Kilometres travelled and vehicle occupancy in urban areas: improving evaluation and monitoring

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Abbreviations and acronyms

ARTA: Auckland Regional Transport Authority

HTS: New Zealand Household Travel Survey

KT: kilometres travelled

MUA: main urban area

MoT: Ministry of Transport

NZDep: New Zealand Deprivation Index

NZTA: NZ Transport Agency

SNZ: Statistics New Zealand

SOV: single-occupant vehicle

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Executive summary

Context

This project lays some foundations for better evaluation and monitoring of interventions (eg travel plans) in cities. Estimating changes in distances related to interventions (rather than just mode shifts) has recently become a higher priority because of the effects of transport emissions on climate change.

The Ministry of Transport's Household Travel Survey (HTS) is the main data source. Analysis focuses on 'main urban areas' (MUAs); these are areas centred on a city or major urban centre with a population of 30,000 or more.

Distance to work in main urban areas

The HTS data shows the median distance travelled to work in MUAs during 2003–07 is 7.2km and the mean distance is 10.0km. Averages by mode (see table XS1) are useful for checking the plausibility of average distances in workplace travel plan surveys. Recent difficulties encountered when evaluating travel plans show such HTS comparison data could help prevent implausible average distances being used. The 99th percentiles in table XS1 can help determine which individual values from workplace travel plan surveys are so high as to justify special checks (or even outright exclusion from some analyses).

Table XS1 Distances (km) travelled to work by main mode (all MUAs, HTS 2003–07)

	All modes[a] ***N***[b] = 3567	**Driver** ***N*** = 2784	**Passenger** ***N*** = 329	**Bus** ***N*** = 167	**Walk** ***N*** = 174	**Cycle**[c] ***N*** = 110
Median	7.2	7.8	7.3	8.5	1.1	3.7
Mean	10.0	10.7	9.5	9.5	1.4	5.2
99th percentile (1% of distances greater than this)	50	51	47	26	3.8	NA

Notes to table XS1:

a 'All modes' includes three cases using 'Other' modes.

b Unweighted chains

c Warning: being based on only 110 chains, the estimates for 'Cycle' will have relatively large sampling errors.

Census results show more people living further from work in 2006 than in 1996:

- The median straight-line distance from home to work in all MUAs combined increased from 3.7km in 1996 to 4.0km in 2006. (The Census straight-line distances are inevitably shorter than HTS estimates of actual on-road distances travelled.)
- The upper quartile straight-line distances (ie for the 25% of workers that live the furthest from work) increased from 11.3 to 11.6km for Auckland, from 10.2 to 11.3km for Wellington and from 8.1 to 9.0km for Christchurch.

Such Census results suggest that average distance travelled to work may be increasing by roughly 1% a year. Evaluation of workplace travel plans in terms of change in kilometres travelled should take this increase into account.

Distance travelled to school in MUAs

According to HTS data, children of primary school age (5–10 years) in MUAs travel a median distance of 1.8km (that is, about half travel less than this distance and about half travel further). Those of secondary school age (13–17) travel a median distance of 2.6km (table XS2).

Table XS2 Distances (km) travelled to school (all MUAs, HTS 2003–07).

	All (5–17 years) ***N* =** 1378	**5–10 years** ***N* =** 729	**11–12 years** ***N* =** 214	**13–17 years** ***N* =** 435
Median	2.2	1.8	1.9	2.6
Trimmed mean*	3.2	2.8	3.2	3.9

*5% trimming (ie the largest 5% of values and the smallest 5% are removed before the mean is calculated to reduce the effect of outliers/extreme values)

Results about extreme values in distance travelled to school are useful to help judge the data quality with school travel plans, where the simpler data collection methods typically lead to implausibly long walk and cycle distances in a small percentage of cases. For schools, we suggest special treatment (eg extra checks or even exclusion from analysis) for values above those recorded by the highest 1% in the HTS: ie 21km for passengers (15km for primary schools), 5.1km for walking (2.9km for primary schools) and 7km for cycling.

Actual distance travelled to work/school compared with quickest route

Monitoring of workplace and school travel plans in New Zealand typically estimates distances by capturing home and work/school addresses, and then assuming that the quickest route between these addresses is taken. Some criticise this as unacceptably inaccurate because people often do not take the quickest route (eg people detour for shopping or to drop children at school as part of the journey to work).

The overall impact of approximating the distance travelled to work by assuming that the quickest route is taken seems likely to be fairly small on estimates of change over time: on average, the actual distance travelled is only **9% more** (10.2km compared with 9.3km). (Note: to prevent a small number of extreme values strongly affecting these means, we excluded trip chains of 100km or more in these analyses.)

Vehicle occupancy

Given our focus on MUAs, we restricted occupancy analyses to exclude trip legs 60km or more, because such long trip legs will often involve travel outside the urban area of interest. Mean occupancy (per kilometre driven) in MUAs (using the HTS 2003–08) was **1.54.** Mean occupancy differed little between any of the three major centres and other MUAs.

Clear differences in occupancy by trip purpose appeared. Work trips typically have low occupancy (the mean occupancy per kilometre driven was 1.15). Shopping and social trips have higher mean occupancies of 1.72 and 1.85, respectively. The large differences in occupancy for different trip purposes mean that changes observed in occupancy over time (eg by roadside cordon counts) may not reflect success or failure of policies aimed at increasing occupancy if the mix of purposes on the roads monitored has changed (eg because of new shopping, recreational or office/educational developments).

We attempted to broaden the usual measure of single-occupant vehicle travel to also reflect trips with a single passenger where the driver purpose was to 'accompany someone else'. But we could not find a tolerably simple and practical method for doing this using HTS data. We showed the impact to be small (a couple of percentage points).

Recommendations

- Those analysing travel plans in terms of average distance should use the HTS results in this report to check the plausibility of their results.
- Those analysing travel plans in terms of distance should use the 99th percentiles from the HTS in this report to help judge which individual distances in travel plan surveys are so high as to justify special checks (or even outright exclusion from some analyses).
- Evaluation of workplace travel plans in terms of kilometres travelled should note that average distances travelled to work may be increasing by roughly 1% a year.
- Continuing the current common practice in workplace travel plan surveys of approximating distances by assuming that the quickest direct route is taken seems acceptable; the actual average distance is only about 9% more and is thus likely to have tolerably small impact on estimates of change over time.
- Observed changes in occupancy should not automatically be assumed to reflect the impact of policies aimed at increasing occupancy. This is because the changes in occupancy may simply reflect a change in the mix of purposes of travel on the roads monitored (sharp differences in occupancy for different travel purposes are apparent, eg occupancy rates are low for work, but higher for shopping and social trips).
- We recommend against any further attempts to broaden the usual measure of single-occupant vehicle travel to also reflect trips with a single passenger where the driver purpose was to accompany someone else.

Abstract

This report lays some foundations for improving how interventions (eg travel plans) are evaluated and monitored in cities. The main data source used is the New Zealand Household Travel Survey (HTS). Some Census results on distances between home and work are a useful complement.

Distance travelled to work in main urban areas (ie urban areas with populations of 30,000 or more) is a major focus because these are the settings for the vast majority of travel plans. Because travel plan monitoring surveys typically estimate distances by assuming that workers take the quickest route from home to work, we checked on the extent to which actual routes taken are longer than the quickest route.

The report also analyses distances travelled to school in main urban areas. In particular, it provides HTS results that help to judge when distances collected by school travel plan surveys are implausibly long.

Vehicle occupancy is the report's final topic. Mean occupancy (per kilometre driven) in main urban areas was 1.54 and has not changed detectably since the 1997/98 HTS.

1. Introduction and objectives

1.1 Introduction

This project lays some foundations for better evaluation and monitoring of interventions in urban areas, such as travel plans, other travel behaviour change interventions, including some 'hard' measures such as high occupancy vehicle lanes. Commuter distances are also seen as an indicator of urban form.

Recently problems have become apparent both in New Zealand and the UK with evaluating the impact of travel plans and other travel behaviour change methods[1]. In particular, better understanding of kilometres travelled (KT) can make a substantial difference to policy decisions. For example, in the UK, a recent Department for Transport report on carbon reduction made a major change to assumptions about the effect of the *Smarter choices* promotion (ie use of travel behaviour change methods). The original *Smarter choices* report (Cairns et al 2004) assumed that an 11% reduction in car trips would result in an 11% reduction in vehicle-kilometres for cars. In contrast, the more recent report (Department for Transport (UK) 2009) concluded that the reduction in car-kilometres would be only about half of the reduction in car trips (eg a 3.7% reduction in car-kilometres would result from a 7% reduction in trips). This was because the National Transport Model predicted that most of the substitution in car journeys would be for those of shorter than average distance (which seems logical, given the greater attractiveness of substitutes such as walking, cycling and public transport for shorter trips).

For evaluation of travel plans in New Zealand, apart from the fundamental issue of getting sound estimates of mode shifts that are attributable to travel plans, problems include the following:

- Insufficient understanding of kilometres travelled (KT) and the statistical options for analysing KT data collected in travel plan surveys limits our ability to estimate the impacts (eg carbon dioxide reduction) of shifts measured in mode use (eg car v bus). Note that some travel behaviour change interventions are targeted at modes that typically replace long journeys (eg ride-share programmes) and some typically change mode for much shorter journeys (eg walking school buses). Therefore, approximating the effect of emissions from general average distances can be very inaccurate as an indicator of impact of interventions.
- We lack appropriate comparison data against which to assess changes measured at schools or workplaces: for example, a decrease in car use observed at workplaces might merely be reflecting general factors such as sharp fuel price increases rather than an effect of travel plans. Hence, to know whether a reduction of 5% in car driving reflects the effect of a travel plan rather than just an overall national or regional trend, we need clearer data on trends in KT that are specifically relevant to workplace and school travel plans.

In addition, reducing single-occupant car use (ie solo driver trips) remains a key focus for many travel plans and other interventions, but a detailed analysis of occupancy remains rare. Our earlier research using the 1997/98 New Zealand Household Travel Survey (HTS) data suggested that some misinterpretations of occupancy are likely.

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1 See, for example, Integrated Travel Planning (2007). Further critical examination of the UK situation is provided by Bonsall (2007 and 2008). New Zealand work specifically on travel plans includes Sullivan (2008).

1.2 Objectives

1.2.1 Kilometres travelled

The project delivers detailed analysis of urban workplace and school travel in terms of KT (as opposed to the more common focus on mode share) from the HTS. It focuses on the characteristics of trips of particular relevance to travel planners in monitoring/evaluating travel plans, such as:

- average distance driven to work/school, travelled by public transport to work/school and cycled to work/school: this includes updated values for average trip length for various modes for work and school travel in the format of those in Land Transport New Zealand's 2004 *Travel behaviour change evaluation procedures technical report* (Maunsell Australia, Pinnacle Research and Booz Allen Hamilton 2004)
- comparisons of kilometres travelled to work/school by
  - main urban area (eg is Auckland distinctly different than other main urban areas (MUAs) for some major modes?)
  - income group and other major demographics
  - distribution of distances of policy interest (eg trip lengths most amenable to changing modes, such as trip chains by car less than 2km or 5km)
  - parking type
- distribution of extreme values such as cycling more than 20km to work/school: we use this analysis to establish guidelines for processing travel plan survey data regarding detecting and removing outliers or possible geocoding errors (in combination with travel plan data direct from regional councils where available)
- comparison of actual distance travelled to work/school with the direct distance between the addresses: this has become highly relevant because the most common way for collecting a distance indicator with workplace and school travel plan surveys in New Zealand now is by collecting home and work/school addresses then estimating the quickest route between them after geocoding. Some criticise this as unacceptably inaccurate because people do not always take the shortest route. Hence, it seems useful to quantify the size of the problem and to suggest appropriate adjustment factors if these seem necessary.

1.2.2 Vehicle occupancy

Several targets in recent use have been expressed in terms of reducing single occupant vehicle (SOV) use, for example, the *New Zealand transport strategy* (Ministry of Transport (MoT) 2008) states that one goal is to:

> *Reduce the kilometres travelled by single occupancy vehicles, in major urban areas on weekdays, by ten per cent per capita by 2015 compared to 2007.*

The project delivers an up-to-date analysis of vehicle occupancy for comparison with our occupancy analysis of the 1997/98 HTS. Characteristics analysed include how vehicle occupancy varies by day of week, time of day, purpose of trip, vehicles per adult in the household and MUA.

We do not analyse the number of household and non-household passengers carried, nor the age and sex of passengers. Both these analyses have already been done and are available on the MoT website (MoT 2007).

2. Main data sources

2.1 The HTS dataset

The main dataset used is the New Zealand Household Travel Survey (HTS) supplied by the MoT. When no other source is given, the HTS is the data source for results.

The HTS was established as a continuous survey in 2003. With the continuous survey, people in over 2000 households in 280 meshblocks[2] throughout New Zealand were sampled each year (the sample size increased to 4500 households per year from June 2008). Every member normally resident in a participating household is then visited and interviewed about all of their travel for two consecutive days specified by the interviewer. Day 1 begins at 4:00am and Day 2 ends at 3:59am[3].

To be consistent with current MoT reporting conventions (eg MoT 2009), the HTS 2003–2007 refers to the four years of data collected between July 2003 and June 2007. (This convention differs from that used in our earlier analyses of this data such as O'Fallon and Sullivan 2009.)

2.1.1 HTS key definitions

2.1.1.1 Trip leg

A trip leg (or segment) is a row in the trips database of the HTS. For example, if you drive from home to work but stop for 30 seconds to drop off a passenger, that travel is counted as two trip legs (but as one 'trip chain' in our reformulation of the datasets).

2.1.1.2 Trip chain

Our definition of a trip chain is generally anchored at home or at work (ie when an individual departs from home or departs from work, this begins a new chain).

A new trip chain starts when a person leaves from home or work, or from a location where they remained for 90 minutes or longer. Similarly, the current trip chain ends when the person arrives at work or at home, or when they stay at one location for 90 minutes or longer.

We modified the database of trip chains very slightly from that used for our recent analysis of trip chains (O'Fallon and Sullivan 2009). During the current project, we discovered that a small number of the underlying trip legs wrongly had distances of 0km recorded. These distances were included in our earlier estimates of chain distance, and so underestimate the true chain distance. Hence we have excluded the few affected chain distances from all analyses here. This reduced the number of chains with estimated distances from 66,407 to 66,351 nationwide.

2.1.1.3 Tour

A tour is a series of trip legs that starts from home and ends at home.

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2 'The meshblock is the smallest geographic unit for which statistical data is collected and processed by Statistics New Zealand. A meshblock is a defined geographic area, varying in size from part of a city block to large areas of rural land. Each meshblock abuts against another to form a network covering all of New Zealand.' (Statistics New Zealand 2010a)

3 Further detailed information about the continuous survey can be obtained from the MoT website www.transport.govt.nz/research/TravelSurvey/.

2.1.1.4 Main mode

The main mode of a trip chain or tour is the one used for the greatest distance. In the 2003–07 dataset, several modes (train, ferry, taxi, mobility scooter and 'other') did not have geocoded trip leg lengths. Hence, where a trip chain or tour included legs using such modes, we classified the chain or tour as 'main mode not defined'.

2.1.2 Confidence interval estimates

Confidence intervals in this report use the 'random groups' methods of estimation (eg Wolter 2007) as documented in the report on the 1997/98 HTS (Land Transport Safety Authority 2000). In summary, the estimate of interest was calculated for five random groups whose structure matched that of the parent sample, and then the variance was calculated. This procedure was repeated for 10 independent random groupings and the median of these 10 variances was taken as the best variance estimate.

