



ITLS

**WORKING PAPER**

**ITLS-WP-10-04**

**What does it cost to travel in  
Sydney? Spatial and equity  
contrasts across the  
metropolitan region.**

**By**

**David Hensher and Xiaofen Chen**

**February 2010**

**ISSN 1832-570X**

**INSTITUTE of TRANSPORT and  
LOGISTICS STUDIES**

The Australian Key Centre in  
Transport and Logistics Management

The University of Sydney

*Established under the Australian Research Council's Key Centre Program.*

**NUMBER:** Working Paper ITLS-WP-10-04

**TITLE:** **What does it cost to travel in Sydney? Spatial and equity contrasts across the metropolitan region.**

**ABSTRACT:** There is a strong belief, often perceptual, that residents in the outer suburbs of Sydney are at a transport disadvantage in terms of the generalised cost of daily travel in absolute terms, and in relation to the percentage of income, personal and household, spent each day on travel. This paper investigates this claim using the Sydney Household Travel Survey, an annual survey of randomly selected individuals, from June 1997 to June 2008, a total of 92,413 respondents. We pool the entire data set, adjusting costs for different years, and undertake a spatial interrogation of the data, initially for 13 sub-regions, and then drill down to postcodes to identify sources of systematic variation in the daily generalised cost of travel for individuals and households. In assessing the evidence, we compare public transport outlays with car outlays, where the latter is defined in terms of marginal outlays (i.e., fuel and parking) and all costs (i.e., marginal outlay plus car ownership costs). Given the cost of using public transport (i.e., fares) we speculate that the provision of improved public transport services (and switching from car to some extent) is likely to result in a lower monetary cost of travel, but only if individuals and/or households dispose of vehicles. This seems to apply even where public transport offers a lower travel time, which is not sufficient to compensate for retention of the car. If they retain their cars, then given the lower marginal cost of car use compared to public transport, the contribution of improve public transport translated into a switch of usage from car to public transport will have little impact on accessibility and equity. Hence the entire argument hinges on what response will be made to car ownership in the presence of a non-marginal injection of investment in public transport. The paper also cautions about making statements on mobility equity at a highly spatially aggregate level (i.e., a sub-region), in contrast to establishing the causal links at a more spatially disaggregate level (i.e., the postcode).

**KEY WORDS:** *Household and personal travel, Sydney, travel time, travel cost, generalised cost, public transport, equity, car ownership costs*

**AUTHORS:** David Hensher and Xiaofen Chen

**CONTACT:** Institute of Transport and Logistics Studies (C37)  
The Australian Key Centre in Transport Management  
The University of Sydney NSW 2006 Australia

Telephone: +61 9351 0071  
Facsimile: +61 9351 0088  
E-mail: [itls@sydney.edu.au](mailto:itls@sydney.edu.au)  
Internet: <http://www.itls.sydney.edu.au>

**Acknowledgments:** We thank the Transport Data Centre for all its support in both access to the Sydney Travel Survey and advice in preparing and analysing the data. In particular we thank Tim Raimond and Grace Corpuz. Tim Raimond, Peter Stopher and John Stanley provided useful comments on earlier drafts.

## 1. Introduction

Sydney and its surrounding regions are served by the largest physical public transport system in Australia, including heavy rail, light rail, bus, and ferry. Despite the extensive public transport network, Sydney has fallen behind other Australian cities in its public transport performance, with the growth over the last 10 years of public transport ridership of five percent in contrast to 30-40 percent for Brisbane, Melbourne and Perth. Commentators have suggested that this is attributable to the confusion surrounding public transport planning and insufficient funding of public transport (Glazebrook 2009). The market share for public transport in Sydney has remained somewhat flat over the decade, despite the absolute growth of patronage, with a lack of suitable public transport claimed as a significant barrier to improving social equity for transit-dependent people.

Social equity is a construct defining an equitable outcome for all people through a fair distribution of public services and implementation of public policy, the central element in the distribution of the wealth produced by society (Crompton and Lamb 1998). Urban public transport has an important role to play in facilitating social equity, by providing individuals who are economically, physically and socially disadvantaged with basic mobility and necessary access to public services including markets, employment, health services, and education (Krygsman, *et. al.*, 2004).

The equity implication of public transport can be measured by mobility (physical travel) or accessibility, where the latter represents the ability of individuals to reach desired destinations for different purposes (Todd 2007). Overlying the accessibility objective is the role for public transport to supply a basic level of mobility to low-income populations, since mobility is essential for access to jobs, services, and social activities (Giuliano *et. al.* 2001).

In establishing the overall travel cost associated with movement to and from specific geographical locations within the Sydney metropolitan area, we draw on the Sydney Household Travel Survey (HTS) over a 11-year period<sup>1</sup> up to June 2008, to obtain data on daily travel times and money costs outlaid by individuals and households at two levels of spatial aggregation – a postcode and a sub-region (defined below). Mobility indicators should capture all these aspects of travel. Mobility is measured as personal money, time and generalised expenditure on public transport and private vehicles over the course of one-day period (Nicolas, *et. al.* 2003 and Litman 2009). We source data from the NRMA (2008) on the costs of car ownership by class of vehicle in order to obtain estimates of the annualised cost of car ownership and use.

Together with estimates of average gross personal and household income, and other descriptors of the population at each spatial level (e.g., cars owned per capita), we assess the relationship between the cost of travel, defined as a generalised cost that converts time to money using a behavioural value of travel time savings, and income at both the individual and household level, at a postcode and a sub-region level. We identify the role that public transport currently plays, and the extent to which specific spatial entities are well served by public transport, and the extent to which such locations are public transport deprived in contrast to transport deprived in terms of a number of indicators of the cost of mobility relative to income.

The paper is organised as follows. We begin with an overview of the data sources and the geographical representation of the Sydney metropolitan area. This is followed by definitions of the main data items, namely travel time, travel cost, generalised cost and income. A descriptive analysis of the evidence at a sub-region level is then presented and discussed to highlight the relationship between expenditure on daily travel and income. The next section investigates potential sources of systematic variation in the daily average generalised cost of travel at a postcode level per individual and per household, with particular emphasis on the influence of public transport use in the daily cost of travel. In reporting the evidence we present two levels of cost for car – the marginal user cost (which is fuel and parking costs), and the full cost of use and ownership. The latter is especially relevant when the focus is on equity, a major interest herein.

---

<sup>1</sup> TDC uses "Wave" to define the start year for annual data collection (e.g. Wave 2007 is the period between June 17<sup>th</sup> 2007 and June 14<sup>th</sup> 2008), the HTS data covers a period of 11 years.

## 2. Data description

The primary data used for the research is obtained from the Household Travel Survey (Transport Data Centre 2009) collected by the Transport Data Centre. The survey area is the Greater Metropolitan Area (GMA) of Sydney including the Sydney Statistical Division, Low Hunter Statistical Sub-division and Illawarra Statistical Division (Transport Data Centre 2009). The data was collected by personal interview of randomly selected individuals, continuously undertaken from June 1997 to June 2008 with a total 92,413 respondents. On average, 3,000 to 3,500 households out of 5,000 approached for an interview, fully responded each year. Respondents were asked for information about trips made during the assigned day. Among the data items recorded are attributes of travel (e.g., mode, travel time, fare, distance, and trip purpose), and socioeconomic variables (e.g., gender, age, personal and household income, and place of residence). Out of 92,413 residents in the GMA in the HTS data, the sample used for this research is 77,047, after deleting respondents whose trip destinations were outside the study area, did not travel on the survey day, and who did not report complete information, for example, individuals who only provided information about train fares, but did not specify the ticket type (e.g., weekly or monthly ticket), preventing measurement of the daily travel money expense on train. Approximately 16.4 percent of individuals and 9.46 percent of households in the HTS data did not report any trips on the survey day although they would have undertaken some trips over a weekly period (see Appendix 8 for details for each sub-region). The HTS data is complemented by data from the NRMA (2008) on the cost of car ownership, disaggregated by class of vehicle. The car ownership data comprises depreciation, interest, vehicle charges and fees, and maintenance and repair costs<sup>2</sup>. We have taken into account the differences in mix of vehicle types between each sub-region, and used data from the HTS to identify the vehicle type class share in each sub-region, and applied the average daily cost per vehicle class to obtain a sub-region specific weighted average car ownership cost (see Appendix 7). The cost difference for vehicle classes varies from a low of \$16.55 for light cars to \$34.1 for large SUV's.

There are 13 subregions in the Greater Metropolitan Area (GMA) of Sydney (Transport Data Centre 2009) (Figure 1). Seven subregions are located in Inner and Eastern Sydney, which include Sydney City, East, South, Inner West, Inner North, North, and North East subregions. The other subregions are located in the outer areas of Sydney. They are West Central, North West, South West, Central Coast, Hunter and Illawarra subregions.

The annual gross household and personal income for each subregion is estimated from the household travel survey (HTS) data. Given that the HTS data cover the period from 1997 to 2008, household and personal income are adjusted, based on June 2006 Sydney CPI, to make data more consistent. As expected the economic affluence of subregions will be different (Table 1), as defined by average gross household or personal income. For example, in terms of annual household income, the North Subregion with an average household income of \$107,958 per year is on average more affluent than other areas, while the Central Coast Subregion is the least well off, with an average household income of \$58,020 per year. However, when annual gross personal income is used, the Inner North Subregion becomes the highest average income area in Sydney and the West Central Subregion has the lowest mean personal income. In terms of social equity, the implications may be different depending on which measure of income is selected<sup>3</sup>.

