economics, 23*(1), 23-29. doi: 10.1016/j.retrec.2008.10.003
Hill, J., Grzywacz, JG, Allen, S., Blanchard, VL, Matz-Costa, C., Shulkin, S., et al. . (2008). Defining and conceptualizing workplace flexibility. *Community, Work & Family, 11*(2), 149–163.
Hoehner, C. M., Soares, J., Parra Perez, D., Ribeiro, I. C., Joshu, C. E., Pratt, M., . . . Brownson, R. C. (2008). Physical Activity Interventions in Latin America: A Systematic Review. *American Journal of Preventive Medicine, 34*(3), 224-233.e224. doi: 10.1016/j.amepre.2007.11.016
Hulme-Moir, A. (2010). *Making Way for the Car: Minimum Parking Requirements and Porirua City Centre.* Master of Environmental Studies Masters Thesis Victoria University of Wellington, Wellington. Retrieved from http://researcharchive.vuw.ac.nz/handle/10063/1458
Illich, I. (1974). *Energy and Equity*. London: Calder & Boyars.
Inglehart, R. (1990). *Culture shift in advanced industrial society.* Princeton, NJ: Princeton University Press.

Inglehart, R. (1997). *Modernization and postmodernization: Culture, economic, and political change in 43 societies.* . Princeton, NJ: Princeton University Press.
Jacobson, S. H., King, D. M., & Yuan, R. (2011). A note on the relationship between obesity and driving. *Transport Policy, 18*(5), 772-776. doi: 10.1016/j.tranpol.2011.03.008
Jeffrey Hill, E., Grzywacz, J. G., Allen, S., Blanchard, V. L., Matz-Costa, C., Shulkin, S., & Pitt-Catsouphes, M. (2008). Defining and conceptualizing workplace flexibility. [Article]. *Community, Work & Family, 11*(2), 149-163. doi: 10.1080/13668800802024678
Keall, M., Chapman, R., & Howden-Chapman, P. (2009). Changes in New Zealand transport mode choices over time by size of city. *WIT Transactions on The Built Environment,, 107*.
Klˆckner, C. A., & Friedrichsmeier, T. (2011). A multi-level approach to travel mode choice - How person characteristics and situation specific aspects determine car use in a student sample. *Transportation Research Part F: Traffic Psychology and Behaviour, 14*(4), 261-277. doi: 10.1016/j.trf.2011.01.006
Klˆckner, C. A., & Matthies, E. (2004). How habits interfere with norm-directed behaviour: A normative decision-making model for travel mode choice. *Journal of Environmental Psychology, 24*(3), 319-327. doi: 10.1016/j.jenvp.2004.08.004
Krizek, K. (2003). Neighborhood services, trip purpose and tour-based travel. *Transportation, 30*, 387-410.
Law, R. (2011). *The determinants of home-to-work active transport in Wellington*. Geography Department. Victoria University of Wellington.
Lee, I. M., Ewing, R., & Sesso, H. D. (2009). The Built Environment and Physical Activity Levels: The Harvard Alumni Health Study. *American Journal of Preventive Medicine, 37*(4), 293-298. doi: 10.1016/j.amepre.2009.06.007
Leyden, K. (2003). Social capital and the built environment: the importance of walkable neighborhoods. *Am J Public Health, 93*(9), 1546–1551.
Li, F., Fisher KJ., Bauman A, et al. (2005). Neighborhood influences on physical activity in older adults: a multilevel perspective. *Journal of Aging and Physical Activity, 13*(32).
Limtanakool, N., Dijst, M., & Schwanen, T. (2006). The influence of socioeconomic characteristics, land use and travel time considerations on mode choice for medium- and longer-distance trips. *Journal of Transport Geography, 14*(5), 327-341. doi: 10.1016/j.jtrangeo.2005.06.004
Lindsay, G., Macmillan, A., & Woodward, A. (2010). Moving urban trips from cars to bicycles: impact on health and emissions *Australian and New Zealand Journal of Public Health, 35*(1), 54-60.
Litman, T. (2004). Quantifying the benefits of nonmotorized transportation for achieving mobility management objectives. Victoria, BC, Canada: Victoria Transport Policy Institute.
Macpherson, D. (2012). *Shared Space & Cycling - Report on 2011 Study Tour to UK & Netherlands*. Paper presented at the 2 Walk and Cycle Conference, Hastings, New Zealand.
Martinez-Alier, J. (1995). The environment as a luxury good or 'too poor to be green? *Economie Appliquée, 48*, 215–230.
Maslow, A. (1954). *Motivation and Personality.* New York: Harper.
McGuckin, N., Murakami, E. (1999). Examining trip-chaining behaviour: comparison of travel by men and women. *Transportation Research Record, 1693*, 79-85.
McKenzie-Mohr, D., Smith, W. (1999). Fostering Sustainable Behavior: An Introduction to Community-Based Social Marketing. Canada: New Society Publishers.
Merom, D., Miller, Y. D., van der Ploeg, H. P., & Bauman, A. (2008). Predictors of initiating and maintaining active commuting to work using transport and public health