2.2 Census journey-to-work data

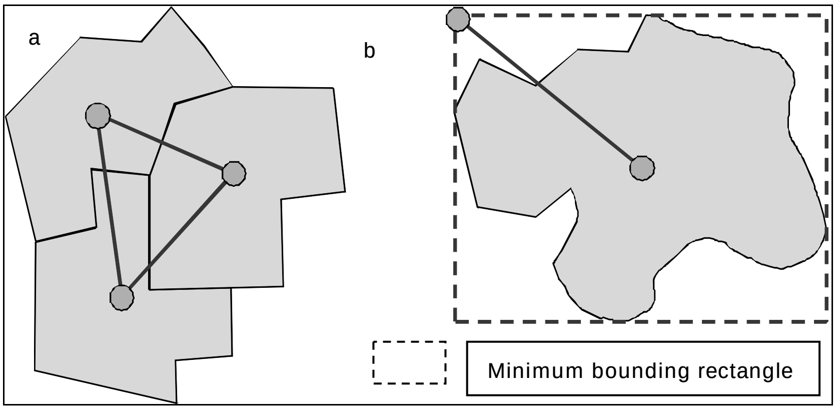
Statistics New Zealand (SNZ) has recently produced a new analysis of journeys to work that is highly relevant (Ralphs and Goodyear 2008, SNZ 2009a). The source data is from the New Zealand Census of Population and Dwellings for 1996 and 2006, and we found this to be very useful because the Census does not have the sample size limitations of the HTS. Employed adults were asked to give 'the full name of the business or employer you mostly worked at' and where that workplace was located. This information, combined with the location of their usual place of residence, allows distances to be estimated.

However, the estimation of distances is done in a different way to the HTS (where road distances are approximated by geocoding addresses and assuming[4] that the fastest route is chosen). Because Census responses are coded to areas rather than to the physical addresses of properties and because it is presently too difficult to obtain address-level geographical references for responses, they approximate the distances travelled by commuters by using two simple proxy measures which are illustrated in figure 2.1. For commutes between areas, Ralphs and Goodyear (2008) used the straight-line (Euclidean) distance between the geometric centroids of area units[5]. Where travel occurred within a single area unit, they used a value equal to half the diagonal distance across the minimum bounding rectangle that enclosed the area unit.

4 This is far from being a sweeping assumption. If a trip leg was 10km or more (15 minutes or more if walking or using a mobility scooter), then HTS respondents were asked whether or not they took the quickest route. If they said that the quickest route was not taken, then they were asked to describe their route by a waypoint (which was used to estimate the distance).

5 Area units of main or secondary urban areas generally coincide with suburbs or parts of suburbs. Area units within urban areas normally contain 3000–5000 population, though this can vary as a result of such things as industrial areas, port areas, rural areas and so on within the urban area boundaries.

Figure 2.1 Calculation of 'centroid to centroid' (a) and 'within area distance travelled' (b) proxy measures for area units



These proxy distances work reasonably well when area units are small (which is the case for cities, which are the focus of this report). However, they are less reliable in large rural area units.

The key differences for the Census compared with the HTS with respect to estimated distance are:

- straight-line distances instead of road-based measures (the straight-line approximations will lead to lower estimates relative to road-based measures)
- direct distances (in contrast, HTS trip chains to work include distance travelled to stops on the way eg to drop children at school)
- location classified by workplace address not residence: for example, SNZ results concerning Auckland come from those commuting to workplaces in Auckland (including a few with Wellington as their usual place of residence). In contrast, HTS estimates are based on commuting distances (excluding air travel) of people residing in Auckland (even if they work outside Auckland). The SNZ approach presumably leads to higher estimates (because they include people commuting longer than average distances from territorial local authorities outside MUAs).

An underlying limitation with the SNZ data is that around 20% of workplaces could not be coded to a specific area unit and hence no distance estimate was possible (SNZ 2009c). Workers who did not specify their workplace address in sufficient detail to allow it to be coded to an area unit also had distinct characteristics. In general, they were:

- disproportionately from areas where income levels were low
- more likely to have few qualifications
- more often male
- more likely to have not specified answers to a range of other questions such as mode of transport used to travel to work, occupation and industry.

But even given such limitations and the use of straight-line rather than road-based distance estimates, the Census distance results are a very valuable complement to the HTS results. This is particularly because they can reliably show changes in distance over time split by city and mode (whereas the HTS does not have sufficient sample size to compare such details reliably).

3. Kilometres travelled (KT) to work

3.1 Introduction

Distance travelled to work in urban areas is of interest for several reasons. First, a key motivation for this analysis was difficulties encountered in recent investigations for the NZ Transport Agency (NZTA) of the extent to which KT might be used to add value beyond mode share data for monitoring/ evaluating the impact of workplace travel plans (Sullivan 2008). Admittedly, such estimates of change in KT assume the availability of reliable estimates of change in mode share as an essential foundation but getting data of sufficient quality on mode shift (outside organisations with a transport focus) has proved surprisingly difficult both here and overseas (eg Australian states report that poor response rates of 30–50% are common; Sinclair Knight Merz 2007). Second, average distances travelled to work can be useful indicators in their own right. For example, the NZTA's *Statement of intent 2009–2012* (NZTA 2009) lists 'average length (km) of commuter trips' as a key performance indicator for urban form. Note that rural travel is not of interest in either of these two issues.

3.2 Basis for HTS analysis

The HTS enables many different options for defining travel 'to work'. Hence, results here may differ from other analyses of the HTS (one of the few other HTS analyses of KT to work we have seen is Tin et al 2009; that report only briefly included mean distances by region).

The analysis here is based on trip chains in MUAs[6] that started from home and ended with the purpose/activity of 'Main job' at the address recorded for their main workplace. We removed the following as being outside the focus of this project:

- people whose work address was identical to their home address or who recorded no fixed place of work
- trip chains where a chain from home to work had already been recorded earlier on the same day[7].

A total of 3656 such trip chains were recorded. Note that this definition of travel to work excludes travel ending with a purpose/activity of 'other job' or 'employer's business'; it also excludes chains where people worked somewhere other than the main work address recorded for their job (eg if they first went to a client on a particular travel day).

6 Many analyses in this report concern MUAs. These are areas centred on a city or major urban centre with a population of 30,000 or more (so Gisborne and Invercargill are included, but Timaru is not). Satellite areas are included (note particularly that the Cambridge and Te Awamutu areas near Hamilton are included, as is the Kapiti zone near Wellington).

7 Excluding trip chains where an earlier home-to-work journey had been made on the same day (eg because someone went home for lunch then returned to work) is open to debate. Others analysing the journey to work with different objectives will wish to include such trip chains. For this project, excluding them makes our results more comparable with Census journey to work distance estimates and with results from workplace travel plan surveys. Note that our data contains a considerable number of these trip chains (if included, they would increase the total number of home-to-work trip chains by around 7%). Not surprisingly, these chains are shorter than average (a median of 3.5km compared with 7.2km and a 5% trimmed mean of 4.3km compared with 8.9km). They are disproportionately done by people outside the three main centres (including these journeys would increase the number of journeys by only 4% in Auckland, Wellington and Christchurch combined but by 12% for other MUAs).

Of these trip chains, 3567 had valid distances (see table 3.1 for a breakdown by area). Some distances were not available because the respondent did not provide the data needed, while others were omitted because a mode was used for which distance was not geocoded (rail, ferry, mobility scooter or 'other').

Table 3.1 Trip chains available for analysis of KT to work in MUAs using HTS 2003–07 data.

MUA	Trip chains
Auckland*	904
Wellington**	503
Christchurch	550
Other MUAs	1610
Total	3567

* 'Auckland' includes the Central Auckland, Northern Auckland, Western Auckland and Southern Auckland urban areas, as defined by SNZ

** 'Wellington' includes the Wellington, Lower Hutt, Upper Hutt and Porirua urban zones, but not Kapiti.

This data was collected during four years, from mid-2003 through to mid-2007. Although 2008 data became available during this project, and have been used for the occupancy analyses in this report, we could not use the most recent data for analysing travel to work or to school because trip chains had only been created for the HTS up to June 2007.

We had planned to compare current HTS results for travel to work with results from the 1997/98 HTS. But during the course of the project a superior data source became available for such comparisons over time: SNZ's Census of Population and Dwellings journey to work distances. In particular, the complete coverage of the Census enables precise analysis of differences between cities which would have been awkward or impossible with the smaller sub-sample sizes for cities within the HTS (particularly given the effects that a few extreme distance values can have on overall averages).

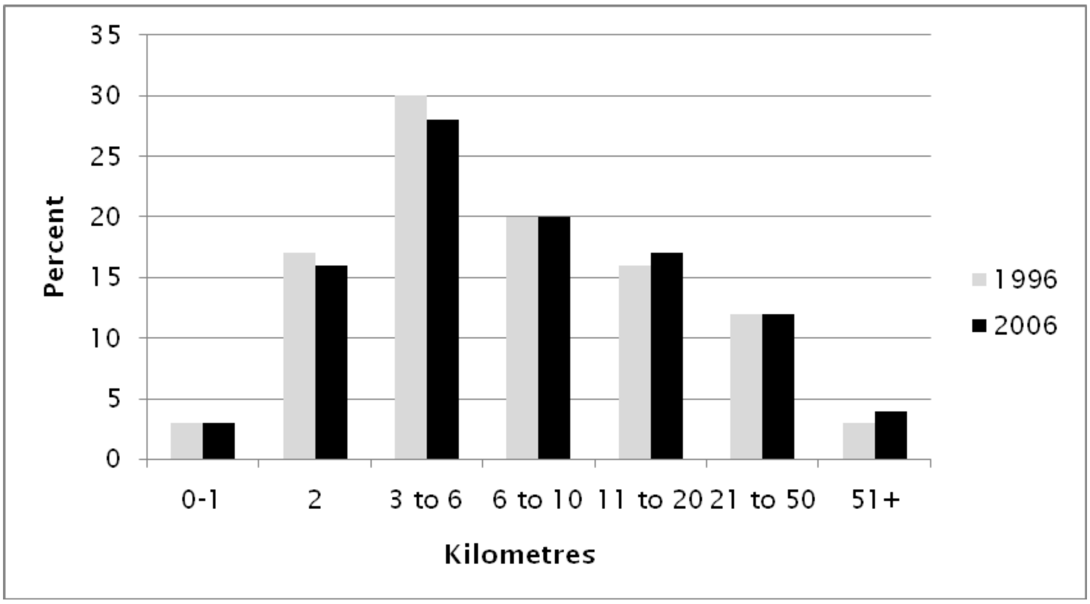
Thus, before using the greater detail about travel available from the HTS, we present the Census results (alongside some evidence showing that these are consistent with key HTS results).

3.3 Broad context – nationwide estimates

Before focusing on MUAs, we consider some recently reported Census results for the whole of New Zealand that deserve to become widely known in transport circles. Several patterns and trends are clear (SNZ 2009a and 2009b; Ralphs and Goodyear 2008):

- Most commuters live fairly close to their workplace (see figure 3.1).
  - The median straight-line distance was 5.5km in 2006.
  - Three-quarters lived 13.7km or less away from work in 2006 (in a straight line).
- Distances have increased slightly over the past 10 years for nearly all modes.
  - The median straight-line distance increased from 5.1km in 1996 to 5.5km in 2006.

Figure 3.1 Straight-line distances to work nationwide (adapted from SNZ 2009a)



Appendix A shows the medians and quartiles of distances to work for different transport modes (nationwide).

3.4 Straight-line distances from Census results

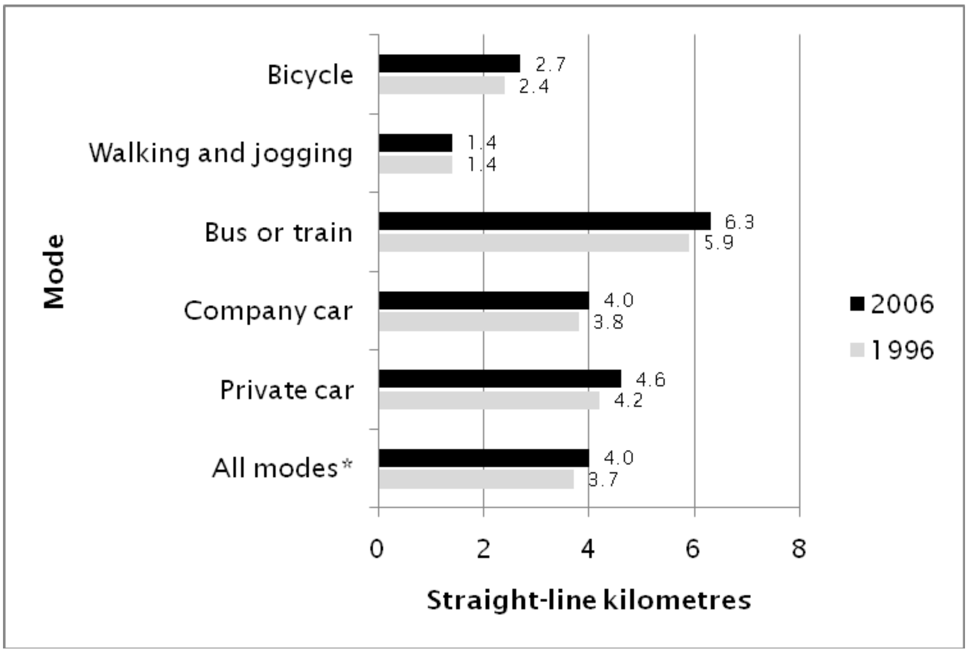
3.4.1 Home-to-work distances in 1996 and 2006

Compared with nationwide distances, distances to work in MUAs are typically shorter:

- The median straight-line distance from home to work in 2006 was 4.0km (compared with 5.5km nationwide).
- In 2006, three-quarters of commuters in MUAs lived 7.8km or less away from their workplace (compared with 13.7km nationwide).

Figure 3.2 shows median distances by mode for all MUAs combined. The median distances to work increased slightly from 1996 to 2006 for each mode except walking and jogging. The increase in medians was from 3.7km to 4.0km for all modes combined. The upper quartiles (ie distances for the 25% living furthest from work) also increased: for all modes combined, the upper quartile increased from 7.0 to 7.8km. (For reference, appendix A has a table of medians and quartiles for each mode.)

Figure 3.2 Median straight-line distances to work (in km) in MUAs by mode (SNZ Census of Population and Dwellings)



*All modes includes the category 'other'.

3.4.2 Implications for evaluating travel plans

The increasing distances travelled to work have implications for evaluation of travel plans. For example, let us assume that the average distance travelled to work has been increasing by about 1% a year in New Zealand MUAs (as suggested by the increase from 1996 to 2006 in the median straight-line distance from 3.7km to 4.0km, and in the upper quartile from 7.0km to 7.8km). This suggests that a workplace travel plan in Wellington found to have resulted in zero change in vehicle-kilometres travelled over four years might nevertheless be seen as a (modestly) useful intervention (because without the travel plan, KT may well have increased by 4% in line with the trend of increasing by about 1% a year). One of the challenges in evaluating travel plans is that the changes expected are relatively small in size; detecting and interpreting such small changes demands special care.

3.4.3 Comparing Auckland, Wellington and Christchurch

The median straight-line distances from home to work changed only slightly for the three main centres between 1996 and 2006 (Auckland cities had a median of 6.0 km both times; Wellington cities increased from 4.6km to 4.8km; Christchurch increased from 4.9km to 5.0km). However, figure 3.3 shows that the upper quartile distances (ie those for the 25% of workers living the furthest from work) increased for all three main centres (SNZ 2009a)[8].

8 Appendix A contains tables showing the median and quartile straight-line distances by mode for all MUAs combined, and also separately for MUAs in Auckland, Wellington and Christchurch. The figures there differ somewhat from those underlying figure 3.3, because the graph uses the territorial authority boundaries (eg city council boundaries). The published figures using the territorial authority boundaries are preferred here in the body of the report because they have not been affected by extra suppression of rare longer trips resulting from additional confidentiality restraints applied to tables disaggregated by mode.

Figure 3.3 Straight-line distances (upper quartiles, in km) to work in major cities (adapted from SNZ

Increases in distances between home and work in Auckland are contributed to by a sharp increase in commuters to the Auckland metropolis who live outside the Auckland Region (3300 in 2006, a sharp increase of 69% since 1996; SNZ 2009d).