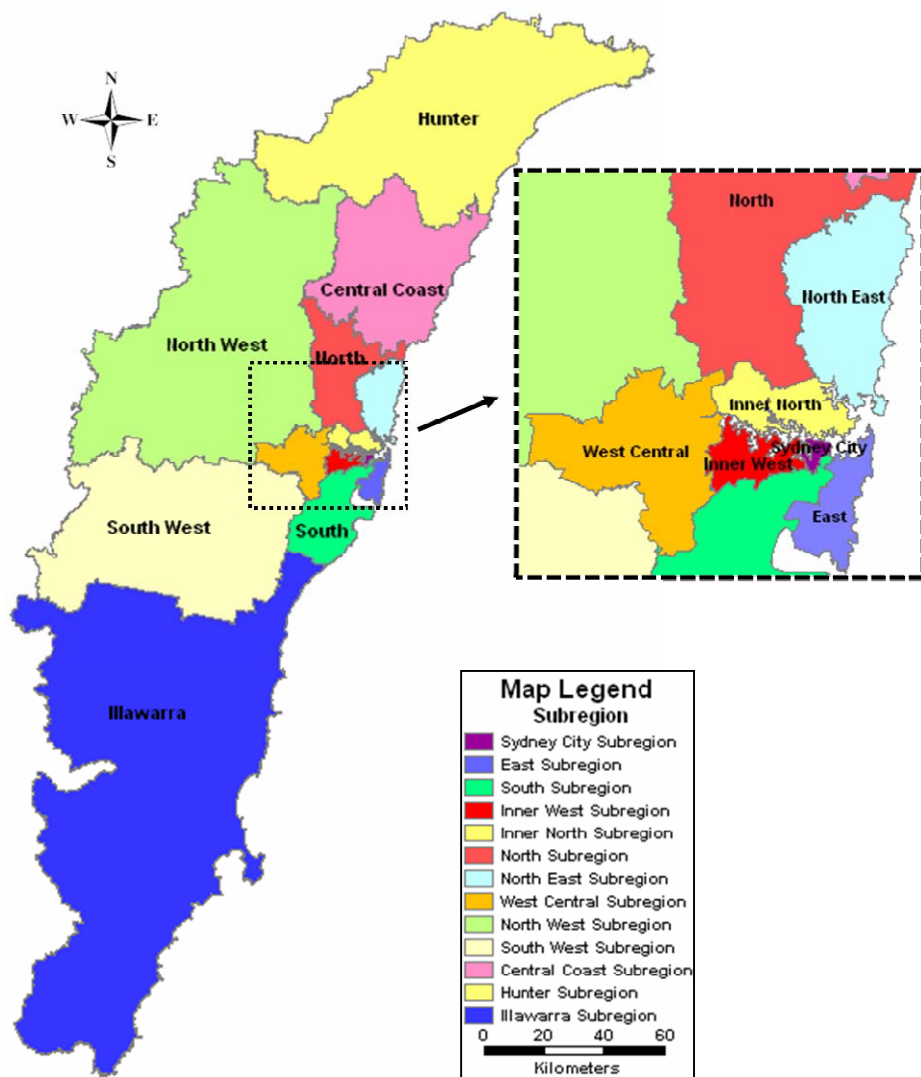
---

2 Usage costs of private vehicle were calculated from the HTS data, while ownership costs were obtained by using the NRMA data. The vehicle classes in HTS data were converted into those in the NRMA data based on the assumption in Appendix 7

3 It is interesting to note that some households will have a high annual household income but a low average personal income simply because of the number of workers. Some commentators have indicated that mobility and accessibility are personal issues; however the support offered through all sources of income produced by the decision unit (which is often a household) are what matter in establishing personal financial capability in purchasing specific mobility and accessibility capability.

*Table 1: Characteristics of subregions by average annual household and personal income*

Metro Subregion	Annual ave gross household income (\$2006)	Annual ave gross personal income (\$2006)
Sydney City	81,464	47,977
East	86,796	46,681
South	74,444	36,872
Inner West	84,416	42,356
Inner North	103,621	55,251
North	107,957	47,906
North East	95,458	47,467
West Central	63,246	29,779
North West	78,694	36,787
South West	68,827	32,120
Central Coast	58,020	30,826
Hunter	61,238	31,227
Illawarra	61,624	31,140



*Figure 1: Subregions of the Greater Metropolitan Area of Sydney*

## 2.1 Travel cost

Table 2 summarises the personal daily travel cost by public transport and private vehicle based on the actual users of each mode. For public transport this is the fare, for car this has a use component and an ownership component. All trip purposes are combined.<sup>4</sup> The percentage of income spent on (public or private) transport is obtained by dividing annual (public or private) travel money cost by annual income. We report separate evidence for public transport and private vehicles; the combined mean (which is not a simple sum of the mean for public transport and car, but a separate calculation from individuals and households), for each subregion, is given in Appendix 5.

We have presented the marginal use costs of car, but focus our comparison of public transport and car on the full costs of car ownership and use, converted to a daily average. Money spent on public transport varies widely across residential locations, from \$3.41 per user per day<sup>5</sup> for the Hunter Subregion to \$17.85 per user per day for the North East Subregion. Individuals living in the affluent subregions located in the east and inner areas of Sydney, tend to spend more on public transport than those in the west. This can be explained largely by the high level of service offered in the areas that are served by the State Transit Authority and the availability of rail services, which are well patronised, in comparison to other areas of Sydney. The variation in daily travel cost by private vehicle between subregions ranges from a high of \$19.95 in Illawarra to a low of \$10.81 for the Sydney City Subregion. Excluding the Sydney City and regions outside of Sydney (i.e., Hunter, Illawarra and Central Coast), the variation in daily average car cost in the Sydney area is between \$14.94 (Inner West) and \$19.87 for the South West region. In general, there is greater reliance on the car for residents living further away from the centre of Sydney; however the disparate destinations for such residents are well served by the car, albeit at a higher daily cost than public transport, and hence there is less patronage activity (and hence lower cost outlaid) on public transport.

**Table 2 Personal daily travel cost by mode and residential subregion, and percentage of annual income allocated to public transport and private vehicle, HTS 1997-2008**

Residential Subregion	Travel cost, \$ per person per day			% of annual household income allocated to travel			% of annual personal income allocated to travel		
	Public transport	Private vehicle		Public transport	Private vehicle		Public transport	Private vehicle	
		Usage	All cost		Usage	All cost		Usage	All cost
Sydney City	11.56	2.78	10.81	5.18%	1.25%	4.84%	8.79%	2.11%	8.23%
East	15.28	2.50	15.39	6.43%	1.05%	6.47%	11.95%	1.95%	12.03%
South	8.60	2.79	16.69	4.22%	1.37%	8.18%	8.51%	2.76%	16.52%
Inner West	11.53	2.53	14.94	4.99%	1.09%	6.46%	9.94%	2.18%	12.87%
Inner North	14.75	2.90	16.24	5.20%	1.02%	5.72%	9.74%	1.92%	10.73%
North	7.54	3.12	18.63	2.55%	1.05%	6.30%	5.74%	2.38%	14.19%
North East	17.85	2.95	17.15	6.83%	1.13%	6.56%	13.73%	2.27%	13.19%
West Central	7.17	2.59	16.72	4.14%	1.49%	9.65%	8.79%	3.17%	20.49%
North West	6.49	3.98	19.76	3.01%	1.85%	9.17%	6.44%	3.95%	19.61%
South West	5.91	4.26	19.87	3.13%	2.26%	10.54%	6.72%	4.84%	22.58%
Central Coast	9.66	3.97	19.67	6.08%	2.50%	12.37%	11.44%	4.70%	23.29%
Hunter	3.41	3.74	19.65	2.03%	2.23%	11.71%	3.99%	4.37%	22.97%
Illawarra	4.85	3.90	19.95	2.87%	2.31%	11.82%	5.68%	4.57%	23.39%

Table 2 shows that the proportion of income spent on public transport is higher than the proportion spent on the marginal cost of car use; however when the cost of car ownership is included, the daily car cost relative to public transport is higher in the outer region but surprisingly similar in inner regions such as Sydney City, East, Inner north, and north east. The percentage of annual household income spent on public transport is highest for the North East Subregion (6.83% of household income) and lowest for the Hunter Subregion (2.03% of household income). The percentage of total private automobile travel cost varies between regions, accounting for between 4.8% (for Sydney City Subregion) and 12.37% (for Central Coast Subregion) of household income (see Figure 2). A similar result can be observed, when the share of transport is measured on the basis of personal income

<sup>4</sup> This may result in estimates that are on the high side, but they are comparable across regions.

<sup>5</sup> This figure and all other results in this section (and the next sections on travel time and generalised cost) refer to the amount, on average, outlaid by those individuals *who actually used the mode*. It does not include the individuals who did not use that mode who are resident in the region.

(Figure 3). Graphs of the amount of travel cost for public and private transport are presented in Figures A1.1 to 1.3 (See Appendix 2).