perspectives in Australia. *Preventive Medicine, 47*(3), 342-346. doi: 10.1016/j.ypmed.2008.03.014

Merom, D., van der Ploeg, H. P., Corpuz, G., & Bauman, A. E. (2010). Public Health Perspectives on Household Travel Surveys: Active Travel Between 1997 and 2007. *American Journal of Preventive Medicine, 39*(2), 113-121. doi: 10.1016/j.amepre.2010.04.007

Meyer, R., Liebe, U. (2010). Are the affluent prepared to pay for the planet? Explaining willingness to pay for public and quasi-private environmental goods in Switzerland. *Population and Environment, 32*(1), 42-65.

Milne, A., Rendall , S., Abley, S. (2011). National travel profiles part B: trips, trends and travel prediction *NZ Transport Agency research report 467* (p. 94 pp.).

Ming Wen, L., & Rissel, C. (2008). Inverse associations between cycling to work, public transport, and overweight and obesity: Findings from a population based study in Australia. *Preventive Medicine, 46*(1), 29-32. doi: 10.1016/j.ypmed.2007.08.009

Ministry of Health. (2003). Nutrition and the Burden of Disease. New Zealand 1997-2001. Wellington: Ministry of Health.

Ministry of Transport. (2009a). How New Zealanders Travel: Trends in New Zealand Household Travel 1989-2008. Wellington: Ministry of Transport.

Ministry of Transport. (2009b). *Ongoing Travel Survey Variables*. Wellington.

Ministry of Transport. (2010). Travel Survey - Information for Researchers. Retrieved 14 June 2011

Miralles-Guasch, C., & Domene, E. (2010). Sustainable transport challenges in a suburban university: The case of the Autonomous University of Barcelona. *Transport Policy, 17*(6), 454-463. doi: 10.1016/j.tranpol.2010.04.012

Mokhtarian, P. L., & Cao, X. (2008). Examining the impacts of residential self-selection on travel behavior: A focus on methodologies. *Transportation Research Part B: Methodological, 42*(3), 204-228. doi: 10.1016/j.trb.2007.07.006 http://www.abp.unimelb.edu.au/gamut/pdf/mees-moriarty.pdf

Morrison, P. S. (2011). The creative city and its distributional consequences: the case of Wellington. In D. Andersson, Mellander, C., Andersson, A (Ed.), *Handbook of Creative Cities* (pp. 482-497). Camberley, UK: Edward Elgar Publishing.

Nagel, C. L., Carlson, N.E., Bosworth, M., Michael, Y.L. (2008). The Relation between Neighborhood Built Environment and Walking Activity among Older Adults . *American Journal of Epidemiology, 168*(4), 461-468.

National Party of New Zealand. (2011). Economic Development Action Plan. Retrieved March 24th 2012, from http://www.national.org.nz/PDF_General/Economic_Development_Action_Plan.pdf

Nelson City Council. (2009). Nelson City Council Regional Land Transport Strategy (pp. 1-108).