Christchurch shows a clearly smaller proportion of longer distances between home and work (the upper quartiles depicted in figure 3.3 for 2006 are 9.0km for Christchurch compared with 11.6km for Auckland and 11.3km for Wellington). Logically, it is possible for greater distances to be associated with equal travel times (eg because of greater congestion in Auckland). However, the HTS suggests that a similar pattern exists in the upper quartiles for time spent travelling to work (Christchurch 25 minutes; Auckland 30 minutes; Wellington 35 minutes).

Details about distances (split by mode) for each of the three main centres separately and 'other MUAs' combined are shown in appendix A.

3.4.4 Impact of those working from home or not going to work

All of the analyses above concern distances by those who actually travel to work. However, the increasing demands on the transport system of greater distances travelled when people go to work can be reduced if the proportion of workers travelling to work changes (eg because they work from home more often or work fewer days). Hence, we also checked on whether clear changes in such behaviour were apparent.

Table 3.4 shows that although the proportion of those working from home dropped nationwide, it increased slightly in the largest cities (particularly Wellington). A higher proportion of workers did not travel to work on Census day in 2006 than in 1996. These changes offset the increased distances travelled to work to some extent. But the offset seems far from enough to reduce total KT to work[9].

9 Even in Wellington, where the increase in working from home or not going to work was greatest, the offset is far from sufficient to balance the impact of increased average distances fully. We do not have mean distances available from the Census for exact calculations, but even using change in the upper quartile as a probably generous

Table 3.2 Workers not travelling to work in 1996 and 2006 (derived from Census of Population and Dwellings 1996–2006)

'Main means of travel to work'	Year	All New Zealand	Auckland cities	Wellington cities	Christchurch*
Worked at home	1996	9.7%	5.7%	4.3%	5.3%
	2006	8.3%	5.9%	4.8%	5.3%
Did not go to work today	1996	9.8%	9.4%	9.4%	10.8%
	2006	10.3%	9.4%	9.8%	11.5%

*For 1996, we combined data from Christchurch and Banks Peninsula to increase comparability with the 2006 data recorded after the amalgamation of these two territorial authorities.

3.5 HTS distances 2003–07 (on road or footpath)

3.5.1 Average KT to work

Because a few high distances can strongly influence the usual mean, table 3.3 also provides the median and the 5% trimmed mean[10] for each mode. In addition to these various averages, we include the 75th percentile (or upper quartile) to enable comparison with such results from the Census (in section 3.4 and appendix A). The overall median of 7.2km is distinctly shorter than for larger cities overseas (eg a median of 14.3km for the Melbourne metropolitan area in 2007–08; Department of Transport (Australia) 2009).

Table 3.3 Distances (km) travelled to work by main mode in all MUAs (HTS 2003–07).

	All modes[a] ***N***[b] = 3567	Driver ***N*** = 2784	Passenger ***N*** = 329	Bus ***N*** = 167	Walk ***N*** = 174	Cycle[c] ***N*** = 110
Median	7.2	7.8	7.3	8.5	1.1	3.7
75th percentile	13.8	14.6	12.3	12.6	1.8	6.0
Mean	10.0	10.7	9.5	9.5	1.4	5.2
5% trimmed mean	8.9	9.6	8.5	9.2	1.3	4.5

Notes to table 3.3:

a 'All modes' includes three cases using 'Other' modes.

b Unweighted chains

c Warning: Being based on only 110 chains, the estimates for cycling will have relatively large sampling errors.

The shorter distances to work for Christchurch apparent from the Census data are confirmed by the HTS averages for all modes combined: median KT to work for Christchurch residents was 6.4km compared with 9.6km for Auckland and 8.0km for Wellington. The median for other MUAs was 5.0km. We do not attempt more detailed comparisons of averages from the HTS over time or between cities because the Census figures in section 3.4 and appendix A show such differences much more clearly and reliably. Indeed, even using data from all MUAs, the 110 chains for cycling in table 3.3 is below the minimum of 120 where we usually stop publishing results; bending such a rule of thumb seems

approximation for change in the mean suggests that the offset in Wellington is only about 1/10 of that required to balance the effect of increased average distances fully.

10 The 5% trimmed mean avoids the effects of a small number of extreme values by removing the longest 5% of values (and the shortest 5%) before averaging.

justifiable in this case, given that we have parallel estimates from the Census to protect us from extreme error.

Distances to work reported here (eg medians and means by mode) should be useful for checking the plausibility of average distances in workplace travel plans. A recent report to the NZTA concluded that regional averages from workplace travel data were useful not just for the NZTA but also potentially for feedback to participating workplaces:

> *But data quality problems (eg a small number of errors in data collection or geocoding) and/or a small number of extreme values (eg a couple of staff or school students joining who regularly commute far from the site) do severely affect estimates of average KT. Hence, using the distance data gathered for each workplace or school to monitor change specific to each workplace or school is firmly discouraged. If individual sites want such estimates, then a pragmatic alternative suggested by ARTA [Auckland Regional Transport Authority] is to use regional average distances together with mode shift data specific to the site.* (Sullivan 2008)

3.5.2 Comparing Census and HTS distances

The Census is expected to yield somewhat shorter home-to-work distances than those estimated by the HTS because the HTS distances concern on-road rather than straight-line distances, and also include extra distances that result from any detours (eg to drop off passengers) on the way to work. Given this expectation, key estimates seem reasonably consistent between the Census and the HTS, and similar patterns appeared in both datasets:

- The median distance travelled to work from the HTS 2003–07 in MUAs was 7.2km (compared with 4.0km from the 2006 Census[11]).
- When the main mode was 'driver', the HTS 2003–2007 figures found that the upper quartile distance in MUAs was 14.6km, which is around double the median distance for all modes (7.2km). Similarly, the 2006 Census upper quartiles for private car (8.3km) and company car (7.5km) were around double the median for all modes from the Census (4.0km).
- HTS results also show fewer long distances to work in Christchurch (as shown by figure 3.3 for the Census results). The HTS gives upper quartiles of 10.7km for Christchurch compared with 15.6km for Auckland and 15.7km for Wellington.

Walking is the exception: the HTS median of 1.1km is shorter than the Census median for all MUAs[12] of 1.4km. This implausible pattern may reflect data quality limitations in both sources:

- Unlike other distances in the HTS, walking distances are not based directly on geocoding the route; rather, we imputed them from the time taken. This could create substantial possible inaccuracies, not least because people often round recorded times to the nearest five minutes and so on. The MoT is collecting more accurate walking distances in the current HTS. Initial results suggest that the 4.4km/h value we used for imputing walk distances may be around 10% lower than the ideal for people of working age (personal communication from Lynley Povey, 18 June 2009).

11 Sources for these Census figures are the customised tables supplied by SNZ in appendix A.

12 As graphed in figure 3.2 and listed in appendix A.

- Even given these limitations, the walking distances in the HTS provide a useful warning that the Census results may well be systematically overestimating straight-line distances for walks. The Census estimates of walking distances may be affected more than other modes by approximations because the distances are so much shorter than distances for other modes (and hence more commonly take place within a single area unit or between two adjoining area units).
  - Straight-line distances for walks within the same area unit may well be overestimated. Other things being equal, where people live within the same area unit as their work, it seems safe to assume that they are more likely to walk when work is closer than half the diagonal distance across a rectangle enclosing the area unit than when work is further away. (See figure 2.1 explaining the distance across a rectangle within an area unit.)
  - Straight-line distances for walks to an adjoining area unit may also be overestimated. Other things being equal, where people walk to an adjoining area unit, it seems safe to assume they are more likely to walk when the distance is less than the distance between the centroids of the area units. (See figure 2.1 explaining the distance between centroids.)

We sought to complement the medians and percentiles used for Census data by another average (the trimmed mean) for comparison with our analyses of HTS data. But such means were not available from SNZ for this Census data.

3.5.3 Short trips suitable for active modes instead of driving

Research users specifically requested us to present distributions of distances of policy interest; in particular, short trip chains by car less than 2km and less than 5km (because such distances are often relatively easy to walk or cycle). As table 3.4 shows, about 1 in 13 trip chains (8%) driven to work in MUAs were less than 2km long, and 1 in 3 (32%) were less than 5km.

Table 3.4 Length of trips driven to work in MUAs (HTS 2003–07)

Distance	**All MUAs** N^b = 2784	**Auckland** *N* = 719	**Wellington** *N* = 362	**Christchurch** *N* = 399	**Other MUAs** *N* = 1304
<2km	8%	6%	8%	5%	12%
2.00–4.99km	24%	19%	19%	23%	34%
5.00–9.99km	27%	24%	26%	39%	28%
10.00–19.99km	28%	38%	22%	28%	16%
20.00+km	12%	13%	24%	5%	10%
Total[b]	**100%**	**100%**	**100%**	**100%**	**100%**

Notes to table 3.4

a Unweighted chains

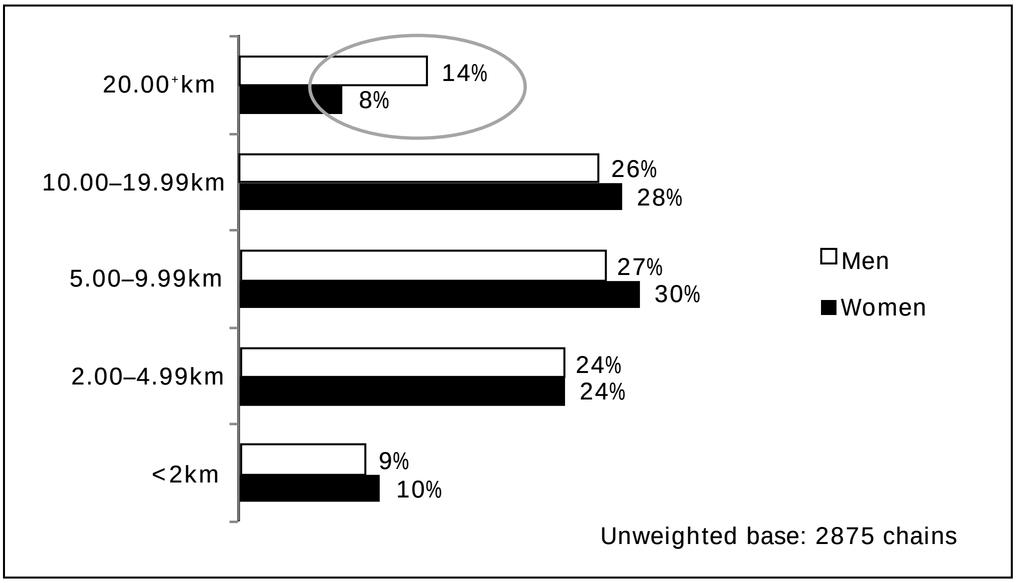
b Rows may not sum to 100% exactly because of rounding

3.5.4 Demographic differences

3.5.4.1 Gender

The main gender difference apparent in figure 3.4 is that men in MUAs are statistically significantly more likely than women to travel longer distances to work. Men travel 20km or more for 14% of their trips compared with only 8% for women (95% confidence intervals (CIs) 10.6%–17.0% and 4.9%–10.3%, respectively). Part-time workers are excluded so that any gender differences in the extent of part-time work do not confound this comparison.

Figure 3.4 Gender differences in distance travelled to work by full-time workers in MUAs, highlighting the gender difference for longer distances (HTS 2003–07)



3.5.4.2 Age

No particularly marked differences appeared in distance travelled to work with respect to age (table 3.5). Those aged 60+ may be less likely to travel longer distances (eg 10km or more); but the small sample size for this age group meant that this estimate would have a wide confidence interval, reflecting considerable uncertainty as to its magnitude.

Table 3.5 Age differences in distance to work for full-time workers in MUAs (HTS 2003–07)

Distance	**All** N[a] = 2875	**15–24** N = 340	**25–39** N = 1081	**40–59** N = 1259	**60+** N = 195
<2km	10%	9%	9%	10%	14%
2.00–4.99km	24%	23%	25%	23%	29%
5.00–9.99km	28%	34%	26%	27%	28%
10.00–19.99km	27%	23%	30%	27%	21%
20.00⁺km	11%	11%	10%	14%	7%
Total[b]	**100%**	**100%**	**100%**	**100%**	**100%**

Notes to table 3.5:

a Unweighted chains

b Rows may not sum to 100% exactly because of rounding.

3.5.4.3 Income-related differences in distance travelled to work

Summarising findings relating to income and distance travelled to work in MUAs is simple: we find almost no clear differences of practical interest.

Details of how this conclusion was reached are less simple. Measuring the impact of income is usually awkward for several reasons:

- A personal income of $0 tells us little about economic constraints on a person (eg they may have a spouse who earns plenty). Hence we tend to prefer household rather than personal income in general (but in this report, we also analyse by personal income because the distance concerned is the journey to work for that individual).

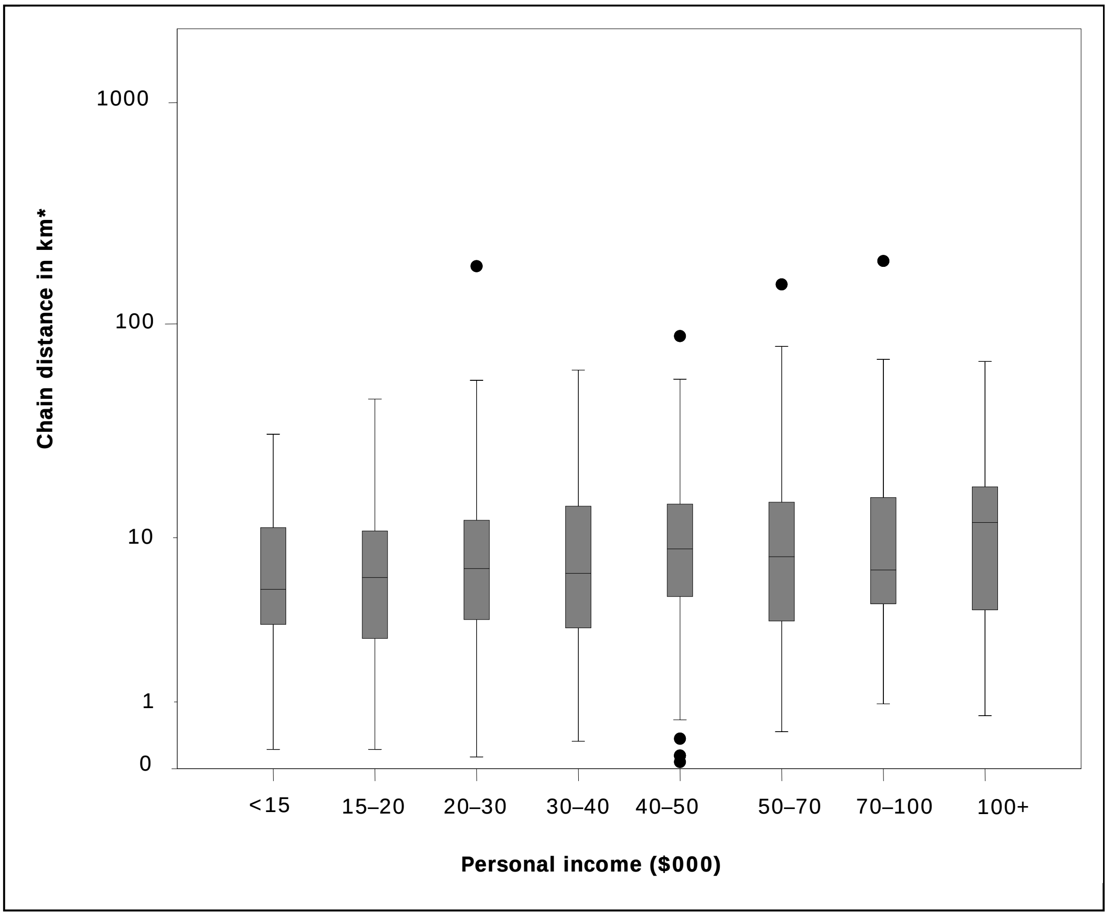
- A household income of $50,000 may be reasonably comfortable for a single person living alone, but very constraining for a person supporting a spouse and several children.
- An initial analysis of all workers (full- and part-time) showed no clear pattern overall apart from shorter distances for the very lowest level of personal and household adjusted income. For example, in MUAs, the median distance was 4.4km for those with personal incomes under $10,000 compared with 12.2km for those earning $100,000 or more. But this pattern could have been a misleading result of part-time workers having both lower incomes and not being prepared to travel as far. Hence, the main analyses are restricted to full-time workers only.