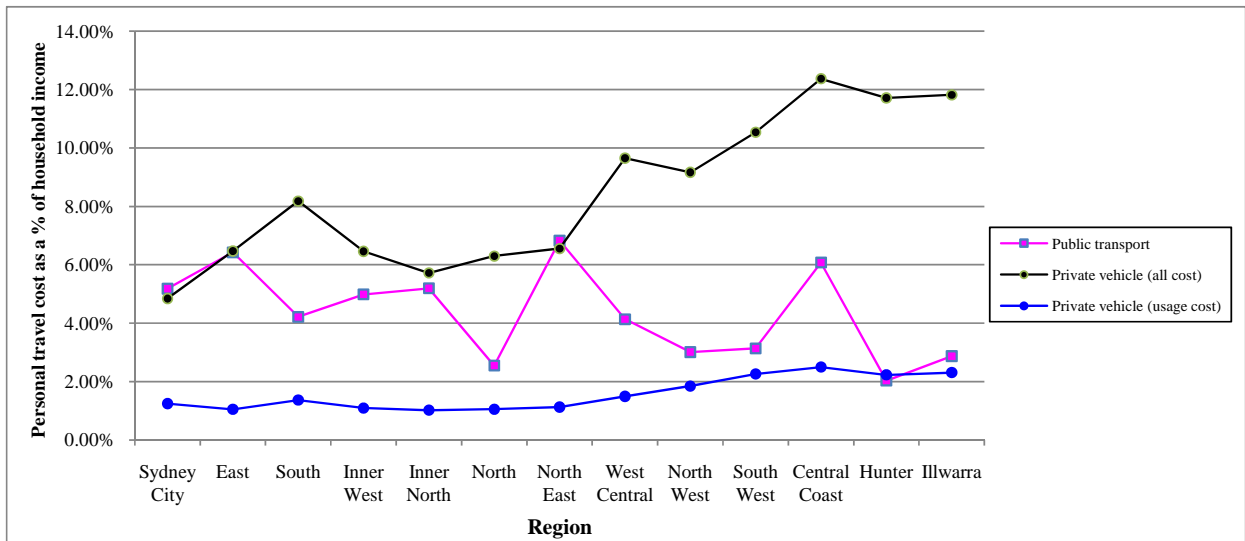


Figure 2: Personal travel cost by public transport and private vehicle as a percentage of household income by region

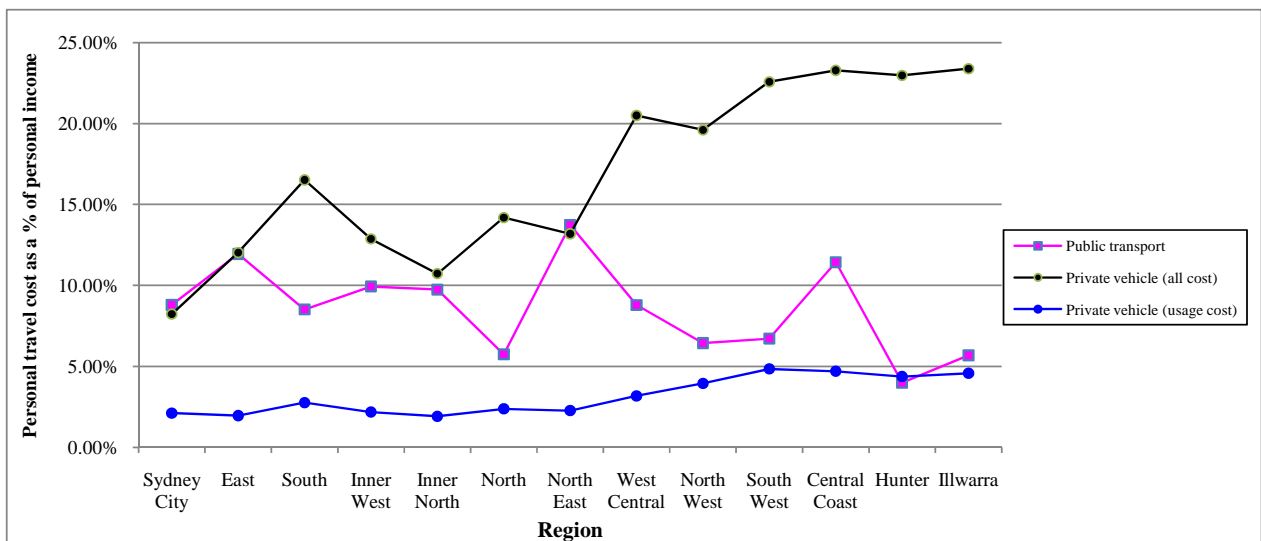


Figure 3: Personal travel cost by public transport and private vehicle as a percentage of personal income by region

## 2.2 Travel time

We report separate evidence for public transport and private vehicles; the combined mean for each subregion which is not a simple sum of the mean for public transport and car, but a separate calculation from individuals and households, is given in Appendix 5. According to the travel time data (See Table 3), residents in the Central Coast Subregion spend more time using public transport (84.85 minutes per user per day) than residents in other areas, and people in the Sydney City Subregion spend the least time travelling on public transport (40.25 minutes per user per day). The travel time by public

transport for Sydney' west is higher than that for the eastern and inner subregions. This result differs from that obtained for money spent on public transport. Average travel time by car is very similar across regions (about 70 minutes per user per day) with the exception that people in the North West and South West Subregions spend a little more time on car travel, respectively 76.44 and 77.22 minutes per user per day. By comparing, the time spent on both modes, we see that car travel time is higher than by public transport for most areas of Sydney except for the Central Coast Subregion. The graph of the amount of travel time on public and private transport is given in Figure A2.1 (See Appendix 2).

*Table 3: Personal daily travel time by mode and residential subregion, HTS 1997-2008*

Residential Subregion	Travel time, minute per person per day	
	Public transport	Private vehicle
Sydney City	40.25	68.27
East	49.16	66.39
South	55.77	69.74
Inner West	51.66	66.36
Inner North	46.12	68.57
North	59.62	71.22
North East	61.38	69.14
West Central	59.96	66.81
North West	66.65	76.44
South West	72.2	77.22
Central Coast	84.85	71.78
Hunter	55.41	66.31
Illawarra	64.63	66.2

### 2.3 Generalised cost

Travel cost and time can be combined as the generalised cost of travel. Time has been converted to money using a behavioural value of travel time savings (VTTS) per person hour for each mode as follows: \$16 for car commuting, \$12 for car non-commuting, and \$22 for travel as part of work; \$9 for public transport commuting or non-commuting. Walking and other modes are assigned the same VTTS as public transport. We report separate evidence for public transport and private vehicles; the combined mean, which is not a simple sum of the mean for public transport and car, but a separate calculation from individuals and households, for each subregion is given in Appendix 5.

As indicated in Table 4, the generalised cost for daily travel by public transport ranges from \$27.55 per user per day for the North East Subregion to \$11.94 per user per day for Hunter Subregion, a result similar to that observed for travel cost only on public transport. In contrast, the average daily generalised cost of travel by private vehicle varies from \$26.26 for Sydney City to \$37.96 for the South West Subregion, with the majority of daily car cost outlays in the \$30-\$35 range. If only the marginal user cost of car is taken into account, generalised cost of public transport and car use are on average very similar; however in the East, Inner West, Inner North, North East, and Central Coast Subregions, the generalised cost of public transport travel is higher than for car travel. The reverse is the case for the other regions except for the Sydney City Subregion, where the generalised use cost for each mode is very similar.

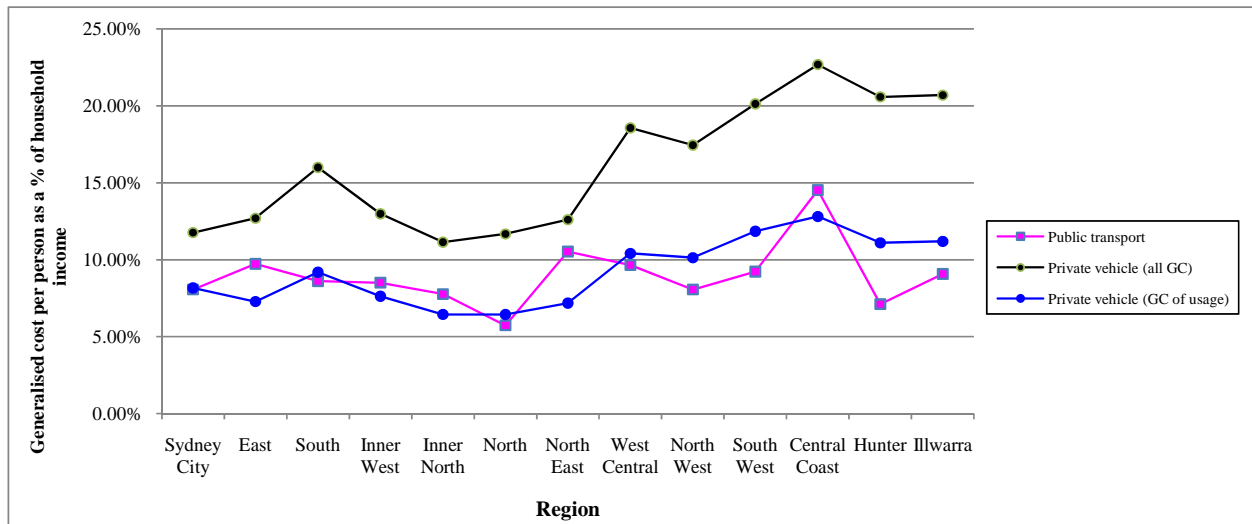
When related to income, the generalised cost of daily travel as a percentage of household income indicates that the generalised cost by public transport is highest for the Central Coast Subregion (14.53%), followed by North East Subregion (10.53%), and lowest for the North Subregion (5.74%). Similarly, private vehicle generalised (use and ownership) cost as a percentage of household income varies between 22.69% of household income in the Central Coast Subregion and 11.14% in the Inner North Subregion. A similar spatial pattern exists relative to personal income. What we see in Figures 4



and 5 is an increasing generalised cost expressed as a percentage of income for regions further away from the central business district. Graphical maps of the generalised cost of public and private transport are shown in Figure A3.1, A3.2, and A3.3 (See Appendix 2).