New Zealand Press Association. (10 March 2010). Petrol spike prompts call for more public transport spending, *The New Zealand Herald*.

New Zealand Transport Agency. (2010). Model Communities. Retrieved February 29, 2012, from http://www.nzta.govt.nz/planning/process/model-communities.html

New Zealand-NZ.net. (2011). New Zealand Geography. Retrieved 30 January 2012, from http://www.new-zealand-nz.net/geography.html

O'Fallon, C., Sullivan, C., & Hensher, D. A. (2004). Constraints affecting mode choices by morning car commuters. *Transport Policy, 11*(1), 17-29. doi: 10.1016/s0967-070x(03)00015-5

O'Fallon, C., and Sullivan, C. (2009). Trends in older people's travel patterns: Analysing changes in older New Zealanders' travel patterns using the Ongoing New Zealand

Household Travel Survey. *NZ Transport Agency Research Report 369.* (p. 50 pp.). Wellington: NZ Transport Agency.
O'Fallon, C., and Sullivan, C. (2009). Trends in trip chaining and tours: analysing changes in New Zealanders' travel patterns using the Ongoing New Zealand Household Travel Survey. *NZ Transport Agency Research Report 373.* (p. 60 pp.). Wellington: NZ Transport Agency.
O'Fallon, C., and Sullivan, C. . (2003). *Older people's travel patterns and transport sustainability in New Zealand cities.* . Paper presented at the Australasian Transportation Research Forum, Wellington, New Zealand. www.patrec.org/atrf/index.php
O'Fallon, C., Sullivan, C (2005). Trip chaining: understanding how New Zealanders link their travel. *Research Report No. 268.* (pp. 1-70): Transfund New Zealand
Ogilvie, D., Egan, M., Hamilton, V., Petticrew , M. (2004). Promoting Walking And Cycling As An Alternative To Using Cars: Systematic Review. *British Medical Journal, 329*(7469), 763-766.
P·ez, A., & Whalen, K. (2010). Enjoyment of commute: A comparison of different transportation modes. *Transportation Research Part A: Policy and Practice, 44*(7), 537-549. doi: 10.1016/j.tra.2010.04.003
Parks, K., Steelman, LA. (2008). Organizational wellness programs: A meta-analysis. *Journal of Occupational Health Psychology, 13*(1), 58-68.
Peterson, D. (2000). *Petrol prices and taxes*. Wellington: New Zealand Parliamentary Library Retrieved from http://www.parliament.nz/NR/rdonlyres/E3FF7098-DBEF-4ECA-9E26-AB2AA13C39AC/448/0015Petrol3.pdf.
Pronk, N., Martinson, B., Kessler, R., Beck, A., Simon, G., and Wang, P. (2004). The association between work performance and physical activity, cardiorespiratory fitness, and obesity. *Journal of Occupational and Environmental Medicine, 46*, 19–25.
Pucher, J., Dill, J., & Handy, S. (2010). Infrastructure, programs, and policies to increase bicycling: An international review. *Preventive Medicine, 50*(Supplement 1), S106-S125. doi: 10.1016/j.ypmed.2009.07.028
Pucher, J., Garrard, J., & Greaves, S. (2011). Cycling down under: a comparative analysis of bicycling trends and policies in Sydney and Melbourne. *Journal of Transport Geography, 19*(2), 332-345. doi: 10.1016/j.jtrangeo.2010.02.007
RodrÌguez, D. A., Brisson, E. M., & EstupiÒ·n, N. s. (2009). The relationship between segment-level built environment attributes and pedestrian activity around Bogota's BRT stations. *Transportation Research Part D: Transport and Environment, 14*(7), 470-478. doi: 10.1016/j.trd.2009.06.001
RodrÌguez, D. A., & Joo, J. (2004). The relationship between non-motorized mode choice and the local physical environment. *Transportation Research Part D: Transport and Environment, 9*(2), 151-173. doi: 10.1016/j.trd.2003.11.001
Rutherford, G. S., McCormack, E., Wilkinson, M (1997). *Travel Impacts of Urban Form: Implications from an analysis of Seattle area travel diaries. Summary, Recommendations and Compendium of papers.* Paper presented at the Urban Design, Telecommuting and Travel Forecasting Conference
Rye, T., & Ison, S. (2005). Overcoming barriers to the implementation of car parking charges at UK workplaces. *Transport Policy, 12*(1), 57-64. doi: 10.1016/j.tranpol.2004.11.002
Saelens, B. E., Sallis, J. F., & Frank, L. D. (2003). Environmental Correlates of Walking and Cycling: Findings From the Transportation, Urban Design, and Planning Literatures. [Article]. *Annals of Behavioral Medicine, 25*(2), 80.