Given these issues, we used three complementary approaches for this analysis:

- personal income (based on 2655 trip chains after missing income values)
- household income adjusted for household size (based on 2163 trip chains after missing income values and missing information about numbers and ages of household members; adjustments for household size use results by Easton (2004))
- socio-economic deprivation of the area lived in (based on 2716 trip chains after missing values; the derivation of the NZ Deprivation Index (NZDep) used for this is explained below.

Considering personal income, the most marked difference suggested in figure 3.5 is the longer distances typically travelled by the highest income group (a median of 11.9km compared with medians of 6.0–8.8km for the other income groups shown). Higher income groups (personal income of $70,000 or more) travel 20km or more to work statistically significantly more often than lower income groups (personal income up to $30,000): 16% compared with 5% (95% CIs (7.3–24.3 and 2.6–7.1).

Figure 3.5 Personal income and distances travelled to work by full-time workers in MUAS (HTS 2003–07)



Notes to figure 3.5:

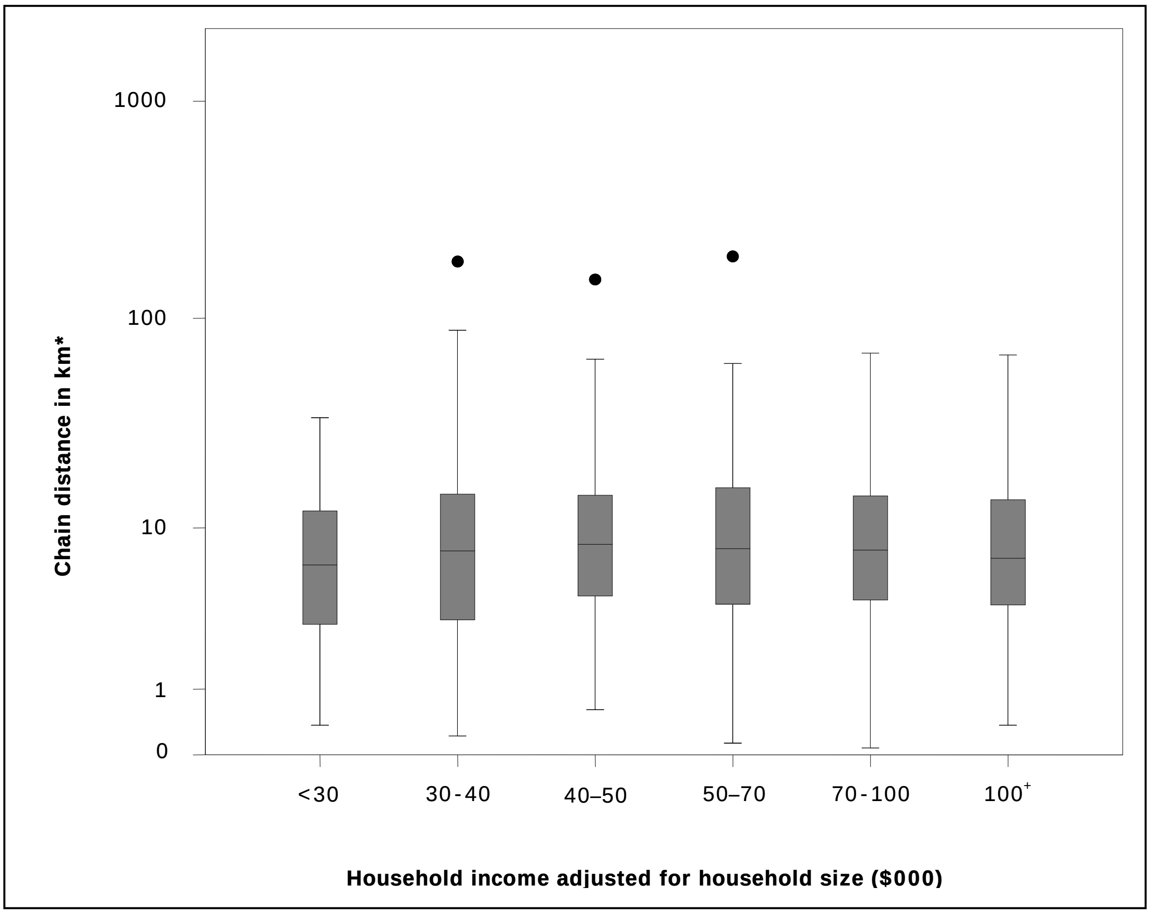
* Walking distances have been imputed.

** The following should be noted when interpreting this boxplot and those in figures 3.6 and 3.7:

- The y-axis uses a logarithmic transformation so as to 'stretch' the axis where the bulk of the data are (below 10km) and to reduce the visual impact of the few outliers/extreme values over 100km.
- The 'dots' at the top of some of the 'box and whiskers' shapes represent individual outliers/extreme values.

Comparisons by household income adjusted for household size showed no marked differences (figure 3.6).

Figure 3.6 Household income v distances travelled to work by full-time workers in MUAs (HTS 2003–07)



* Walking distances have been imputed.

A complementary approach is to consider the relative deprivation of the areas lived in rather than the specific personal or household incomes. To do this, we used the NZDep. NZDep combines nine variables from the 2006 Census to provide an index of socio-economic deprivation for each meshblock in New Zealand (Salmond et al 2007). A value of 10 indicates that the meshblock is in the most deprived 10% of areas in New Zealand; a value of 1 indicates that it is in the least deprived 10%. Meshblocks are geographical units defined by SNZ. In urban areas, meshblocks are roughly the size of city blocks and contain about 110 people (SNZ 2009e). The nine Census variables combined are:

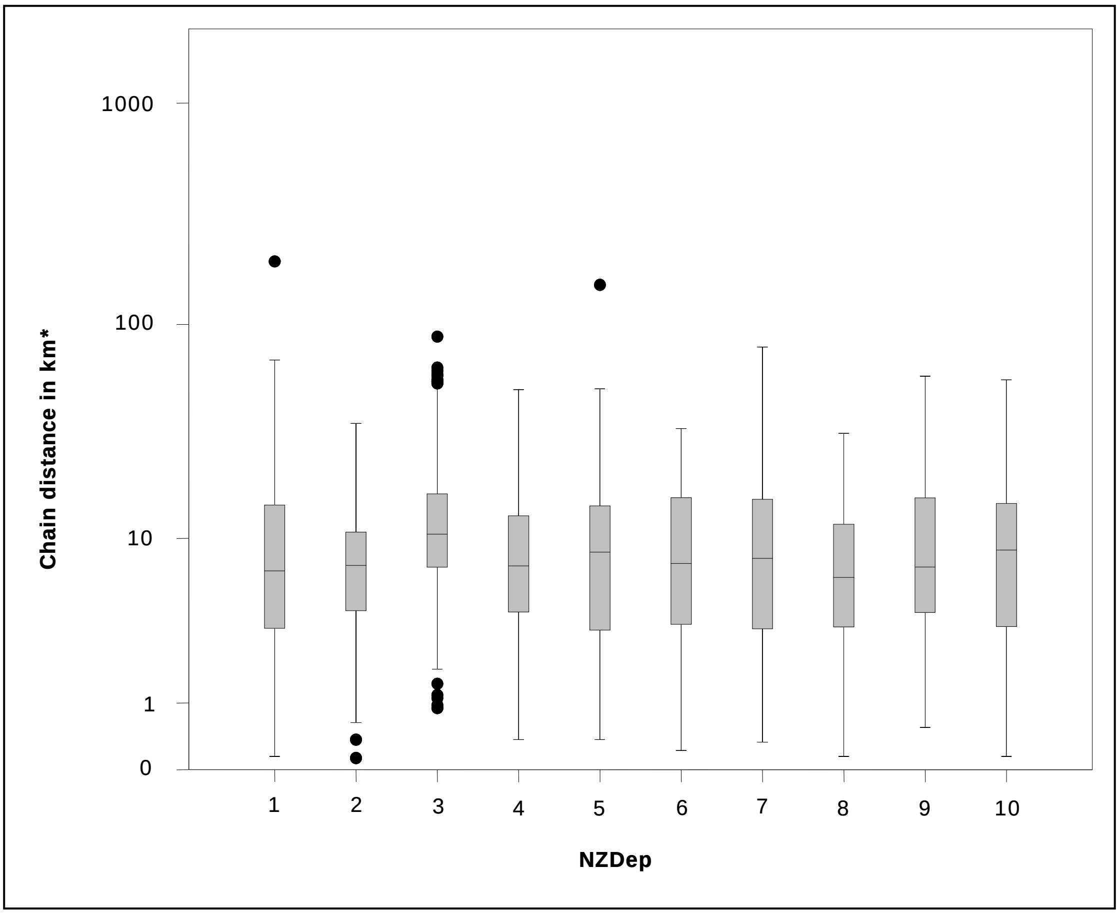
- people aged 18–64 receiving a means tested benefit
- people living in equivalised[13] households with an income below a set income threshold
- people not living in their own home (ie renting, private boarding or similar)
- people aged <65 living in a single parent family
- people aged 18–64 who are unemployed
- people aged 18–64 without any qualifications

13 Equivalisation: methods used to control for household size and composition.

- people living in equivalised households below a bedroom occupancy threshold
- people with no access to a telephone
- people with no access to a car.

No marked differences in typical distance or spread of distances were apparent in relation to the NZDep (figure 3.7).

Figure 3.7 Socioeconomic deprivation of meshblock lived in and distances travelled to work by full-time workers in MUAs (HTS 2003–07)



* Walking distances have been imputed.

3.5.5 Differences associated with parking type

The sub-sample sizes associated with specific types of parking for travel to work are too small to provide reliable average distances if split by city. Table 3.6 therefore lists median distances by parking type for all MUAs combined and for Auckland/Wellington/Christchurch combined (because the largest cities tend to have different parking arrangements and higher parking charges). We show medians rather than means because these are much less affected by a few extremely high distances. No particularly marked differences are apparent.

Table 3.6 Parking and distance (km) driven to work in MUAs (HTS 2003–07)

Parking type	All MUAs		Auckland, Wellington and Christchurch	
	Median	Chains (unweighted)	Median	Chains (unweighted)
All parking types	7.8	2798	9.2	1489
Not parked	NA*	15	NA	11
Off street: resident's property	NA	56	NA	21
Off street: private (eg business premises)	8.0	2160	9.6	1139
Off street: public	7.2	246	7.9	149
On street: time limit	NA	54	NA	26
On street: no time limit	6.5	266	7.0	142
Other	NA	1	NA	1

* NA = Results are unavailable because the sub-sample size is too small, ie it is based on fewer than 60 people or 120 trip legs (following MoT guidelines for use of the dataset; we also apply the 120 limit to trip chains).

3.5.6 Extreme values

Information about extreme values of KT data is useful for evaluating the effect of travel plans. Recent analysis of travel plan monitoring data collected by Auckland Regional Transport Authority (ARTA) and Greater Wellington (Sullivan 2008) showed that the data typically included a small number of extreme values (eg walks to school of over 20km) that were not credible. Such extreme values can distort the key measures for monitoring impact such as total KT. It is useful to have guidance from an independent data source as to what values might be regarded as ‘extreme’ (and hence worth considering for extra checks or even exclusion from some analyses). Although large inaccuracies in estimated distances seemed more likely with school than workplace travel plan data (Sullivan 2008), HTS results on distances travelled to work are useful as a check on the plausibility of distributions of estimated distances to work.

Travel plan data collection is not alone in generating extreme values. SNZ Census data for 2006 (SNZ 2009b) also records some surprisingly high data values (eg 2% of those walking/jogging to work claiming distances of over 50km and 7% reporting over 20km).

Given that approximating the distribution of extreme values is very demanding on sample size, we use all MUAs for this analysis (while acknowledging that cities may differ). The 99th percentiles[14] in table 3.7 are useful guides as to distances that should be viewed skeptically (eg walk values longer than 3.8km) and distributions that should be viewed skeptically (eg driver/passenger distance distributions with more than a couple of percent being longer than 50km). Table 3.7 is less reliable for walking and bus trips because the smaller sample sizes for those modes result in the extreme values depending greatly on relatively few data points.

14 Note that several different methods can be used for calculating percentiles and these yield somewhat different answers. The differences can become relatively large for 99th percentiles, particularly where the data is relatively sparse.

Table 3.7 Extreme values of distances (km) to work by main mode in MUAs (HTS 2003–07)

	Driver *N** = 2784	Passenger *N* = 329	Bus *N* = 167	Walk *N* = 174	Cycle *N* = 110
95th percentile (5% of distances greater than this)	28	24	20	3.3	NA**
99th percentile	51	47	26	3.8	NA
Maximum	193	55	26	4.4	NA

** NA = Not available because the sub-sample size was below 120 trip chains.

3.6 Mean trip length estimates for travel behaviour change evaluation procedures

Using the 2003–07 trip chain dataset, we re-calculated the trip lengths (tables 3.8 and 3.9) that formed the basis of the composite benefit values for the travel behaviour change evaluation procedures found in the NZTA's *Economic evaluation manual, volume 2* (NZTA 2010). Composite benefit values are used in the estimation of benefit–cost ratios for travel behaviour change proposals.

As was also the case when these values were originally estimated (Maunsell Australia, Pinnacle Research & Booz Allen Hamilton 2004), professional judgement was sometimes applied to adjust raw values where sample sizes fell below MoT guidelines for HTS output. Also, we again prevented the means being affected by a small number of extreme values of questionable relevance to travel behaviour change procedures by excluding chains that were longer than 30km. Several values were identical across the columns (eg bus); this is because sample sizes were insufficient to provide separate values for different areas and/or times, as was the case in 2004.

Some notable changes have been made from the earlier (2004) estimation using the 1997/98 HTS:

- We tightened our definitions of 'commuting'. While the focus had been on commuting to and from work or 'own education' (for those aged 18+), we further limited the analysis to chains from home to the address/location of their 'main job' or from that 'main job' address to home – excluding people travelling to second (or third) jobs or on 'employer's business' or those stopping off to visit a client or another worksite on the way to the office/shop. This tighter definition has seen some values change for car driver and car passenger commuting trips.
- 'Other (non-commuting) trips' have been affected by the definition for commuting, because previously we only included those trip chains where the person travelled from work *directly* to home in the 'commuting' category, allowing all trip chains with intermediate stops between work and home to be treated as 'other' trips. Now 'other (non-commuting) trips' exclude any trip chains from work to home, irrespective of the purpose of any intermediate stops. Home to work chains continue to be excluded. Again, this refined definition has caused some values to change for car driver and car passenger commuting trips.
- Previously, we had included 'public transport', using the trip length values for train, bus and ferry in the 1997/98 dataset. The values for train and ferry have since been considered suspect, and their use has been discouraged by the MoT. Hence the new trip length values are for 'bus' only. Train trip lengths were generally longer than bus trips, generating higher values.

- Fewer cycle trips meant that we had to average the trip length values across the whole day for commuters and other trip purposes.