**Table 4: Personal daily generalised cost by mode and residential subregion and percentage of annual income for generalised cost of public transport and private vehicle, HTS 1997-2008**

Residential Subregion	Generalised cost, \$ per person per day			GC as a % of annual household income			GC as a % of annual personal income		
	Public transport	Private vehicle		Public transport	Private vehicle		Public transport	Private vehicle	
		Usage	All GC		Usage	All GC		Usage	All GC
Sydney City	18.00	18.23	26.26	8.06%	8.17%	11.77%	13.69%	13.87%	19.98%
East	23.15	17.32	30.21	9.74%	7.28%	12.70%	18.10%	13.54%	23.62%
South	17.57	18.75	32.65	8.61%	9.19%	16.01%	17.39%	18.56%	32.32%
Inner West	19.68	17.64	30.05	8.51%	7.63%	12.99%	16.96%	15.20%	25.89%
Inner North	22.07	18.30	31.64	7.77%	6.45%	11.14%	14.58%	12.09%	20.90%
North	16.98	19.04	34.55	5.74%	6.44%	11.68%	12.94%	14.51%	26.32%
North East	27.55	18.79	32.99	10.53%	7.18%	12.61%	21.18%	14.45%	25.37%
West Central	16.73	18.05	32.18	9.66%	10.42%	18.57%	20.51%	22.12%	39.44%
North West	17.39	21.85	37.63	8.07%	10.13%	17.45%	17.25%	21.68%	37.34%
South West	17.40	22.35	37.96	9.23%	11.85%	20.13%	19.77%	25.40%	43.14%
Central Coast	23.10	20.37	36.07	14.53%	12.81%	22.69%	27.35%	24.12%	42.70%
Hunter	11.94	18.63	34.54	7.12%	11.10%	20.59%	13.96%	21.78%	40.37%
Illwarra	15.33	18.90	34.95	9.08%	11.19%	20.70%	17.97%	22.15%	40.97%



**Figure 4: Generalised cost of travel per person by public transport and private vehicle as a percentage of household income by region**

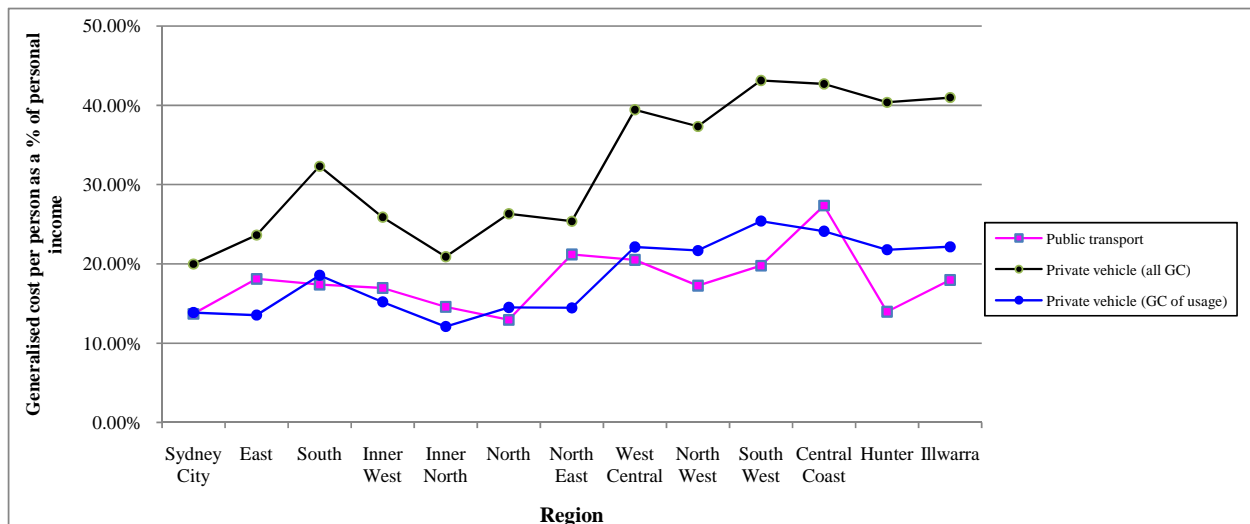


Figure 5: Generalised cost of travel per person by public transport and private vehicle as a percentage of personal income by region

### 3. Identifying influences on spatial differences in generalised cost of daily travel

The descriptive overview in the previous section provides evidence of differences in travel costs and times of actual users of each mode and the relationship to income. What it does not reveal is the extent to which variations in the daily generalised cost of travel can be explained by systematic sources of influence. In this section we investigate candidate influences at the postcode level using ordinary least squares (OLS) regression models, where generalised cost is defined at the individual level, and at the household level. A full list of explanatory variables is given in Appendix 1. They include socioeconomic and travel-related characteristics and year and subregion dummies.

Eight regression models are estimated for personal generalised cost, which include different income and travel distance variables. Four models are constructed to study how different travel distance variables influence generalised cost per household. Different functional forms (linear, square root, natural logarithmic, double natural logarithmic) are also investigated; the best results in terms of adjusted R square and standard error of the estimate are obtained using double logarithmic models. These models have the attraction of readily translatable parameter estimates as elasticity measures.

#### 3.1 Assessment of generalised cost and income

Descriptive statistics are summarised in Tables 5 and 6. Generalised cost of daily travel by all modes is \$22.17 per person and \$53.11 per household on average, when car ownership costs are excluded, and \$36.59 per person and \$82.04 per household when car ownership costs are included. The percentage of generalised cost that is allocated to travel time is very close at the individual and household levels (78.30% versus 78.20%). Average vehicle ownership per household is 1.58. It is not surprising to note that the modal share for public transport is close to 13% (12.65% of personal trips and 12.75% of household trips). The average daily distance travelled is 37.22 km per person and 91.00 km per household, respectively. The scatter plots for personal and household generalised cost are provided in Appendices 3 and 4 respectively.

**Table 5: Aggregate descriptive statistics of variables in the personal generalised cost model**

	Minimum	Maximum	Mean	Std. Deviation	Skewness			Kurtosis		
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Ratio	Statistic	Std. Error	Ratio
Personal generalised cost on all modes (excluding ownership cost of private vehicle)	6.17	49.80	22.17	6.03	0.73	0.050	15	1.12	0.100	11
Personal generalised cost on all modes (including all cost of private vehicle)	14.30	67.29	36.59	7.38	0.46	0.050	9	0.74	0.100	7
Annual household income	9729	201068	78981	30417	0.71	0.050	14	0.47	0.100	5
Annual personal income	8480	102193	39099	14818	0.93	0.050	19	1.07	0.100	11
Household vehicle ownership	0.11	3.75	1.58	0.50	0.48	0.050	10	0.76	0.100	8
Share of generalised cost allocated to travel time	49.55%	98.01%	78.30%	7.48%	-1.10	0.050	-22	1.44	0.100	14
Share of public transport	0.43%	52.00%	12.65%	9.64%	1.35	0.050	27	1.65	0.100	16
Personal travel distance	7.35	107.57	37.22	17.18	1.08	0.050	22	1.17	0.100	12
Std.deviation of personal travel distance	1.56	129.02	37.28	20.73	1.14	0.050	23	1.32	0.100	13
Mean-centered personal daily travel distance	-30.94	69.27	-1.07	17.18	1.08	0.050	22	1.17	0.100	12
Square of mean-centered personal daily travel	3.29	16954.34	2022.05	2245.76	2.67	0.050	53	8.86	0.100	88
Distance to CBD	1.28	194.00	34.15	34.96	1.53	0.050	31	1.50	0.100	15

**Table 6: Aggregate descriptive statistics of variables in the household generalised cost models**

	Minimum	Maximum	Mean	Std. Deviation	Skewness			Kurtosis		
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Ratio	Statistic	Std. Error	Ratio
Household generalised cost on all modes (excluding ownership cost of private vehicle)	12.35	127.43	53.11	17.78	0.75	0.050	15	1.004	0.100	10
Household generalised cost on all modes (including all cost of private vehicle)	14.58	188.11	82.04	23.32	0.56	0.050	11	0.625	0.100	6
Annual household income	9729	218318	78971	30643	0.76	0.050	15	0.677	0.100	7
Annual personal income	8480	112050	39226	15111	1.03	0.050	21	1.490	0.100	15
Household vehicle ownership	0.11	3.75	1.58	0.50	0.44	0.050	9	0.695	0.100	7
Share of generalised cost allocated to travel time	48.58%	98.01%	78.20%	7.57%	-1.11	0.050	-22	1.462	0.100	15
Share of public transport	0.43%	52.17%	12.75%	9.73%	1.35	0.050	27	1.673	0.100	17
Household travel distance	12.18	287.87	91.00	49.46	1.14	0.050	23	1.302	0.100	13
Std.deviation of household travel distance	0.07	292.90	82.53	50.00	1.22	0.050	24	1.570	0.100	16
Mean-centered household daily travel distance	-79.14	196.55	-0.32	49.46	1.14	0.050	23	1.302	0.100	13
Square of mean-centered household daily travel distance	190.77	101494.25	10643.44	12899.76	2.88	0.050	57	9.802	0.100	98
Distance to CBD	1.28	194.00	34.17	35.01	1.52	0.050	30	1.464	0.100	15

### 3.2 Daily average generalised cost per person

Table 7 (Models 1-4) and 8 (Models 5-8) summarise the models for average daily generalised cost per person per postcode, excluding and including car ownership costs. The models explain 43 percent to 49 percent of the variation in daily generalised cost when travel characteristics are measured by mean-centered personal daily travel distance and its square. However, when the previous distance variables are replaced with average personal travel distance and its standard deviation (Model 3, 4, 7 and 8), the overall goodness-of-fit improves significantly, with an adjusted  $R^2$  of 0.755 when car ownership costs are excluded and 0.663 and 0.668 when car ownership costs are included; hence about 66-76 percent of the variation in personal generalised cost can be explained by the explanatory variables in models 3, 4, 7 and 8.