Sallis, J. F., Bauman, A., & Pratt, M. (1998). Environmental and policy interventions to promote physical activity. *American Journal of Preventive Medicine, 15*(4), 379-397. doi: 10.1016/s0749-3797(98)00076-2
Scheiner, J. (2010). Interrelations between travel mode choice and trip distance: trends in Germany 1976-2002. *Journal of Transport Geography, 18*(1), 75-84. doi: 10.1016/j.jtrangeo.2009.01.001
Schor, J. (1991). *The Overworked American: The Unexpected Decline of Leisure*. New York: Basic books.
Schwanen, T., Dijst, M (2001). *Time windows in workers' activity patterns: empirical evidence from the Netherlands*. Paper presented at the NECTAR Conference, Espoo, Finland.
Schwanen, T., & Mokhtarian, P. L. (2005). What affects commute mode choice: neighborhood physical structure or preferences toward neighborhoods? *Journal of Transport Geography, 13*(1), 83-99. doi: 10.1016/j.jtrangeo.2004.11.001
Scott, D. (2010). Social and economic indicators of education: Tertiary Sector Performance Analysis and Reporting, Ministry of Education.
Sevick, M., Dunn, AL,. Morrow, MS,. Marcus,. BH, Chen, GJ,. Blair, SN. (2000). Cost-effectiveness of lifestyle and structured exercise interventions in sedentary adults: Results of project ACTIVE. *American Journal of Preventive Medicine, 19*(1), 1-8.
Shannon, T., Giles-Corti, B., Pikora, T., Bulsara, M., Shilton, T., & Bull, F. (2006). Active commuting in a university setting: Assessing commuting habits and potential for modal change. *Transport Policy, 13*(3), 240-253. doi: 10.1016/j.tranpol.2005.11.002
Shiftan, Y., Suhrbier, J (2002). The analysis of travel and emissions impacts of travel demand management strategies using activity-based models. *Transportation, 29*, 145-168.
Shiva, V., & Jafri, A. (1998). Stronger than steel: Indian people's movement against the Gopalpur steel plant. *Ecologist, 26*, 349–353.
Solnit, R. (2001). *Wanderlust: a history of walking*. New York: Penguin Books.
Southworth, M. (2005). Designing the Walkable City. *Journal of Urban Planning and Development, 131*(4), 246-257.
SPARC. (2003). SPARC Facts: Results of the New Zealand Sport and Physical Activity Surveys 1997-2001. Wellington: Sport and Recreation New Zealand.
Statisitcs New Zealand. (2007). Workforces on the move: Commuting patterns in New Zealand (pp. 1-13).
Statistics New Zealand. (2008). Survey of Working Life. Retrieved 1 April 2011, from http://www.statistics.govt.nz/browse_for_stats/income-and-work/employment_and_unemployment/survey-of-working-life.aspx
Statistics New Zealand. (2011a). Bigger, safer, better: tracking retail and quality adjusted new car prices in the CPI. Wellington: Statisitcs New Zealand.
Statistics New Zealand. (2011b). Demographic trends 2010: Subnational population estimates. Retrieved 30 January 2012, from http://www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/demographic-trends-2010/chapter6.aspx
Statistics New Zealand. (2012). Table Builder: Income by age, sex and labour force status. Retrieved March 30, 2012, from http://wdmzpub01.stats.govt.nz/wds/TableViewer/tableView.aspx?ReportName=Incomes/Income%20by%20age,%20sex%20and%20labour%20force%20status