Table 3.8 Worksheets for deriving composite benefit values for commuting and non-commuting trips (travel behaviour change evaluation procedures) updated using HTS 2003–07 data

Trip type	Mean trip lengths (km)					
	Peak[a]			Off-peak[b]		
	Auckland	Wellington	Christchurch and other urban areas	Auckland	Wellington	Christchurch and other urban areas
Commuting to/from work/own education						
Car driver	10.6	10.9	7.5	9.6	10.3	6.3
Car passenger	9.5	9.5	7.3	9.5	9.5	5.7
Bus	9.3	9.3	9.3	9.3	9.3	9.3
Cycle	4.5	4.5	4.5	4.5	4.5	4.5
Walk	1.5	1.5	1.3	1.3	1.3	1.3
Other (non-commuting) trip chains						
Car driver	9.0	9.3	7.5	8.9	8.6	7.7
Car passenger	9.1	10.2	7.5	9.4	10.2	8.1
Bus	8.0	8.0	8.0	7.8	7.8	7.8
Cycle	6.5	6.5	6.5	6.5	6.5	6.5
Walk	1.9	1.8	2.1	1.7	1.8	2.0

Notes to table 3.8:

a Peak times are 7:00am to 9:00am and 4:00am to 6:00pm.

b Off-peak times are 9:01am to 3:59pm and 6:01pm to 11:00pm.

c Maunsell Australia, Pinnacle Research & Booz Allen Hamilton (2004) included separate columns for peak commuting travel to/from the CBD versus other areas (for consistency with other benefit calculations, which vary according to location). But the separate columns had identical values and so the format was not repeated here. As in 2004, we have not tried to calculate different values for CBD commuting because we only had small HTS sample sizes.

Table 3.9 Worksheet for deriving composite values for education trips (travel behaviour change evaluation procedures) updated using HTS 2003–07 data

Mode	Mean trip lengths for schools in km for all urban areas and all times	
	Primary	Secondary and intermediate
Car driver	NA	9.0
Car passenger	3.9	4.3
Bus	8.1	8.4
Cycle	2.3	2.3
Walk	0.9	1.4

Maunsell Australia, Pinnacle Research & Booz Allen Hamilton (2004) created two sets of trip lengths and diversion rates for schools, one for primary and the other for secondary/intermediate (table 3.9). This was largely based on a professional judgement that intermediate school travel patterns and trip lengths were more like secondary than primary school patterns. We can now confirm that secondary school distance values can be used for intermediate schools. Although this cannot be confirmed using HTS data – because the HTS datasets in their current form do not readily distinguish between intermediate students and older students at a full primary school – we have two reasons for this. First, ARTA travel plan data from nearly 1700 intermediate students shows that their walking distances are clearly more like those of secondary students than primary school children (Sullivan 2008). Secondly, because intermediate schools are ‘feeder’ schools (ie they draw their student population from several primary schools), they are much more widely spaced around our cities than primary schools.

4. Kilometres travelled (KT) to school

4.1 Introduction

School travel has been of increasing interest in recent years. Partly this is because the modes used have changed markedly. For example, a recent MoT report (2009) confirmed that the proportion of primary and intermediate age students (5–12 year-olds) walking or cycling to school roughly halved from 1989/90 to 2004–08 (from 54% to 29%). Such children were driven to school much more often in 2004–08 (56% 'passenger only' compared with 31% in 1989/90). More students of secondary school age were also being driven in 2004–08 (35% 'passenger only' compared with 20% in 1989/90).

Furthermore, the sheer volume of school travel being done by car has become clearly apparent on New Zealand roads and has generated responses such as school travel plans. The volume is particularly a concern during the morning peak when it adds to congestion in the largest centres.

4.2 Method details

The base for analysing travel to school is any trip chain by a respondent aged 5–17 which started before 10:00am and where the activity at the end of the last trip leg was 'education'[15]. This is broadly consistent with the process used for our earlier analyses of school travel (O'Fallon and Sullivan 2004). The HTS 2003–07 has 1412 such chains in MUAs; of these, 1378 have valid distances (table 4.1).

Table 4.1 Trip chains for analysis of KT to school in MUAs (HTS 2003–07)

Area	Number of trip chains
Auckland*	405
Wellington**	184
Christchurch	195
Other MUAs	594
All MUAs	1378

* 'Auckland' includes the Central Auckland, Northern Auckland, Western Auckland and Southern Auckland urban areas, as defined by SNZ

** 'Wellington' includes the Wellington, Lower Hutt, Upper Hutt and Porirua urban zones, but not Kapiti.

4.3 Distance travelled to school in MUAs

Not surprisingly, distance travelled to school (see table 4.2) is obviously shorter for children of primary school age (a trimmed mean of 2.8km) than for those of high school age (a trimmed mean of 3.9km).

15 This does exclude a small number of journeys where the trip chain did not finish on arrival at school (eg because a school trip started less than 90 minutes later). But excluding such journeys seemed reasonable, given that these were relatively few and because other information calculated for the whole chain would then have been unreliable for such journeys.

Trimmed means are a useful single figure summary for such distance data because they reflect the distribution of higher values more sensitively than the median, while not being susceptible to major fluctuations because of a small number of outliers/extreme values (which is why the usual mean is not presented for these comparisons). Table 4.2 includes the 75th percentile as well as the median; this is because some changes are more apparent in such higher percentiles (as found with work distances in section 3.4).

Table 4.2 Kilometres travelled to school in MUAs (HTS 1997/98 and 2003–07)

Age	Unweighted chains		Median		5% trimmed mean	
	1997/98	2003–07	1997/98	2003–07 [95% CI]	1997/98	2003–07
All 5–17 years	1853	1378	2.2	2.2 [1.9–2.5]	3.2	3.2
5–10 years	1003	729	1.4	1.8 [1.4– 2.2]	2.0	2.8
11–12 years	291	214	2.1	1.9 [1.1–2.7]	3.4	3.2
13–17 years	559	435	3.7	2.6 [1.8–3.4]	4.9	3.9

Table 4.2 suggests that difference in distances travelled to school between children of primary school age and those of secondary school age may have narrowed since 1997/98. For example, the difference in trimmed means was 2.9km (4.9 – 2.0 = 2.9) in 1997/98 compared with 0.9km (3.9 –2.8 = 0.9) in 2003–07. This result merits further investigation, although the analysis required to establish its statistical significance is outside the scope of the current study[16].

It seems possible that these patterns reflect different underlying processes:

- The possible increase in distances for primary schools reflects the general trend towards longer travel shown also in travel to work (as shown in section 3.4), for example, because of greater use of cars. It would also result if parents were increasingly choosing for their children not to go to the nearest primary school.
- The possible decrease in distances for secondary school may reflect the reintroduction of school zoning (LaRocque 2005) between the 1997/98 survey and the 2003–07 data in the HTS. Zoning mainly affects secondary schools and, in effect, encourages enrolment at closer schools. Reintroduction of zoning was accompanied by efforts to increase confidence in local high schools in some problematic areas.

The sample size is obviously not sufficient to do a detailed analysis of distance for each main centre split by mode or age group. However, we do not seem to have any clear evidence (given the modest sample size for such comparisons of centres) of differences between main centres in average distance travelled to school (table 4.3). Although the Christchurch median seems longer, the Wellington trimmed mean is similar to that of Christchurch; so we draw no firm conclusion about differences in average distance.

16 The 95% CI for median distance travelled by children aged 13–17 suggests that the change since 1997/98 may be statistically significant. But the results are not sufficiently clear to claim this without doing a similar analysis of the 1997–98 data (and creating a system to estimate confidence intervals of the 1997–98 chain dataset just for this one result would have been excessively time-consuming).

Table 4.3 Kilometres travelled to school in MUAs (HTS 2003–07)

Area	Unweighted chains	Median	75th percentile	5% trimmed mean
All MUAs	1378	2.2	5.1	3.2
Auckland	405	2.0	5.6	3.2
Wellington	184	1.9	5.9	3.9
Christchurch	195	2.6	6.2	3.7
Other MUAs	594	2.1	4.3	3.1

Table 4.4 shows differences by mode. Given the quality problems with distance data collected as part of travel plan monitoring, it is reassuring to find that the HTS trimmed means for walking to school by primary school age children and secondary school age children of 0.9 and 1.5km, respectively, are almost identical to trimmed means of 0.9 and 1.6 km from primary and secondary schools collected by ARTA (Sullivan 2008).

Table 4.4 Kilometres travelled by school-age children to school by main mode in MUAs (HTS 2003–07)

Mode	Unweighted chains	Median	75th percentile	5% trimmed mean
All modes	1378	2.2	5.2	3.2
Vehicle passenger	792	2.9	6.0	3.7
Walk	355	1.1	1.8	1.1
Bus	122	8.4	9.8	8.3

Note: Results for driving, cycling and 'other' modes are not available because the sub-sample size is too small: it is based on fewer than 60 people or 120 trip legs (following MoT guidelines for use of the dataset; we also apply the 120 limit to trip chains).

4.4 Distances relevant to increasing walking and cycling

Research users requested us to present distributions of distances of policy interest; in particular, short trip chains by car less than 2km and less than 5km (because such distances are often relatively easy to walk or cycle). About 1 in 3 trip chains (35%) where children were driven to school (as vehicle passengers) in MUAs were less than 2km long, and 2 in 3 (68%) were less than 5km (table 4.5).

Table 4.5 Length of trips to school by mode in MUAS (HTS 2003–07)

Distance	All modes *N* = 1378*	Vehicle passenger *N* = 792	Walk *N* = 355	Bus *N* = 122
<2km	46%	35%	83%	12%
2.00–4.99km	28%	33%	16%	18%
5.00–9.99km	19%	25%	1%	47%
10.00–19.99km	6%	6%	0%	17%
20.00+km	1%	1%	0%	7%
Total**	**100%**	**100%**	**100%**	**100%**

* Unweighted chains

** Rows may not sum to 100% exactly because of rounding.

4.5 Income-related differences in distance travelled to school

We investigated income-related differences in school travel using household income (adjusted for household size) and the NZDep as introduced for work travel (section 3.5.4). We focused on children aged 5–10 only, because it seemed possible that total results could be misleading if children from higher income households tend to go to high school at a slightly younger age or stay disproportionately longer at high school (as seems likely, given the higher achievement by children from higher decile households (Ministry of Education 2008)).

No clear differences were apparent with respect to NZDep (the socio-economic level of the area lived in). However, lower household incomes were associated with lower distances travelled to school (see table 4.6). The median distance for children aged 5–10 years from households with an adjusted income of less than $35,000 was 1.2km compared with 2.1km for those from households with an adjusted income of $50,000 or more (and the 95% CIs for the medians barely overlap).

Table 4.6 Kilometres travelled by children aged 5–10 years to school in MUAs by household income (adjusted for household size) (HTS 2003–07)

Adjusted household income	Unweighted chains	Median [95% CI]	75th percentile [95% CI]	5% trimmed mean
<$35,000	192	1.2 [0.9–1.5]	2.2 [0.4–4.0]	1.8
$35,000–$50,000	114	1.8 [0.6–3.0]	6.8 [4.3–9.3]	3.2
$50,000+	225	2.1 [1.5–2.7]	3.6 [1.9–5.3]	2.7

4.6 Extreme values

Dealing with extreme values in kilometres travelled to school is even a greater problem for monitoring school travel plans than for monitoring workplace travel plans. Data collection for school travel plans typically relies on a 'roll survey' (ie depending on the home address information collected by the school) rather than an online survey linked to a geographical information system for capturing a home address typed in by an adult (as is often done for workplace travel plans). Furthermore, the option of an additional question about time taken for commuting (which can be useful to detect and remove non-valid distances in workplace surveys) is not practical within the constraints of data collection at school. Hence, table 4.7 provides extreme values useful for judging whether recorded distances might be implausibly high. For example, note that one large travel plan dataset had around 10% of distances walked to school being 5.1km or longer (Sullivan 2008) whereas the more reliable HTS data here has only 1% of walking trips being this long (as shown by the 99th percentile in table 4.7).

Table 4.7 Extreme values of KT to school by mode in MUAS (HTS 2003–07)

	Passenger *N** = 792	Walk *N* = 355	Bus *N* = 122
95th percentile	12.3	2.6	26.3
99th percentile	21.3	5.1	45.4
Maximum	119.6	6.4	46.8

* Unweighted chains

The sample size does not allow us to produce these passenger, walk and bus results separately for students of primary and high school age. But the sample size for students aged 5–10 is sufficient to produce two useful extra results:

- The 99th percentile for passenger is 15.0km.
- The 99th percentile for walking trips is 2.9km.

Hence, for primary schools, we suggest special treatment (eg extra checks or even discarding from analysis) for roll surveys yielding KT values beyond these 99th percentiles.

Cycling results for KT to school in 2003–07 are not available because fewer than 120 such chains are available (only 68). But combining 2003–07 cycling data with that for 1997/98 so as to get a larger sample size suggests the following results:

- The median distance is just over 2km.
- The 95th percentile is around 6km.
- The 99th percentile is around 7km.

Hence we suggest re-examination or even possible discarding of roll survey data suggesting cycling trips more than about 7km in MUAs. The maximum distance from 264 chains cycled to school in MUAs from either the HTS 1997/98 or the HTS 2003–07 was 10.4km.

5. KT: actual distance travelled to work/school compared with quickest route

5.1 Context

Comparing actual distances travelled to work/school with the direct distances between the addresses has become highly relevant because of monitoring and evaluation of travel plans. More specifically, a distance indicator with workplace and school travel plan surveys is commonly collected (eg in the NZTA, ARTA and Greater Wellington surveys) by capturing home and work/school addresses then estimating the quickest route between them (after geocoding). Some criticise this as unacceptably inaccurate because people often do not take the shortest or quickest route.

Given the differences of opinion apparent, it seemed useful to quantify the size of the problem by analysing HTS data to quantify whether this inaccuracy is large enough to be a genuine concern and to suggest appropriate adjustment factors if deemed necessary.

The details of the analysis are complex. Hence in the interests of clarity, we will begin by stating the main conclusion:

- The extra distance travelled by drivers (and their passengers) not travelling directly to work does not appear to be large enough to make a dramatic difference to analyses of KT for workplace travel plans. The indirect routes add roughly 8% to the distances estimated by assuming that the quickest direct route is taken.

5.2 Using trip tours as an initial approximation

Our analysis of 'tours' (O'Fallon and Sullivan 2009) provides a useful introduction to the context and an initial estimate of the number of trips to work that are not direct. A tour (or round trip) is a series of segments/trip legs that starts from home and ends at home. Table 5.1 shows that most of the work tours (17.7% of tours in total) are not of interest to us as they involve travelling directly to work and directly home later (the 'simple work tours', 'multi-part work tours' and 'composite at work tours').

The three work tour types with some personal or education stops (symbolised by 'psl/e') on the way to or from work are shaded in pale grey. These comprise 8.4% of tours. That is, roughly one-third[17] of round trips to and from work do not go directly to and from work, but include other stops. In the more detailed analysis below, we focus on travel to work only; the data below suggests that roughly 1 in 6 (16%)[18] of the trips to work include other stops.

17 8.4 / (17.7 + 8.4) = 32.2%

18 (2.2 + 1.9) / (17.7 + 8.4) = 15.7%

Table 5.1 Types of tours (HTS 2003–07).

Tour type	Purposes of segments/trip legs*	%
Simple work tour	h–w–h	12.7
Multi-part work tour	h–w–(w)–w–h	3.2
Composite at work tour	h–w–(psl/w/e)–psl/e–(psl/w/e)–w–h	1.8
Subtotal		**17.7%**
Composite to work tour	h–psl/e–(psl/w/e)–w–h	2.2
Composite from work tour	h–w–(psl/w/e)–psl/e–h	4.3
Composite to and from work tour	h–psl/e–(psl/w/e)–w–(psl/w/e)–psl/e–h	1.9
Subtotal		**8.4%**
Simple/multi-part own-education tour	h–e–(e)–h	6.7
Composite own-education and non-work tour	h–psl–e–(psl)–h and h–(psl)–e–psl–h	3.4
Simple non-work/non-education tour	h–psl–h	40.0
Multi-part non-work/non-education tour	h–psl–psl–(psl)–h	23.9
Total		**100.0%**

*h=home, w=work, e=education, psl=personal (ie personal business, medical, shopping and leisure); h–w–h indicates a tour from home to work to home again

5.3 Selecting relevant trips to work/school (indirect trip chains)

5.3.1 Criteria for selection

Choosing trips that are relevant to this analysis could be done in many different ways. Selecting trips through the tour types in table 5.1 was not precise enough because the work travel used in the tours includes some travel 'on employer's business' (eg the many possible stops of someone going to business meetings), not just travelling to and from a workplace. Hence we chose to focus on trip chains from home to work/school (because chains are neatly defined as ending when a person reaches their workplace, and we have already identified chains that involve travel to school). More specifically, we used the following criteria:

- We selected work trip chains as those that begin at home and end at the address of their main place of work but excluded trip chains where the workplace and home address were the same as irrelevant.
- We selected school trip chains as those that begin at home before 10:00am by those aged 5 to 17 and finish with the reason for travel being 'education'.