Household income is found to be a significant positive factor explaining variations in personal generalised cost for all four models when car ownership costs are excluded, with household income elasticities of personal generalised cost being 0.031 to 0.164 for models 3 and 1, indicating that a one percent increase in household income leads to a 0.031 and a 0.164 percentage increase in generalised cost, all other factors held constant. When car ownership costs are included household income is not statistically significant although the personal income elasticity is significant. The personal income elasticities (0.043 and 0.163) for models 4 and 2 are similar to the household income elasticities; when car ownership costs are included the personal income elasticities are 0.048 to 0.093 for models 6 and 8. Given our preference for model 8 over model 6 (the difference being in the treatment of distance), the personal direct generalised cost elasticity with respect to personal income is 0.093, very inelastic.

It is interesting to note that household vehicle ownership does not have a statistically significant impact on generalised cost when car ownership costs are excluded, but is statistically significant and

positive when car ownership costs are accounted for. The direct elasticity of generalised cost with respect to car ownership in Table 8 (model 8) is 0.167, suggesting that a 10 percent increase in the average number of cars per household results in an increase in average daily generalised cost per person of \$1.67. A clear negative linkage between personal generalised cost and its share allocated to travel time is observed in all models in Tables 7 and 8, with estimated coefficients (and direct elasticities) of -0.759 and -0.452 from the preferred models (4 and 8). An important point to note is that the public transport modal share has a positive influence on generalised travel cost in three models when car ownership costs are excluded (estimated elasticities are 0.14 and 0.19 (twice)), but is not statistically significant when car ownership costs are included. This suggests that public transport plays an important role, more so than the private vehicle, in explaining variations in generalised cost between postcodes only when car ownership costs are excluded.

There are mixed findings on the influence of travel distance on generalised cost. A negative influence is found when distance is measured by the absolute value of mean-centered personal travel distance. Conversely, the square of mean-centered personal travel distance appears to positively impact personal generalised cost. Similarly, with the increase in average travel distance, generalised cost increases as well, while there is an inverse relationship between the standard deviation of travel distance and generalised cost.

With regards to the year-specific dummies, only the years between June 2004 and June 2008 were statistically significant, with personal generalised cost in this period tending to be higher than in the previous years. The straight line distance to the CBD is found to be inversely related to generalised cost, which suggests that residents in postcodes around the centre of Sydney tend to have a greater generalised cost than those in locations further away from the CBD. One major reason, given the evidence in Section 2, is that residents located closer to the CBD of Sydney use public transport far more often, and hence spend more on public transport due to its high level of service. Public transport does not serve the outer postcodes as well, and hence the reliance on the car (with a lower marginal cost of use, although clearly higher overall costs when ownership costs are included) is greater. However what is especially interesting is the important role that the car plays (once acquired) in offering a very attractive and relatively low cost alternative to public transport, which may be difficult to replicate by public transport (given the disparate nature of trip destinations), without a substantial increase in public transport infrastructure to improve travel times and service frequency.

The coefficient estimates of subregion dummies show changing signs when different travel distance variables are entered into the regression models. For models 1 and 2 which exclude car ownership costs (which also include the absolute value of mean-centered personal travel distance and its square), inhabitants in the South West Subregion have the highest personal generalised cost for all modes than those in other areas, while the Illawarra subregion has the lowest generalised cost. In models 3 and 4, people living in Sydney City and West Central subregions have the highest generalised cost by all modes compared to other areas, and residents in Central Coast Subregion have the lowest generalised cost. When car ownership costs are included, the statistical significance of subregions dummies is limited to only the north, north west and south west in models 5 and 6, with positive parameters, suggesting higher generalised costs per day per person for these subregions after accounting for the other influences; whereas there were no statistically significant subregion dummy variables in the preferred models 7 and 8. This suggests that the inclusion of car ownership costs appears to reduce the heterogeneity between sub-regions in respect of mean daily personal generalised cost.

**Table 7: Regression models for personal generalised cost (excluding ownership cost of private vehicle)**

Dependent variable: Natural logarithm of personal generalised cost								
Independent Variable	Model 1		Model 2		Model 3		Model 4	
	Coeff	t-value	Coeff	t-value	Coeff	t-value	Coeff	t-value
Constant	0.108	0.78	0.16	1.07	0.989	11	0.885	9.14
LN (annual household income)	0.164	13.42	na	na	0.031	3.75	na	na
LN (annual personal income)	na	na	0.163	11.93	na	na	0.043	4.54
LN (household vehicle ownership)								
LN (share of generalised cost that allocated to time)	-0.808	-16.58	-0.845	-18.05	-0.758	-24.34	-0.759	-24.05
LN (share of public transport)	0.014	2.15			0.019	4.59	0.019	4.6
LN (personal travel distance)	na	na	na	na	0.615	50.51	0.616	51.35
LN (Standard deviation of personal travel distance)	na	na	na	na	-0.073	-8.28	-0.074	-8.46
LN (Absolute value of mean-centered personal travel distance)	-0.018	-4.42	-0.019	-4.51	na	na	na	na
LN (Square of Mean-centered personal travel distance)	0.147	26.18	0.147	26.18	na	na	na	na
LN (Straight line distance to CBD)	-0.036	-6.07	-0.032	-5.41	-0.108	-25.6	-0.106	-24.43
Year dummy (2000 to 2003)								
Year dummy (2004 to 2007)	0.026	2.91	0.022	2.5	0.03	5.1	0.028	4.78
East Subregion dummy								
South Subregion dummy	0.051	3.7	0.074	5.14				
Inner West Subregion dummy			0.049	2.74				
Inner North Subregion dummy					-0.037	-3.1	-0.037	-3.11
North Subregion dummy	0.076	4.16	0.11	6.01	-0.038	-3.31	-0.034	-2.91
North East Subregion dummy	0.07	3.77	0.083	4.4				
West Central Subregion dummy	0.055	3.84	0.081	5.41			0.02	2.15
North West Subregion dummy	0.085	5.23	0.104	6.29	-0.03	-2.86	-0.025	-2.37
South West Subregion dummy	0.135	7.29	0.16	8.5	-0.038	-3.09	-0.031	-2.5
Central Coast Subregion dummy					-0.059	-3.76	-0.056	-3.58
Hunter Subregion dummy								
Illawarra Subregion dummy	-0.046	-2.43	-0.043	-2.26	-0.05	-4.07	-0.046	-3.74
Number of cases	2387							
R-squared	0.439		0.432		0.756		0.757	
Adjusted R <sup>2</sup>	0.436		0.429		0.755		0.755	
Std. Error of the Estimate	0.205		0.207		0.135		0.135	

Variables marked with **na** are not entered into model

**Table 8: Regression models for personal generalised cost (including all cost of private vehicle)**

Dependent variable: Natural logarithm of personal generalised cost								
Independent Variable	Model 5		Model 6		Model 7		Model 8	
	Coeff	t-value	Coeff	t-value	Coeff	t-value	Coeff	t-value
Constant	2.856	104.470	1.876	17.229	2.458	115.108	1.961	22.943
LN (annual household income)			na	na			na	na
LN (annual personal income)	na	na	0.093	9.195	na	na	0.048	6.005
LN (household vehicle ownership)	0.293	30.046	0.251	24.040	0.184	22.370	0.167	19.425
LN (share of generalised cost that allocated to time)	-0.544	-16.785	-0.484	-14.824	-0.484	-18.922	-0.452	-17.448
LN (share of public transport)								
LN (personal travel distance)	na	na	na	na	0.356	34.528	0.348	33.656
LN (Standard deviation of personal travel distance)	na	na	na	na	-0.050	-6.573	-0.048	-6.438
LN (Absolute value of mean-centered personal travel distance)	-0.015	-4.906	-0.012	-4.230	na	na	na	na
LN (Square of Mean-centered personal travel distance)	0.081	20.182	0.078	19.731	na	na	na	na
LN (Straight line distance to CBD)	-0.036	-9.728	-0.017	-4.144	-0.057	-19.393	-0.047	-13.824
Year dummy (2000 to 2003)								
Year dummy (2004 to 2007)	0.049	7.598	0.040	6.311	0.047	9.281	0.042	8.353
East Subregion dummy								
South Subregion dummy								
Inner West Subregion dummy								
Inner North Subregion dummy								
North Subregion dummy			0.033	2.674				
North East Subregion dummy								
West Central Subregion dummy								
North West Subregion dummy	0.034	3.101	0.035	3.218				
South West Subregion dummy	0.049	3.806	0.062	4.935				
Central Coast Subregion dummy								
Hunter Subregion dummy								
Illawarra Subregion dummy								
Number of cases	2386							
R-squared	0.465		0.487		0.664		0.669	
Adjusted R <sup>2</sup>	0.464		0.485		0.663		0.668	
Std. Error of the Estimate	0.149		0.146		0.118		0.117	