Steinbach, R., Green, J., Datta, J., & Edwards, P. (2011). Cycling and the city: A case study of how gendered, ethnic and class identities can shape healthy transport choices. *Social Science & Medicine, 72*(7), 1123-1130. doi: 10.1016/j.socscimed.2011.01.033

Sullivan C, & O'Fallon, C. (2010). Walking and cycling: Improving combined use of physical activity/health and transport data *NZ Transport Agency research report no.435* (p. 74): New Zealand Transport Agency.

Sullivan C, & O'Fallon, C. (2010). Walking and cycling: Improving combined use of physical activity/health and transport data. *NZ Transport Agency research report no.435.* (p. 74pp.). Wellington: NZ Transport Agency.

Sustainable Transport Team, G. W. R. C. (2011). Active a2b Final Report for 2011. Wellington: Greater Wellington Regional Council.

Tashakkori, A., Teddlie, C. (Eds.). (2003). *Handbook of mixed methods in social and behavioral research*. Thousand Oaks, California: Sage Publications.

Th¯gersen, J. (2006a). Norms for environmentally responsible behaviour: An extended taxonomy. *Journal of Environmental Psychology, 26*(4), 247-261. doi: 10.1016/j.jenvp.2006.09.004

Th¯gersen, J. (2006b). Understanding repetitive travel mode choices in a stable context: A panel study approach. *Transportation Research Part A: Policy and Practice, 40*(8), 621-638. doi: 10.1016/j.tra.2005.11.004

Tin Tin, S., Woodward, A., Thornley, S., & Ameratunga, S. (2009). Cycling and walking to work in New Zealand, 1991-2006: regional and individual differences, and pointers to effective interventions. . *International Journal of Behavioural Nutrition and Physical Activity, 6*(64).

Torgler, B., & GarcÌa-ValiÒas, M. A. (2007). The determinants of individuals' attitudes towards preventing environmental damage. *Ecological Economics, 63*(2-3), 536-552. doi: 10.1016/j.ecolecon.2006.12.013

U.S Bureau of Transportation Statistics. (2003). Freedom to Travel. . Washington, DC.: US Department of Transportation.

University of Otago. (2011). Dunedin Multidisciplinary Health and Development Research Unit. Retrieved August 8 2011, from http://dunedinstudy.otago.ac.nz/

van de Coevering, P., & Schwanen, T. (2006). Re-evaluating the impact of urban form on travel patternsin Europe and North-America. *Transport Policy, 13*(3), 229-239. doi: 10.1016/j.tranpol.2005.10.001

Verplanken, B., Walker, I., Davis, A., & Jurasek, M. (2008). Context change and travel mode choice: Combining the habit discontinuity and self-activation hypotheses. *Journal of Environmental Psychology, 28*(2), 121-127. doi: 10.1016/j.jenvp.2007.10.005

Wallace, B., Barnes, J and Rutherford, G S (2000). Evaluating the effects of traveller and trip characteristics on trip chaining, with implications for Transportation Demand Management Strategies. *Transportation Research Record 1718*, 97-106.

Wellington City Council. (2006). *Urban Development Strategy: Directing growth and delivering quality*. Wellington: Wellington City Council.

Woodcock, J., . Banister D,. Edwards P,. Prentice AM,. Roberts I. (2007). Energy and transport. *Lancet*(370), 1078–1088.

Woodward, A., Macmillan, Alex. (2012). *Good health, cycling and walking. Five myths*. Paper presented at the 2 Walk and Cycle Conference, Hastings, New Zealand.

World Health Organization. (2002). Physical activity through transport as part of daily activities. Copenhagen: WHO Regional Office for Europe.