Indirect travel was defined by meeting either one of these two criteria:

- taking more than a single trip leg to get from home to work/school (but ignoring trip legs walked[19], or using mobility scooters or 'other' modes such as horse)
- taking an indirect route on a trip leg, as shown by the HTS variable *TrQuickest* (which was collected from a respondent during the survey interview if a distance recorded was 10km or more, or if the duration was 15 minutes or more when the mode was walk/mobility scooter[20]).

Remaining issues around this selection of travel are detailed in the following subsections. The criteria we selected resulted in around 4000 relevant trip chains from MUAs for travel from home to work or education.

5.3.2 'To' only v 'to and from'

Ideally, we would analyse trips both to and from work/school. However, we analysed only trips **to** work/school for a number of reasons:

- Given a constrained budget and the fact that it is a relatively minor 'extra' analysis for this project, we could do this analysis more quickly because we already had established ways of identifying trip chains going to work/school but we had no simple way of identifying the relevant trips from work/school.
- It is consistent with the focus on travel to work and school chosen by others, eg
  - Census travel results concern the journey to work
  - workplace travel plan surveys in New Zealand almost invariably monitor travel to work; very few also cover travel from work
  - available analyses of school travel cover the journey to school not from school (eg MoT 2009).
- Travel off the direct route home is more common after work and school (eg as shown by the greater number of 'composite from work' trip tours in table 5.1) and often more complex (eg as shown by our analysis of school travel (O'Fallon and Sullivan 2005)). Nevertheless, we checked the average distance of 'composite to work' tours (19km) in MUAs and found it to be more similar to 'composite from work tours' (21km) than to simple work tours (12km).

5.3.3 School travel

Consistent with our earlier report on trip chains and school travel (O'Fallon and Sullivan 2005) and with chapter 4 of this report, we defined travel to school in terms of age (5 to 17 inclusive), purpose of travel (at least one trip leg with the purpose of education) and the time of day (the trip chain started before 10:00am).

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19 We had several reasons for ignoring trip legs walked. Firstly, because whether or not someone had sufficient walking at the end of their work/school trip chain to be recorded would often be largely accidental and irrelevant to evaluating workplace travel plans (eg whether someone's work car park happened to involve crossing a road to reach work is not of interest). Secondly, distances walked (approximated from time spent) are much less accurate than other travel distances (usually based on geocoding of addresses). Thirdly, the walking component of drive + walk trip chains was relatively small: the average (median) walking component of a trip chain involving both driving and walking was only about 4% of the total trip chain distance from home to work (in MUAs).

20 In practice, we had to use another variable as well (*TrMidAddno*, which marks an address on an indirect route), not least because of some irregularities in *TrQuickest* that were clarified for us by the MoT.

5.3.4 Other education travel

Given that universities and similar institutions have implemented travel plans in both Auckland and Wellington, we included other educational trip chains as well. In the absence of better alternatives, this was approximated by identifying trip chains by those aged 16+ with at least one trip leg with the purpose of education without any restriction over time of day. Trip chains by 16- and 17-year-olds with the purpose of education and starting before 10:00am were counted as 'school' trip chains.

5.3.5 Mode

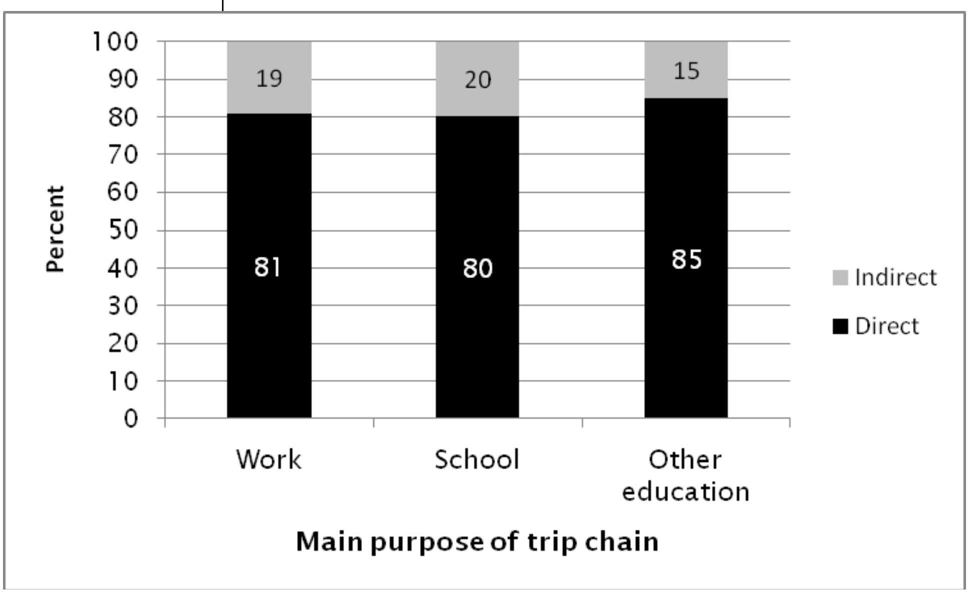
The more detailed analysis deals only with trip chains where the main mode was as a 'vehicle driver' or 'vehicle passenger'. These two modes covered the clear majority of relevant trip chains (about 90%). Train could not be covered as a main mode because distance estimates for it were not present in the HTS at the time of this analysis. Bus was excluded because such travel was not of interest with respect to travel plan monitoring (it would have been no surprise that some bus users had to change buses or got a lift to the bus stop, hence resulting in an 'indirect' route).

Given the age restriction (5–17 years) for travel to school, this means that nearly all of the 'to school' trip chains are as a passenger (whereas the clear majority of relevant trip chains to work are as a driver).

5.4 How many car trips to work or education are indirect?

Using the criteria in section 5.3 to select relevant trip chains to work, 19% of relevant trip chains to work in MUAs are indirect (ie they did not take the most direct route or else they involved a stop on the way). This is broadly comparable with the 1 in 6 suggested by our preliminary analysis of tours. Similar percentages of trip chains to school and to other education are also indirect (see figure 5.1).

Figure 5.1 Direct route versus indirect for trip chains where the main mode was 'vehicle driver' or 'vehicle



5.5 How much does the actual KT to work differ from the quickest direct route?

As background to the analysis, we first considered the typical lengths of trip chains to work and school (table 5.2). Not surprisingly, indirect trip chains were longer than direct. The difference in medians appears quite marked. But these differences do not tell us anything about how different the indirect chains would have been if the direct route had been chosen for those particular chains. Possibly, stops causing minimal change in distance travelled (eg just to pick up things from a dairy on the way or to give a close neighbour a lift) are more common with longer trips.

Table 5.2 Typical distance of trip chains to work/school/other education (HTS 2003–07)

	Purpose		
	Work	**School**	**Other education**
Median km			
Direct	6.8	2.4	6.5
Indirect	11.5	7.1	NA*
Base (unweighted chains)			
Direct	2751	647	225
Indirect	613	159	42

*NA = The results are not available because the estimate was based on fewer than 60 people or 120 trip legs (following MoT guidelines for HTS data use).

The remaining analysis has to focus more closely on trip chains with an indirect route only. For these chains where an indirect route was taken, the MoT's geocoding supplier calculated the distances that would have been travelled if people had driven the quickest[21] route directly from home to their workplace.

To compare these direct route distances with the actual distances travelled to work, we had to focus the analysis a little more tightly again. For this analysis, we:

- used work trip chains only (because sample sizes for other purposes are clearly insufficient (42 only for 'other education') or marginal (159 for 'school')
- excluded 18 of 613 work trip chains with an indirect route as being likely to reduce the validity of the analysis, because of a variety of underlying problems
  - most of these exclusions occurred because the MoT had chosen not to use the geocoded distances originally supplied in their 'best distance' estimate we used for calculating chain distances; these non-comparable cases caused anomalous results if included
  - a few trip chains to work were longer than 100km and were thus excluded because such extreme values can unduly influence results such as means, and we wished to use means rather than trimmed means in this analysis for consistency with typical analysis of travel plan data

21 The method used to choose 'quickest' routes does not take congestion into account. Speed attributes affecting route selection are averages based on speed limit, road surface, circuity and road type (hierarchy classification).

– in a couple of cases where the direct route distance clearly exceeded the indirect chain distance estimated (for reasons still unknown), we allowed small discrepancies of up to 0.5km because of the imputation of distances walked in our calculations of indirect chain distances.

Whether one looks at means or medians (see table 5.3), the direct routes average about 2/3 of the actual trip chain distances when an indirect route is taken.

Table 5.3 Trip chains to work: distances of direct versus indirect routes (HTS 2003–07).

Trip	Median km	Mean km
Actual trip chain (indirect)	11.5	14.1
Direct route for same trip chains	7.1	9.6
Base (unweighted chains)	595	595

To assess the possible overall importance of this difference to travel plan analysis of KT, we had to consider that these indirect routes are only used for 19% of trips to work (section 5.4). Hence, for the next analysis, we returned to the fuller dataset including direct trips to work. We replaced the distances of the indirect trips by distances for the direct route[22] so as to illustrate the overall impact of indirect routes on average distances travelled to work.

Assuming direct home-to-work distances for all trips to work (as done in major workplace travel plan surveys) leads to an overall mean distance of 9.3km[23]. The actual mean distance travelled to work is 10.2km, **9% more**. These figures do not change materially if drivers and vehicle passengers are analysed separately (driving is the mode for around 90% of the relevant trip chains to work selected).

Hence, we have shown that approximating home to work travel in cars by assuming direct routes is reasonably accurate (and we have quantified the discrepancy).

Furthermore, in terms of the purpose of travel plan analyses, using these direct routes (although they measure the actual trip imperfectly) may be more sound as a basis for estimating changes in KT driven if workplace travel plans reduce driving to work. This is because if someone makes a stop when driving to work, some of the extra driving reflected in indirect routes they took might then be done outside of the work commute, although it would still involve driving (eg shopping).

On the other hand, if some travel plan analysts wish to adjust approximated distances upwards so as to better reflect actual distances travelled, then our results suggest that an adjustment factor of around 9% is appropriate (to base distances that assume the direct route is taken).

5.6 Most common causes of indirect routes to work

To understand the indirect trips to work, it is useful to look at the reasons for stopping along the way (table 5.4). The major cause of stops (39%) was to accompany someone else (ie to drop them off or to pick them up).

22 For the few cases we did not receive a comparable estimate for the direct route, we imputed one by using 2/3 of the indirect distance (as justified by table 5.3).

23 As with the earlier analyses, we excluded trip chains of 100km or more.

Table 5.4 Causes of indirect trips to work (HTS 2003–07)

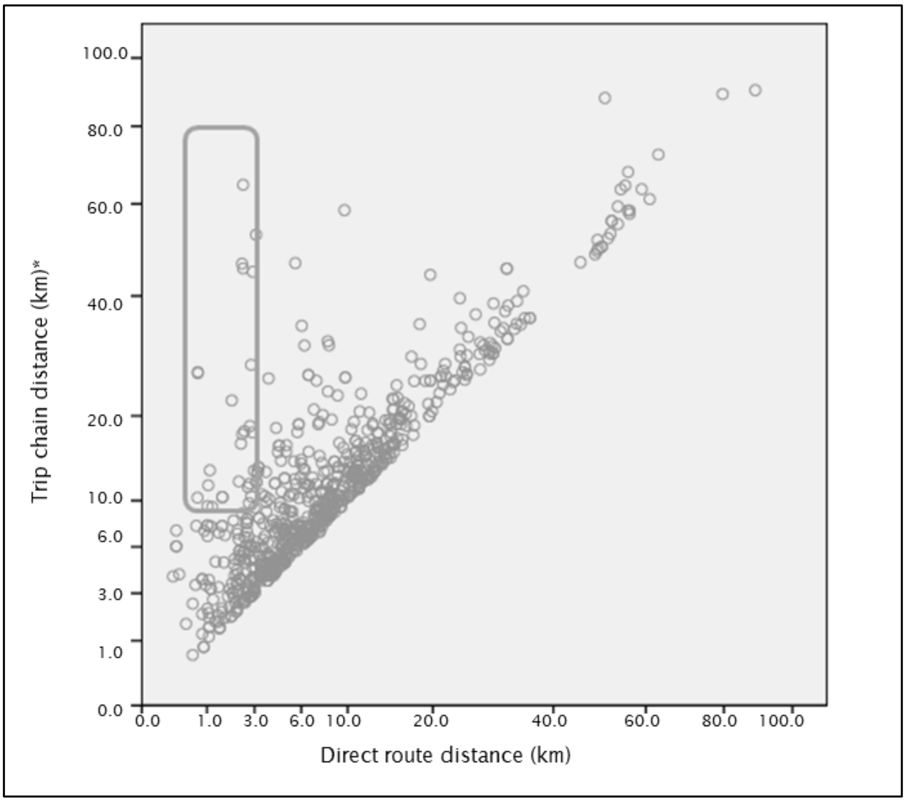
Reason for stop	**%** **(*N* = 841 unweighted trip legs)**
Accompanying someone else	38.9
Shopping	16.0
Personal business/services	15.0
Change to another mode	9.3
Social visit	7.8
Work – employer's business	7.1
Recreational	2.0
No extra stop (but did not take shortest route)	1.9
Medical/dental	1.0
Other	1.0
Total	**100.0**

5.7 Warnings about this type of analysis

First, should others consider similar analyses in the future, we warn that this kind of analysis comparing direct and indirect routes has proven much more time-consuming than expected. In particular, it was difficult to exclude trip chains that were inappropriate for the analysis.

Second, we found that the indirect routes often involve substantial diversions. In several cases, the direct distance to the final place of work or school is around 1km or less, but the actual chain length is much longer (as much as around 30km for work trips and 20km for school). Figure 5.2 compares trip chain distances with direct route distances, and highlights cases (by the rectangle in the upper left of the figure) where the direct route is 3km or less but the actual trip chain is around 10km or more.

Figure 5.2 Trip chains to work (as driver or vehicle passenger) not travelling directly: comparison with direct route distance (HTS 2003–07)**



** To provide more space at the lower left for the majority of trip chains, which are short, the graph uses a square root transformation for both axes.

The overall pattern of responses in the survey database confirms that these trip chains are genuine travel patterns (eg one man drove the woman in the household about 13km to her workplace on two days before returning to his workplace, which is around 1km from their home). Nevertheless, such cases throw the fundamental notion of a trip chain 'to work' or 'to school' into question somewhat because the major motivation for the travelling is not necessarily to get to work or school. For example, we had several cases of children being driven substantial distances and then dropped off at a school very close to home. This may largely reflect the need for young children to have adult supervision rather than revealing anything much about travelling to school. Furthermore, if a school travel plan should change the mode of that trip (eg to walking), then it seems unlikely that kilometres driven would reduce greatly (which is presumably being done for other reasons).

Finally, the extent to which actual travel differs from the quickest route may be underestimated because stops on the way to work or school are probably under-reported in surveys such as the HTS. Use of Global Positioning System (GPS) methods to assess the accuracy of standard household travel has often shown substantial under-reporting. For example, Stopher et al (2007) report that most of these exercises have shown that the standard trip-based computer-assisted telephone interviewing survey conducted in the USA under-reports travel by about 20–25%. Under-reporting in a major Australian survey using diaries and self-reporting (rather than telephone interviewing) is probably more directly relevant to HTS data collection. Although based on a small sample of only 113 people for whom comparisons could be made between GPS and diary data, a recent study of an Australian travel survey collecting data with self-report diaries showed a similar level (19%) of under-reporting of trips (Stopher and Greaves 2009).