Variables marked with **na** are not entered into model

### 3.3 Daily average generalised cost per household

When daily generalised cost by all modes per household is analysed, similar results are obtained (Tables 9 and 10 excluding and including car ownership costs). Household income is found to have a significant effect on generalised cost per household, with income elasticities of 0.047 and 0.192 for the models 9 and 10 when car ownership costs are excluded and 0.149 and 0.030 when ownership costs are included. This indicates that a 10 percent increase in household income results in an increase of generalised cost of 0.47 and 1.92 percent, for each model in the absence of ownership costs and 1.49 and 0.3 percent when ownership costs are accounted for. An important finding, that is different from the personal generalised cost models, is that the number of vehicles in a household becomes statistically significant for all models and has a positive elasticity impact on the generalised cost of all modes; for the preferred models 10 and 12 it is 0.081 and 0.316 respectively. Again, a negative impact on the percentage of travel time cost in generalised cost is observed, with the positive influence of the share of public transport only appearing in model 9. Mixed results on travel distance are also produced, when different travel distance variables are studied separately. The negative signs of the coefficients for distance to the CBD suggest that households closer to the centre of Sydney have higher generalised cost for all modes than those postcodes further away. Year dummy variables are insignificant in models that exclude car ownership costs, suggesting that generalised cost at the household level does not systematically vary over time between postcodes; however it is positive and statistically significant for 2004-2007 for the preferred model 12 that accounts for car ownership costs, indicating that, all other influences held constant, that average daily generalised cost per

household has increased in the period 2004-07 compared to the earlier periods for reasons not explained by the other influences.

**Table 9: Regression models for household generalised cost (excluding ownership costs of private vehicle)**

Dependent variable: Natural logarithm of household generalised cost				
Independent Variable	Model 9		Model 10	
	Coeff	t-value	Coeff	t-value
Constant	0.448	2.26	0.960	8.27
LN (annual household income)	0.192	11.18	0.047	4.46
LN (household vehicle ownership)	0.375	18.04	0.081	6.45
LN (share of generalised cost that allocated to time)	-0.512	-9.25	-0.591	-18.93
LN (share of public transport)	0.031	3.90		
LN (household travel distance)	na	na	0.689	60.62
LN (Standard deviation of household travel distance)	na	na	-0.089	-11.94
LN (Mean-centered household travel distance)	-0.036	-7.05		
LN (Square of Mean-centered household travel distance)	0.147	22.23		
LN (Straight line distance to CBD)	-0.027	-3.57	-0.118	-25.48
Year dummy (2000 to 2003)				
Year dummy (2004 to 2007)				
East Subregion dummy				
South Subregion dummy	0.043	2.72		
Inner West Subregion dummy				
Inner North Subregion dummy	-0.061	-2.89	-0.062	-4.93
North Subregion dummy	0.065	3.10	-0.039	-3.18
North East Subregion dummy				
West Central Subregion dummy				
North West Subregion dummy	0.102	5.46	-0.030	-2.66
South West Subregion dummy	0.147	6.79	-0.039	-2.95
Central Coast Subregion dummy			-0.092	-5.56
Hunter Subregion dummy				
Illawarra Subregion dummy	-0.063	-2.92	-0.065	-5.00
Number of cases	2382			
R-squared	0.508		0.825	
Adjusted R <sup>2</sup>	0.506		0.824	
Std. Error of the Estimate	0.242		0.144	

Variables marked with **na** are not entered into model

*Table 10: Regression models for household generalised cost (including all costs of private vehicle)*

Dependent variable: Natural logarithm of household generalised cost				
Independent Variable	Model 11		Model 12	
	Coeff	t-value	Coeff	t-value
Constant	1.686	14.077	2.290	23.511
LN (annual household income)	0.149	14.567	0.030	3.463
LN (household vehicle ownership)	0.484	38.739	0.316	30.380
LN (share of generalised cost that allocated to time)	-0.373	-10.132	-0.371	-14.445
LN (share of public transport)				
LN (household travel distance)	na	na	0.450	50.869
LN (Standard deviation of household travel distance)	na	na	-0.069	-11.601
LN (Mean-centered household travel distance)	-0.022	-5.976	na	na
LN (Square of Mean-centered household travel distance)	0.086	19.337	na	na
LN (Straight line distance to CBD)			-0.058	-15.433
Year dummy (2000 to 2003)				
Year dummy (2004 to 2007)			0.028	5.479
East Subregion dummy			0.049	4.739
South Subregion dummy	0.067	6.017	0.039	4.894
Inner West Subregion dummy	0.038	2.760	0.028	2.750
Inner North Subregion dummy				
North Subregion dummy			0.023	2.289
North East Subregion dummy				
West Central Subregion dummy	0.091	7.900	0.063	7.830
North West Subregion dummy	0.092	7.342		
South West Subregion dummy	0.111	7.572		
Central Coast Subregion dummy			-0.048	-3.709
Hunter Subregion dummy				
Illawarra Subregion dummy				
Number of cases	2381			
R-squared	0.661		0.844	
Adjusted R <sup>2</sup>	0.660		0.843	
Std. Error of the Estimate	0.171		0.116	

Variables marked with **na** are not entered into model

## 4. Commentary and conclusions

This paper has investigated the relationship between the average daily monetary cost, travel time and generalised cost of travel per person and per household, and average gross personal and household income, in presence and absence of car ownership costs. Using the Sydney Household Travel Survey, a continuous survey of 3,000 to 3,500 households per annum, we are able to identify the amount spent on travel in terms of money and time, at a postcode and a sub-region level. We are specifically interested in identifying the proportion of income that is spent on daily travel, as a way of seeing if individuals and households located in the outer suburbs (especially in the west, south west and north west) spend more in absolute terms, and as a percentage of income, on travel. This is one indicator of the relative cost of mobility, and when related to the availability of public transport (proxied by its use), is an indicator of the role that public transport plays in defining the cost of mobility. Tables 11 and 12 and Figure 6 summarise the main descriptive evidence, drawn from Tables in Appendix 5.

Given the emphasis on mobility and equity, we focus the commentary on the costs that include the annualised cost of car ownership. In terms of monetary outlay only (see also Appendix 5 Tables B1 and B4), travellers from the north west, south west and west central not only spend more in total on their daily travel (around an average of \$20.47 per person or \$45.97 per household), compared to residents in the East (\$19.5 and \$37.94), Inner west (\$17.74 and \$36.72), inner north (20.09 and



\$39.23), the north (\$20.21 and \$46.14) and the north east (\$20.1 and \$42.21); they also outlay a higher percentage of their personal and household income on travel, in line with lower mean income, with a range varying from 20.31 to 24.41 percent of personal income (approximately \$1 in every \$4 earned) and 9.49 to 10.8 percent of household income (approximately \$1 in every \$10 earned). This compares to a range for the rest of Sydney (excluding the Central Coast, Illawarra and Hunter) a range varying from 11.07 to 15.24 percent of personal income (approximately \$1 in every \$9 earned) and 6.52 to 8.94 percent of household income (approximately \$1 in every \$12 earned). The outer subregions (Central Coast, Illawarra and Hunter) outlay the highest percent of personal and household income on monetary travel costs although the amount is on average similar to the west central, north west and south west of Sydney. The story is similar in Table 12 for average daily household monetary outlay on travel.

In terms of travel time outlay (see also Appendix 5 Tables B and B5), the person mean daily average time spent travelling is very similar across the regions, from a low of 73.96 minutes (or 1.25 hours) for the Hunter to a high of 88.19 minutes (or 1.5 hours) for the North region. The household range is from 146 minutes for the Sydney City Subregion and 233 minutes for the north region, a range of 3 to 6 hours per household per day. The north west, south west and wet central regions are very similar to the regions closer to the CBD.