6. Vehicle occupancy

6.1 Introduction

Occupancy of private vehicles is of interest because single-occupant vehicles (SOVs) have essentially the same impact as vehicles with several occupants in terms of road space, fuel use and emissions. Also, other things being equal, SOVs appear to be a more receptive target market for conversion to public transport use (because where more than one person is in a car, public transport is less attractive in terms of cost). Hence, targeting reductions in the proportion of cars with single occupants has been done in several countries (including New Zealand).

The main analysis here updates our analysis of the 1997/98 HTS (eg how vehicle occupancy varies by day of week, time of day, purpose of trip and vehicles per adult in the household). In addition, we add a little new work focusing on SOVs.

6.2 Basis for analysis

The base data for national occupancy estimates is 73,241 trip legs driven in light four-wheeled vehicles (cars, vans, utes, four-wheel-drives and SUVs) excluding taxis collected in the HTS from mid-2003 to mid-2008. We use all the data from the current HTS for analyses (rather than splitting off the most recent four years) so as to maximise the sub-sample size of subgroups we are comparing (eg cities). Information on the number of occupants was available for nearly all such trip legs driven (only nine extra trip legs driven were recorded without associated occupancy data).

Residents of MUAs drove for 44,452 of these trip legs; 15 of the legs were missing distance data, leaving 44,437 trip legs (table 6.1). Analyses for MUAs were further restricted by excluding trip legs of 60km or more (relatively few of these appeared in the data) because longer trip legs will generally involve travel outside the urban area of main interest. Our earlier analysis of 1997/98 occupancy (Sullivan and O'Fallon 2003) also excluded such longer trip legs.

Table 6.1 Trip legs available for analysis of occupancy in MUAs (HTS 2003–08)

Area	All	<60km
Auckland*	10,210	10,129
Wellington**	6,110	6,049
Christchurch	6,158	6,096
Other MUAs	21,959	21,525
Total	**44,437**	**43,799**

* 'Auckland' includes the Central Auckland, Northern Auckland, Western Auckland and Southern Auckland urban areas, as defined by SNZ

** 'Wellington' includes the Wellington, Lower Hutt, Upper Hutt and Porirua urban zones, but not Kapiti.

6.3 Occupancy nationwide 2003–08

Before focusing on MUAs again, we present a few nationwide results to give a context to these results.

The driver was the only occupant for around two-thirds (66%) of trip legs driven. Mean occupancy was **1.53** per trip leg (with a margin of error[24] of ±0.02).

Unless otherwise stated, occupancy rates presented in the following sections refer to mean occupancy **per kilometre driven** (or, more exactly, person-kilometres of travel per kilometre driven) rather than per trip leg. Mean vehicle occupancy per kilometre driven is slightly higher than per trip leg: **1.65** (with a margin of error of ±0.03). This difference reflects a slight tendency to carry more passengers on longer journeys.

We have several reasons for presenting results per kilometre driven than per trip leg. First, it ensures that occupancy estimates are consistent with good practice shown in occupancy analyses done internationally (e.g. with the US National Household Travel Survey; Hu and Young 1999). Second, it keeps estimates conceptually consistent with occupancy as commonly measured in New Zealand by roadside observation. Other things being equal, those who drive further are more likely to drive through cordon lines used for observing occupancy. Third, it matches the commonsense intuition that an appropriate average should be more influenced by longer trip legs than short ones. For example, if the data consists of a 2km trip with one occupant and a 100km trip with five occupants, then it seems obvious that a good occupancy average should be closer to 5 than to 1 (rather than 3, which is the mean occupancy per trip leg in this case).

6.4 Occupancy in MUAs 2003–08

6.4.1 Generalisations

Our remaining analysis of occupancy focuses solely on MUAs (ie travel by residents of MUAs only). Trip legs of 60km or longer have been excluded because these will often go outside the urban area.

The following main findings will be described in detail in the following sections:

- Differences in occupancy between MUAs are minimal.
- Average occupancy is similar to 1997/98.
- Occupancy differs by day of week, time of day and purpose.
- The number of vehicles per adult in a household decreases average occupancy, but the number of children in a household has a greater effect on occupancy than number of vehicles.

6.4.2 Differences in occupancy between MUAs

Table 6.2 shows that travel patterns in Auckland, Wellington, Christchurch and other MUAs show no marked differences between them in terms of mean occupancy, whether by trip leg or per kilometre driven. Table 6.2 also shows that average occupancy per trip leg and per kilometre driven are very similar for MUAs.

24 Margins of error (the half-width of the 95% CIs) were supplied by Lynley Povey at the MoT (pers. comm.). Comparing margins of error for mean occupancy of different regions warns us that margins of error for estimates per kilometre driven are often roughly twice as large as those per trip leg.

Table 6.2 Mean vehicle occupancy in MUAs (HTS 2003–08)

Area	Per trip leg	Per km driven
Auckland	1.54	1.53
Wellington	1.57	1.56
Christchurch	1.54	1.58
Other MUAs	1.51	1.54
All MUAs	1.53	1.54

6.4.3 Average occupancy is similar to 1997/98

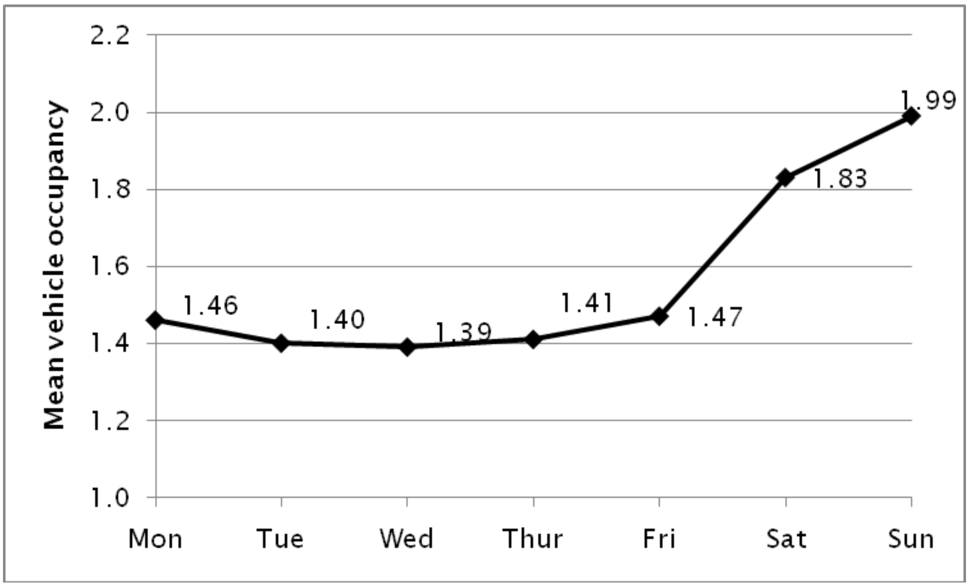
Direct comparisons of these results with the 1997/98 HTS are not possible because the improvements in collecting occupancy data (including the age and gender of non-household passengers) in HTS 2003–08 make the responses from drivers about number of passengers non-comparable. Hence we do not routinely compare occupancy results in this report with 1997/98 data.

Nevertheless, overall, we have evidence that average occupancy in MUAs has been stable since 1997/98. An alternative estimate of overall occupancy (derived from passenger and driver distances) which is measured comparably over the years shows a mean occupancy of 1.49 for 1997/98 and 1.48 for 2003–2008.

6.4.4 Occupancy differs by day of week, time of day and purpose

Occupancy varies sharply by day of the week, being clearly higher in the weekend (figure 6.1). Such clear differences justify specifying whether occupancy targets explicitly relate to weekdays or weekends (eg as is done for the occupancy target in the *New Zealand transport strategy*, which concerns weekdays only (MoT 2008)). The average weekday occupancy for MUAs (2003–08) is 1.43.

Figure 6.1 Mean occupancy per kilometre driven by day of week in MUAs (HTS 2003–08)



Even restricting the analysis to weekdays only, clear differences still appear in occupancy by time of day (table 6.3). The lowest occupancy is before 7:00am, and the highest is in the evening (6:30pm and later).

Table 6.3 Mean weekday occupancy per kilometre driven in MUAs (HTS 2003–08)

Leaving time	Mean occupancy
Up to 7:00am	1.14
7:00–8:59am	1.37
9:00am–2:59pm	1.46
3:00–6:29pm	1.43
6:30pm and later	1.53
All	1.43

Occupancy rates vary substantially by the purpose of travel (figure 6.2). These differences are broadly similar to those found in the USA (eg the average home-to-work occupancy was 1.1 and social/recreational occupancy was 2.1 in 2001 (Davis et al 2009)). Furthermore, the differences by time of day relate to differences in purpose of travel. For example, work travel consistently shows lower occupancy across different times of day, whereas trips for shopping and social visits have consistently higher occupancy (even if the analysis is restricted to weekdays only). Work trips are the predominant trip purpose on weekdays up to 9:00am (80% before 7:00am and 64% between 7:00 and 9:00am[25]), while after 6:30pm, shopping trips and social/recreational visits are more common (23% in total); therefore, it appears that the occupancy rates reflect the purpose of the trips being taken at the time.

Comparing occupancy across different purposes requires some clarification. Trip purpose is recorded from the driver's point of view, hence driving children to school will have the purpose of ‘accompanying someone else’, not ‘education’. If a driver has ‘education’ as the trip purpose, then he/she is travelling to their own place of study. The trip purpose ‘home’ is associated with a mixture of the other purposes. For example, because the purpose is recorded for each trip leg (ie for each stop), returning home from work is assigned the same purpose as returning home from sport. In the few cases where the reason for the trip leg was to change to another transport mode, the purpose was taken from the first trip leg with a purpose/destination other than to simply change mode. That is, if someone walked to a railway station in order to catch a train to work, the purpose for the trip leg walked was recorded as ‘work’ rather than to ‘change mode’.

25 So as to reflect the effect purpose has on occupancy estimates presented per kilometre driven, these analyses are also on a per kilometre driven basis (analysing the results purely in terms of trip legs leads to substantially different results in this instance).

Figure 6.2 Occupancy per kilometre driven by purpose in MUAs on all days of the week (HTS 2003–08)

* 'Personal' includes social welfare and personal businesses/service, eg visiting a bank.

The differences in occupancy by day of week, time of day and purpose all appear stable over time – very similar patterns were apparent in the 1997/98 HTS (Sullivan and O'Fallon 2003).

Note that the large differences in occupancy for different trip purposes mean that changes observed in occupancy over time (eg by roadside cordon counts) may not reflect success or failure of policies aimed at increasing occupancy if the mix of purposes on the roads monitored has also changed. For example, the mix of purposes might change because of new shopping centres, recreational facilities or large office/educational developments nearby.

6.4.5 Effect of number of vehicles in household

Not surprisingly, the number of vehicles in a household typically increases as the number of adults in a household increases. So instead of examining the relationship of occupancy simply with the number of household vehicles, we consider it in relation to vehicles per adult in a household. We count those aged 19 and above as adults (because those aged 15 to 18 typically do relatively little driving). For example, a couple with a single vehicle are represented by a ratio of 0.5 vehicles per adult; a couple with two vehicles are represented by a ratio of 1.0 vehicles per adult. Table 6.4 (second column) shows that occupancy is higher where this ratio is 0.5 or less, and occupancy decreases as the ratio of vehicles per adult increases.

Table 6.4 Occupancy per kilometre driven and number of household vehicles in MUAs (HTS 2003–08)

Vehicles* per adult 19+ in household	Mean occupancy (all households)	Unweighted trip legs	Mean occupancy (households with 0 children)	Unweighted trip legs
<0.5	2.01	840	1.82	365
0.5	1.73	6668	1.53	3822
0.51–0.99	1.54	2433	1.37	1413
1	1.52	24,188	1.34	13,188
>1	1.43	6999	1.26	2786

* 'Vehicles' includes cars, vans, utes, four-wheel-drives and SUVs but not taxis.

Analysis of the 1997/98 HTS showed that average occupancy was more strongly related to the number of children in the household than the number of adults (Sullivan and O'Fallon 2003). Hence, it is prudent to check whether the relationship found in table 6.4 is dependent on children living in the household. The pattern of results in table 6.4 (column two) holds true even for households without any children aged 18 years or younger (see column four in the same table). Note also that mean occupancy rates are consistently lower for households without children (column four) compared with all households (column two), illustrating the substantial impact of children on occupancy.

6.5 Single-occupant vehicle (SOV) travel on weekdays

The *New Zealand transport strategy* (MoT 2008) recently included the following target:

> *Reduce the kilometres travelled by single occupancy vehicles in major urban areas on weekdays by ten per cent per capita by 2015 compared to 2007.*

It is not worthwhile for a project like this to duplicate measures for such targets that are already done as part of the MoT's Transport Monitoring Indicator Framework (MoT 2010). Instead, it was considered useful for this project to broaden general understanding of SOV use. Specifically, we sought to estimate whether the kilometres travelled by SOVs would increase much if the definition were widened to include trips with a single passenger where the driver's purpose of travel is to 'accompany someone else' (such as parents 'chauffeuring' a child to school or an after-school activity). The rationale is that in terms of purpose of travel, such trips function for a single occupant. For example, if the trip was replaced by public transport, only one extra boarding might occur, not two.

We experimented with two different ways of doing this analysis and found both to be somewhat problematic.

First, we simply used the HTS 2003–07 dataset (of trip legs) and included all trip legs with the purpose 'accompany someone else' and only one passenger in our analysis of SOV use. Modifying our definition of an SOV like this increases the percentage of KT in MUAs (in light four-wheeled vehicles) on weekdays classified as single occupant travel by four percentage points (from 71% to 75%).

However, this modified definition of SOV travel is too simplistic. For example, consider travel to work where a driver drops their partner off on the way. The driver might well record that their purpose of travel was to 'accompany someone else' and they would have only one passenger. But continuing on to their own work shows that the first part of the travel did have a 'real' occupancy of two, not one.

Our second approach used our trip chain dataset to consider the journey more broadly, taking into account other trip legs in the same chain. We split chains involving any driving into four categories: Clearly SOV, Quasi-SOV, Partly SOV and Clearly Not SOV (see table 6.5 for definitions). Within the definition of Quasi-SOV, 'hierarchical purpose' needs some explaining. Hierarchical purpose for a trip chain allows nearly all other purposes recorded for a trip leg in the chain (work, education, shopping, social welfare, personal business, social, recreational, left country) to take precedence over 'accompanied someone else'. The exception[26] is 'home', which is sensible for this analysis (eg if a parent drives a child to school then returns home, the hierarchical purpose is to accompany someone and it is appropriate to classify the trip chain as Quasi-SOV).

26 This ignores the rare chains where the only recorded purpose recorded was to change transport mode or to return to the start address (which was not home).

Table 6.5 SOV-related categories for trip chains involving driving

Category	Definition
Clearly SOV	All trip legs driven had no passengers
Quasi-SOV	At least one trip leg driven in the chain had one passenger, but the 'hierarchical purpose' of the driver (from among the various purposes recorded for the chain) was to 'accompany someone else'
Partly SOV	At least one trip leg in the trip chain is SOV, but the chain is neither Clearly SOV nor Quasi-SOV
Clearly Not SOV	All trip legs in the chain have passengers

If SOV kilometres travelled are redefined to also include all driving in Quasi-SOV chains (even where a passenger is in the vehicle), table 6.6 shows that SOV KT would increase by about two percentage points (hence the '2' highlighted in pale grey and bold typeface in the table) from 67%[27] to 69% of kilometres driven in MUAs (in light four-wheeled vehicles).

Table 6.6 Distance driven and SOV category in MUAs (HTS 2003–07)

Category	Unweighted chains	% of total distance driven		
		Driven alone	With passenger(s)	Total
Clearly SOV	8556	58%	0%	58%
Quasi-SOV	456	2%	**2%**	4%
Partly SOV	1146	8%	8%	16%
Clearly not SOV	2053	0%	22%	22%
Total	**12,211**	**67%**	**33%**	**100%**

Given the small effect of this redefinition and the complexity of explaining its derivation, we do not recommend broadening the definition of SOV travel in this way.

27 The 67% here is inconsistent with the 71% a few paragraphs earlier because switching to trip chains resulted in some travel being excluded (eg because occupancy or distance was missing for one leg of the chain).

7. Conclusions and recommendations

7.1 Distance to work in MUAs

HTS data show that the median distance travelled to work in MUAs during 2003–07 is 7.2km and the mean distance is 10.0km. Having separate averages for driving, walking and other modes (see table 7.1) is useful for checking the plausibility of average distances in workplace travel plan surveys before use or publication. The 99th percentiles in table 7.1 can help determine which individual values from a workplace travel plan survey are so high as to justify special checks (or even outright exclusion from some analyses).

Table 1.1 Distances (km) travelled to work by main mode in all MUAs (HTS 2003–07)

	All modes[a] ***N***[b] = 3567	**Driver** ***N*** = 2784	**Passenger** ***N*** = 329	**Bus** ***N*** = 167	**Walk** ***N*** = 174	**Cycle**[c] ***N*** = 110
Median	7.2	7.8	7.3	8.5	1.1	3.7
Mean	10.0	10.7	9.5	9.5	1.4	5.2
99th percentile	50	51	47	26	3.8	NA

Notes to table 7.1:

a ‘All modes’ includes three cases using ‘other’ modes.

b Unweighted chains

c Warning: Being based on only 110 chains, the estimates for cycling will have relatively large margins of error.

It is important to remember that estimates of change in KT from workplace travel plan surveys assume the availability of reliable estimates of change in mode share as a foundation. However, getting data of sufficient quality on mode shift (outside organisations with a transport focus) has proved surprisingly difficult both here and overseas.

HTS results for main urban areas also show the following:

- More men than women travel longer distances to work in MUAs (14% of men in full-time jobs travel 20km or more compared with 8% of women).
- Almost no clear differences of practical interest arise when considering the distances people travel to work related to socio-economic deprivation (as measured by the NZDep) or household income.
- About 1 in 12 drives to work (8%) in MUAs are less than 2km long (such distances are commonly walkable). About 1 in 3 (32%) were less than 5km (a distance that is often easily cycled).

Census results show more people living further from work in 2006 than in 1996.

- The median straight-line distance from home to work in all MUAs combined increased from 3.7km in 1996 to 4.0km in 2006.
- The upper quartile straight-line distances (ie for the 25% of workers living the furthest from work) increased for Auckland from 11.3km to 11.6km, for Wellington from 10.2km to 11.3km, and for Christchurch from 8.1km to 9.0km.

Hence, evaluation of workplace travel plans in terms of KT should take into account that average distances to work may be increasing by roughly 1% a year, as suggested by such Census results (distances to work by car are also increasing at around this rate). For example, given that the impact of a travel plan may take some years to emerge, a reduction of 2% in average KT over four years may seem trivial. However, if it seems likely that average KT would otherwise have increased by 4%, the small reduction found may seem more noteworthy (ie potentially an impact of around 6%).

Such Census results may also be useful as an indicator of the influence of urban form on transport patterns (in particular because they enable reliable comparisons between cities and over time).

7.2 Distance travelled to school in MUAs

According to HTS data (2003–07), children of primary school age (5–10) in MUAs travel a median distance of 1.8km. That is, about half travel less than this distance and about half travel further. Those of secondary school age (13–17) travel a median distance of 2.6km (table 7.2). These distances are useful to check the plausibility of distance results from school travel plan surveys.

Table 7.2 Distances (km) travelled to school in all MUAs (HTS 2003–07)

	All (5–17 years) ***N**** **=** 1378	**5–10 years** ***N*** **=** 729	**11–12 years** ***N*** **=** 214	**13–17 years** ***N*** **=** 435
Median	2.2	1.8	1.9	2.6
5% trimmed mean	3.2	2.8	3.2	3.9

* Unweighted chains

Children of primary school age (5–10 years) from lower income households do not travel as far to school. Those with an adjusted household income of $35,000 or less had a median distance of 1.2km compared with 2.1km for those with adjusted household income of $50,000 or more.

About 1 in 3 trip chains (35%) where children are driven to school in MUAs were less than 2km long (ie a trip chain distance that is often easily walked).

Information about extreme values in distances travelled to school is useful to help judge the data quality with school travel plans, where simpler data collection methods typically lead to implausibly long walking and cycling distances in a small percentage of cases. For schools, we suggest special treatment (eg extra checks or even exclusion from analysis) for values above those recorded by the highest 1% in the HTS:

- 21km for passengers (15km for primary schools)
- 5.1km for walking (2.9km for primary schools)
- 7km for cycling (the sample size is not sufficient for separate results for primary and secondary schools).

7.3 Actual distance travelled to work/school compared with quickest route

Nearly 1 in 5 (19%) relevant journeys to work in MUAs were indirect (ie they did not take the most direct route or involved a stop on the way). When an indirect route was taken to work, the direct route was around two-thirds of the actual journey distance. Combining these two results, the overall impact of approximating the distance travelled to work by assuming that the quickest route is taken seems fairly small: on average, the actual distance travelled is only **9% more** (eg 10.2km compared with

9.3km). (Note: to prevent a small number of extreme values strongly affecting these means, we excluded trip chains of 100km or more in these analyses.)

This difference seems likely to have tolerably little impact on estimates of change over time. Hence continuing current practice with travel plan surveys (ie approximating the distance travelled to work by assuming that the quickest direct route is taken) seems to be acceptable.

Similar proportions of journeys to school (20%) and to other education providers such as universities (15%) were also indirect. But those samples were not large enough for us to estimate the impact on average distances.

7.4 Vehicle occupancy

The mean vehicle occupancy (per kilometre driven) in MUAs was **1.54** in 2003–08, which has not changed detectably since the 1997/98 HTS. Mean vehicle occupancy differed little between any of the three major centres and other MUAs. Given our focus on MUAs, we restricted occupancy analyses to exclude trip legs 60km or more because such long trip legs will often involve travel outside the urban area of interest.

Mean vehicle occupancy (per kilometre driven) differs substantially by:

- day of the week (much higher on the weekend)
- trip purpose (low for work and education; high for social/recreational)
- time of day (it is lowest in the early morning when work trips prevail and higher in the evening when more social/recreational trips take place).

The differences in mean occupancy between trip purposes are large enough (eg 1.15 for work compared with 1.85 for social visits and 1.93 for recreational) that they could affect conclusions drawn from monitoring of occupancy. That is, when occupancy is monitored without also measuring trip purpose (as is commonly done through observational measurement of occupancy), users should be wary of misinterpreting changes in occupancy as reflecting the impact of policy measures when changes in the mix of trip purposes may be a plausible alternative explanation.

Occupancy is affected by household size and composition. Mean occupancy is distinctly higher in households with 0.5 vehicles per adult (eg one vehicle for a couple) or less (compared with households with a higher vehicle:adult ratio). Not surprisingly, mean occupancy is generally higher in households with children. Hence, over time, occupancy is likely to be affected by long-term trends in household composition such as the steady increase in one-person households[28].

Given recent government interest in SOV travel in MUAs, we attempted to broaden the usual measure of SOV travel to also reflect trips with a single passenger where the driver's purpose was to 'accompany someone else'. However, we could not find a tolerably simple and practical method for doing this using HTS data and we showed the impact to be small (a couple of percentage points). Hence we warn against further attempts to broaden the definition of SOV travel in this way.

28 For example, the 2006 Census recorded 23.0% of households as having one usual resident only compared with 20.7% in 1996 (SNZ 2010b)

7.5 Recommendations

- Those analysing travel plans in terms of average distance should use the HTS results in this report to check the plausibility of their results.
- Those analysing travel plans in terms of distance should use the 99th percentiles from the HTS in this report to help judge which individual distances in travel plan surveys are so high as to justify special checks (or even outright exclusion from some analyses).
- Evaluation of workplace travel plans in terms of KT should take into account that average distances travelled to work may be increasing by roughly 1% a year.
- Continuing the current common practice in workplace travel plan surveys of approximating distances by assuming that the quickest direct route is taken seems acceptable; actual average distances are only about 9% more and are thus likely to have tolerably small impact on estimates of change over time.
- Observed changes in occupancy should not automatically be assumed to reflect the impact of policies aimed at increasing occupancy. This is because the changes in occupancy may simply reflect a change in mix of purposes of travel on the roads monitored (different travel purposes have sharp differences in occupancy, eg occupancy is low for work, but is higher for shopping and social trips).
- We recommend against any further attempts to broaden the usual measure of SOV travel to also reflect trips with a single passenger where the driver's purpose was to 'accompany someone else'.

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Appendix A: Supplementary Census tables

Table A1 Distance travelled to work by mode of transport in all New Zealand, 1996–2006 (area unit to area unit)

Mode	Year	Straight-line distance (kilometres): quantiles				
		5%	25%	50%	75%	95%
Bicycle	1996	1.1	1.9	2.9	4.9	s*
Bicycle	2006	1.1	2.0	3.3	5.9	s
Bus or train	1996	1.6	3.4	6.1	12.2	29.4
Bus or train	2006	1.6	3.6	6.4	12.8	35.0
Company car	1996	1.3	2.8	6.2	14.1	37.9
Company car	2006	1.3	3.0	7.1	16.5	49.5
Other mode**	1996	1.1	2.5	5.3	19.4	s
Other mode	2006	1.1	2.7	5.8	16.3	s
Private car	1996	1.3	2.7	5.5	11.9	31.5
Private car	2006	1.3	3.0	6.1	13.2	36.1
Walking and jogging	1996	0.9	1.3	2.0	3.4	s
Walking and jogging	2006	0.9	1.2	1.9	3.2	s
All modes	1996	1.1	2.3	5.1	12.9	37.5
All modes	2006	1.1	2.5	5.5	13.7	42.0

* s = Data has been suppressed because of quality issues.

** ‘Other mode’ includes ferry and aeroplanes; this affects the distance in the highest quantiles.

Tables A2 to A6 have had additional confidentiality restraints applied because of the increased level of disaggregation by mode and area. As a result, the number of extreme values has been reduced, which has had a moderating effect on the median.

Table A2 Distance travelled to work in all MUAs combined in 1996–2006 (area unit to area unit)

Mode	Year	Straight-line distance (kilometres): quantiles				
		5%	25%	50%	75%	95%
Bicycle	1996	1.2	1.7	2.4	3.3	5.1
Bicycle	2006	1.2	1.8	2.7	3.7	6.9
Bus or train	1996	1.9	3.5	5.9	11.8	24.5
Bus or train	2006	2.0	3.7	6.3	12.3	29.6
Company car	1996	1.2	2.0	3.8	6.8	16.7
Company car	2006	1.2	2.0	4.0	7.5	19.0
Other mode	1996	1.1	3.4	4.7	10.9	29.8
Other mode	2006	1.7	3.8	4.8	11.1	29.8
Private car	1996	1.2	2.3	4.2	7.4	17.3
Private car	2006	1.2	2.5	4.6	8.3	18.9
Walking and jogging	1996	0.9	1.1	1.4	1.9	3.3
Walking and jogging	2006	0.9	1.1	1.4	1.9	3.2
All modes	1996	1.1	1.9	3.7	7.0	17.7
All modes	2006	1.1	1.9	4.0	7.8	19.2

Table A3 Distance travelled to work in Auckland* 1996–2006 (area unit to area unit)

Mode	Year	Straight-line distance (kilometres): quantiles				
		5%	25%	50%	75%	95%
Bicycle	1996	1.4	1.9	2.9	3.5	3.7
Bicycle	2006	1.9	2.7	3.2	3.7	5.5
Bus or train	1996	2.1	3.8	6.0	9.0	13.2
Bus or train	2006	2.1	4.2	6.4	9.2	14.7
Company car	1996	1.2	2.1	4.9	8.4	16.9
Company car	2006	1.2	2.0	4.9	9.0	19.2
Other mode	1996	2.0	3.9	4.7	28.3	29.9
Other mode	2006	2.1	3.9	4.7	25.6	29.9
Private car	1996	1.2	2.6	5.0	8.6	16.1
Private car	2006	1.2	2.8	5.3	9.2	17.1
Walking and jogging	1996	0.8	1.1	1.4	1.7	3.7
Walking and jogging	2006	0.7	1.0	1.3	1.7	2.9
All modes	1996	1.0	1.9	4.5	8.4	17.0
All modes	2006	1.0	2.0	4.6	8.8	18.1

* 'Auckland' comprises Western, Northern, Central and Southern Auckland urban zones).

Table A4 Distance travelled to work in Wellington* 1996–2006 (area unit to area unit)

Mode**	Year	Straight-line distance (kilometres): quantiles				
		5%	25%	50%	75%	95%
Bicycle	1996	1.1	1.9	2.7	3.2	4.3
Bicycle	2006	1.2	2.2	3.2	4.3	6.7
Bus or train	1996	1.9	3.6	6.7	14.8	29.6
Bus or train	2006	1.9	3.7	7.1	15.8	44.1
Company car	1996	1.2	2.3	4.3	9.9	23.7
Company car	2006	1.2	2.0	3.9	7.3	22.1
Private car	1996	1.2	2.3	4.3	8.1	21.4
Private car	2006	1.2	2.4	4.5	9.1	22.0
Walking and jogging	1996	0.9	1.1	1.4	2.0	3.2
Walking and jogging	2006	0.9	1.1	1.3	2.0	3.3
All modes	1996	1.0	1.9	3.8	8.5	22.7
All modes	2006	1.0	1.9	3.8	8.8	24.7

* ‘Wellington’ comprises Wellington City, Lower Hutt, Porirua, Upper Hutt and Kapiti. Kapiti is included here, but excluded from the definition of ‘Wellington’ in HTS analyses in the body of this report.

** ‘Other mode’ was not included because numbers were too small.

Table A5 Distance travelled to work in Christchurch 1996–2006 (area unit to area unit)

Mode*	Year	Straight-line distance (kilometres): quantiles				
		5%	25%	50%	75%	95%
Bicycle	1996	1.1	1.9	2.6	3.7	6.2
Bicycle	2006	1.2	2.1	3.1	4.4	7.9
Bus or train	1996	2.0	3.1	4.9	6.9	8.6
Bus or train	2006	2.1	3.4	5.2	7.4	9.5
Company car	1996	1.2	2.6	4.8	7.3	12.5
Company car	2006	1.1	2.5	5.2	8.1	15.5
Private car	1996	1.2	2.8	4.8	7.5	15.5
Private car	2006	1.2	3.0	5.4	8.4	17.6
Walking and jogging	1996	0.9	1.1	1.4	2.1	4.1
Walking and jogging	2006	0.9	1.1	1.4	2.1	3.2
All modes	1996	1.0	2.2	4.2	6.9	14.8
All modes	2006	1.0	2.2	4.5	7.5	16.5

* ‘Other mode’ was not included because numbers were too small.

Table A6 Distance travelled to work in all other MUAs in New Zealand 1996–2006 (area unit to area unit)

Mode*	Year	Straight-line distance (kilometres): quantiles				
		5%	25%	50%	75%	95%
Bicycle	1996	1.2	1.6	2.3	3.1	4.7
Bicycle	2006	1.1	1.6	2.2	2.9	4.9
Bus or train	1996	2.2	3.0	3.6	4.1	6.6
Bus or train	2006	2.2	3.0	3.6	4.3	6.4
Company car	1996	1.2	1.8	3.0	5.0	14.0
Company car	2006	1.2	2.0	3.4	6.1	18.6
Private car	1996	1.2	2.1	3.5	5.8	18.2
Private car	2006	1.2	2.2	3.8	6.9	20.0
Walking and jogging	1996	0.9	1.2	1.5	2.0	3.1
Walking and jogging	2006	0.9	1.2	1.5	2.0	3.1
All modes	1996	1.1	1.8	3.1	5.3	16.5
All modes	2006	1.1	1.9	3.4	6.2	19.1

* 'Other mode' was not included because numbers were too small.