Tables 11 and 12 (reproduced from Appendix 5) summarise the descriptive evidence at a subregion level for generalised cost when time and monetary outlays are summed for all modes combined. The average generalised cost per person per day varies from a low of \$30.14 for Sydney City to a high of \$39.42 for the South West. This difference, while clear, is not as high in percentage terms as the differences in monetary outlays, due to the reduced variance in travel times between the sub-regions. However expressed as a percentage of personal and household income, the differences are very marked. If we use generalised cost as the appropriate measure of the cost of accessibility, and income (personal or household) is an indicator of financial capability, the evidence (Figure 6) suggests that residents in the outer suburbs of Sydney are disadvantaged by a substantial amount

**Table 11: Average personal daily travel by all modes**

Residential Subregion	\$ per person per day					% of annual household income				% of annual personal income			
	Travel cost		Travel time	Generalised cost		Travel cost		Generalised cost		Travel cost		Generalised cost	
	Usage	All cost		Usage	All GC	Usage	All cost	Usage	All GC	Usage	All cost	Usage	All GC
Sydney City	6.51	14.55	83.59	22.1	30.14	2.92%	6.52%	9.90%	13.50%	4.96%	11.07%	16.82%	22.93%
East	6.61	19.50	81.39	22.7	35.59	2.78%	8.20%	9.55%	14.97%	5.17%	15.24%	17.75%	27.83%
South	4.33	18.22	82.55	21.35	35.24	2.12%	8.94%	10.47%	17.28%	4.29%	18.04%	21.13%	34.89%
Inner West	5.34	17.74	82.79	21.82	34.23	2.31%	7.67%	9.44%	14.80%	4.60%	15.29%	18.80%	29.50%
Inner North	6.75	20.09	84.78	23.79	37.13	2.38%	7.07%	8.38%	13.08%	4.46%	13.27%	15.72%	24.53%
North	4.7	20.21	88.19	22.83	38.34	1.59%	6.83%	7.72%	12.96%	3.58%	15.39%	17.39%	29.21%
North East	5.9	20.10	84.74	23.55	37.75	2.26%	7.68%	9.00%	14.43%	4.54%	15.45%	18.11%	29.02%
West Central	3.54	17.67	77.64	19.82	33.95	2.04%	10.20%	11.44%	19.59%	4.33%	21.65%	24.29%	41.61%
North West	4.69	20.47	85.76	23.49	39.27	2.17%	9.49%	10.90%	18.22%	4.65%	20.31%	23.31%	38.97%
South West	4.81	20.42	86.83	23.81	39.42	2.55%	10.83%	12.63%	20.91%	5.46%	23.20%	27.06%	44.80%
Central Coast	4.92	20.62	84.51	22.77	38.46	3.10%	12.97%	14.32%	24.20%	5.83%	24.41%	26.96%	45.54%
Hunter	3.8	19.72	73.96	19.35	35.26	2.27%	11.75%	11.53%	21.02%	4.45%	23.05%	22.61%	41.21%
Illawarra	4.14	20.19	75.54	20.07	36.13	2.45%	11.96%	11.89%	21.40%	4.85%	23.67%	23.53%	42.35%

Table 12: Average household daily travel by all modes

Residential Subregion	\$ per household per day					% of annual household income			
	Travel cost		Travel time	Generalised cost		Travel cost		Generalised cost	
	Usage	All cost		Usage	All GC	Usage	All cost	Usage	All GC
Sydney City	11.43	24.74	146.63	38.78	52.09	5.12%	11.08%	17.37%	23.34%
East	14.11	37.94	173.78	48.48	72.31	5.93%	15.96%	20.39%	30.41%
South	10.24	38.13	195.2	50.48	78.37	5.02%	18.70%	24.75%	38.42%
Inner West	12.21	36.72	189.39	49.92	74.43	5.28%	15.88%	21.58%	32.18%
Inner North	14.54	39.23	182.76	51.28	75.97	5.12%	13.82%	18.06%	26.76%
North	12.43	46.14	233.38	60.41	94.13	4.20%	15.60%	20.43%	31.82%
North East	14.29	42.21	205.24	57.04	84.95	5.46%	16.14%	21.81%	32.48%
West Central	8.95	38.85	196.42	50.14	80.04	5.16%	22.42%	28.94%	46.19%
North West	12.34	45.97	225.76	61.84	95.47	5.72%	21.32%	28.68%	44.28%
South West	12.75	45.86	230.37	63.18	96.29	6.76%	24.32%	33.51%	51.06%
Central Coast	11.33	40.20	194.58	52.42	81.29	7.13%	25.29%	32.98%	51.14%
Hunter	8.87	39.34	172.44	45.11	75.58	5.29%	23.45%	26.89%	45.05%
Illawarra	9.74	40.51	177.91	47.28	78.05	5.77%	23.99%	28.00%	46.23%

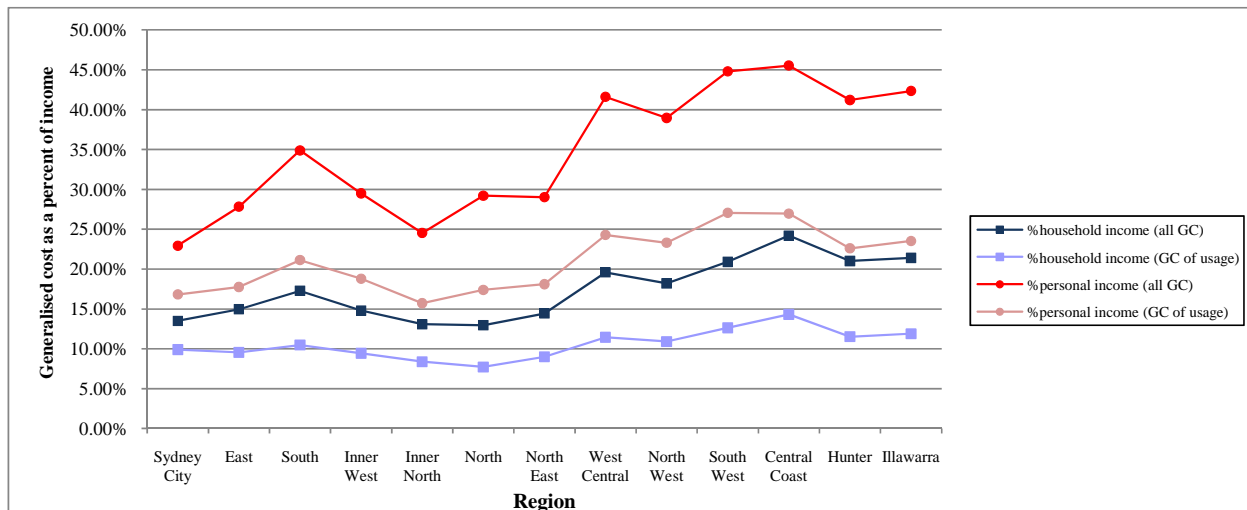


Figure 6: Mean generalised cost as a percentage of income by region

The question we posed earlier is ‘what role does public transport play in the profile of the (generalised) cost of mobility? Given the cost of using public transport (i.e., fares), reported in Section 2 (and Appendix 5), we speculate that the provision of improved public transport services (and switching from car to some extent) in the west is likely to result in a lower monetary cost of travel but only if individuals and/or households dispose of vehicles. If they retain their cars, then given the lower marginal cost of car use compared to public transport, the contribution of improve public transport translated into a switch of usage from car to public transport will have little impact on accessibility and equity. This seems to apply even where public transport offers a lower travel time, which is not sufficient to compensate for retention of the car. Hence the entire argument hinges on what response will be made to car ownership in the presence of a non-marginal injection of investment in public transport. Whereas public transport may be successful in converting commuters, will it be successful in converting non-commuting travel and especially weekend travel where the car may well be the preferred transport mode?

When we investigated the systematic sources of influence on generalised cost across postcodes, we concluded that there is a positive and significant relationship between income and average daily generalised cost of travel. This suggests that those who have higher incomes tend to spend a greater

amount of time and money on travel, which is the opposite of what the descriptive analysis, on average, suggests at a subregion level. This sends a caution about making statements on mobility equity at a highly spatially aggregate level (i.e., a sub-region) in contrast to establishing the causal links at a more spatially disaggregate level (i.e., the postcode). In addition, increasing the share of modal activity in favour of public transport tends to result in higher generalised cost if there is no adjustment to the ownership of cars. This finding is concerning if investment in public transport is linked to the objective of reducing the amount of time and money spent of travel as a means of providing greater mobility access, in the absence of a significant reduction in car ownership.

It is clear that the car has become a major means of supporting coping strategies in the absence of appropriate public transport, and that any effort to use public transport investment as an instrument for reducing the generalised cost of travel may well be questionable, without car ownership reductions, which may well be the outcome if the investment levels in public transport are marginal at best.

## References

- Australian Bureau of Statistic (2009) *Household Income and Income Distribution*, Australia 2007-08, cat. No. 6523.0, ABS, Canberra.
- Andrew, W. (2009) *Train ride subsidies pay off: expert*. Retrieved: 10 October, 2009, from <http://www.smh.com.au/national/train-ride-subsidies-pay-off-expert-20090609-c2a0.html>
- Atherton, A., Riedy, C. and White, S. (2006) *Moving on: the RTBU's Public Transport Blueprint for Sydney*. Retrieved: 1 September, 2009, from <http://rtbu-nsw.asn.au/news/2603.html>
- Banister D. and Woodcock J. (2007) Energy and Transport, *The Lancet*, 370 (9592), 1078-1088.
- Currie, G. Richardson, T. and Smyth, P. *et. al.* (2009) Investigating links between transport disadvantage, social exclusion and well-being in Melbourne –Preliminary results, *Transport Policy*, 16, 97-105.
- Crompton, J. L. and Lamb, C. W. (1998) The Importance of the Equity Concept in the Allocation of Public Services. Retrieved: 2 October, 2009 from <http://www.rpts.tamu.edu/faculty/crompton/Crompton/Articles/6.9.pdf>
- Dodson, J., Gleeson, B. and Sipe, N. (2004) Transport Disadvantage and Social Status: A review of literature and methods, Retrieved: 20 September, 2009, from [http://www.griffith.edu.au/\\_data/assets/pdf\\_file/0006/48642/urp-rm05-dodson-et-al-2004.pdf](http://www.griffith.edu.au/_data/assets/pdf_file/0006/48642/urp-rm05-dodson-et-al-2004.pdf)
- Giuliano, G., Hu, H. and Lee, K. (2001) *The Role of Public Transit in the Mobility of Low Income Household*. Retrieved: 1 September, 2009, from <http://www.vtpi.org/tranben.pdf>
- Glazebrook, G. (2009) *A Thirty Year Public Transport Plan for Sydney*, Retrieved: 30 October, 2009, from <http://www.transportpublicinquiry.com.au/>
- Hensher, D. A. and Button, K. J. (2000) *Handbook of Transport Modelling*, Pergamon, Elsevier Science Ltd., Amsterdam
- Johnson, V., Currie, G., and Stanley, J. (2009) Can measures of disadvantage perpetuate the problems they seek to solve?, Retrieved from <http://www.sprc.unsw.edu.au/ASPC2009/papers/Paper268.pdf>
- Krygsman, S., Dijsta, M. and Arentze, T. (2004) Multimodal public transport: an analysis of travel time elements and the interconnectivity ratio, *Transport Policy*, 11 (3) 265-275.
- Mees, P. (2000) *Rethinking Public Transport in Sydney*. Retrieved: 20 September, 2009, from [http://staff.uws.edu.au/download.php?file\\_id=3564&filename=webb05.pdf&mimetype=application/pdf](http://staff.uws.edu.au/download.php?file_id=3564&filename=webb05.pdf&mimetype=application/pdf)
- NRMA (2008) *Private whole of life vehicle operating costs report: ascending costs summary*, NRMA Motoring and Services, Sydney, October.

Nicolas, J. P., Pochet, P. and Poimboeuf, H. (2003) Towards Sustainable Mobility Indicators: Application to the Lyons Conurbation, *Transport Policy*, 10, 197-208.

Tanner, J. (1982) Expenditure of Time and Money on Travel, *Transportation Research Part A*, 15 (1) 25-38.

Todd, L. (2007) *Evaluating Transportation Equity: Guidance for Incorporating Distributional Impacts in Transportation Planning*. Retrieved: 1 September, 2009, from

<http://www.vtpi.org/equity.pdf>

Todd, L. (2009) Developing Indicators for Comprehensive and Sustainable Transport Planning. Retrieved: 1 September, 2009, from [http://www.vtpi.org/sus\\_tran\\_ind.pdf](http://www.vtpi.org/sus_tran_ind.pdf)

Transport Data Centre (2009) Household Travel Survey Data, NSW Ministry of Transport, Sydney.

## Appendix 1: Definition of variables

Appendix 1: Definition of variables

VARIABLE	DEFINITION
PERGC	Generalised cost of travel by all modes, per person per day per postcode
HHGC	Generalised cost of travel by all modes, per household per day per postcode
HHINC	Annual household income per postcode
PERINC	Annual personal income per postcode
HHVEH	Average household vehicle ownership per postcode
PERGCTIME	Share of generalised cost (per person per day) that is allocated to travel time
HHGCTIME	Share of generalised cost (per household per day) that is allocated to travel time
PTSHARE	Share of public transport (total number of trips by public transport divided by total number of trips by public and private vehicles)
PERDIS	Average travel distance per person per day per postcode
HHDIS	Average travel distance per household per day per postcode
PERSTDIS	Standard deviation of travel distance per person per day per postcode
HHSTDIS	Standard deviation of travel distance per household per day per postcode
PERMCDIS	Mean-centered personal daily travel distance
HHMCDIS	Mean-centered household daily travel distance
PERMSDIS	Square of Mean-centered personal daily travel distance
HHMSDIS	Square of Mean-centered household daily travel distance
CBDDIS	Straight line distance between postcode area and CBD
YR00TO03	Dummy variable that takes the value of 1 for a year from June 2000 until June 2004 (base = June 1997 – June 2000); 0 otherwise
YR04TO07	Dummy variable that takes the value of 1 for a year from June 2004 until June 2008 (base = June 1997– June 2000); 0 otherwise
EAST	Dummy variable that takes the value of 1 for East Subregion (base = Sydney City Subregion); 0 otherwise
SOUTH	Dummy variable that takes the value of 1 for South Subregion (base = Sydney City Subregion); 0 otherwise
INWEST	Dummy variable that takes the value of 1 for Inner West Subregion (base = Sydney City Subregion); 0 otherwise
INNORTH	Dummy variable that takes the value of 1 for Inner North Subregion (base = Sydney City Subregion); 0 otherwise
NORTH	Dummy variable that takes the value of 1 for North Subregion (base = Sydney City Subregion); 0 otherwise
NOREAST	Dummy variable that takes the value of 1 for North East Subregion (base = Sydney City Subregion); 0 otherwise
WCENTRAL	Dummy variable that takes the value of 1 for West Central Subregion (base = Sydney City Subregion); 0 otherwise
NORWEST	Dummy variable that takes the value of 1 for North West Subregion (base = Sydney City Subregion); 0 otherwise
SOUWEST	Dummy variable that takes the value of 1 for South West Subregion (base = Sydney City Subregion); 0 otherwise
CENCOAST	Dummy variable that takes the value of 1 for Central Coast Subregion (base = Sydney City Subregion); 0 otherwise
HUNTER	Dummy variable that takes the value of 1 for Hunter Subregion (base = Sydney City Subregion); 0 otherwise
ILLAWARRA	Dummy variable that takes the value of 1 for Illawarra Subregion (base = Sydney City Subregion); 0 otherwise

Note: Straight line distance between postcode area and CBD is estimated from GIS database

## Appendix 2: Spatial profiles of travel cost, time and generalised cost

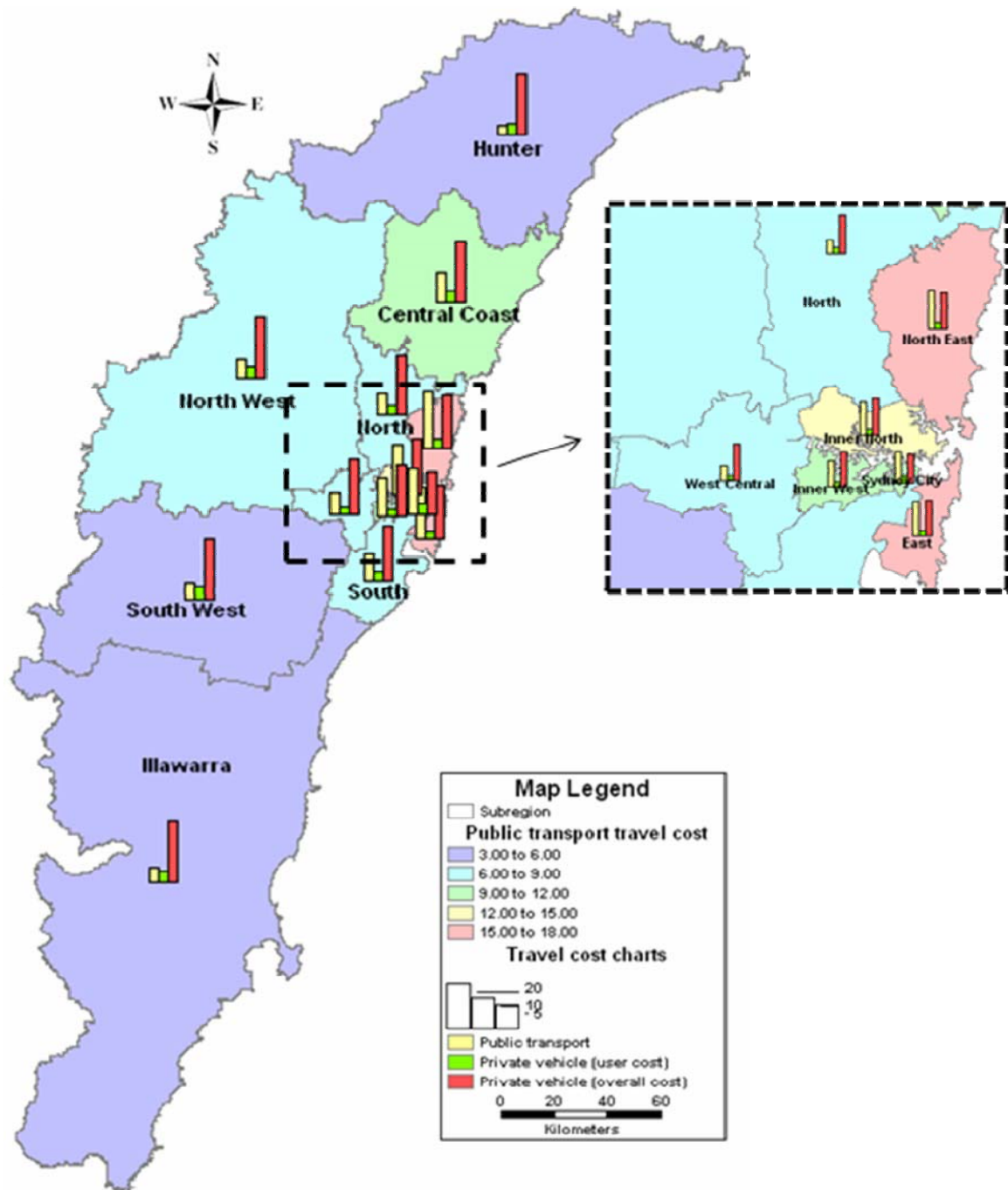


Figure A1.1: Travel cost for public transport and private vehicle, dollar per person per day

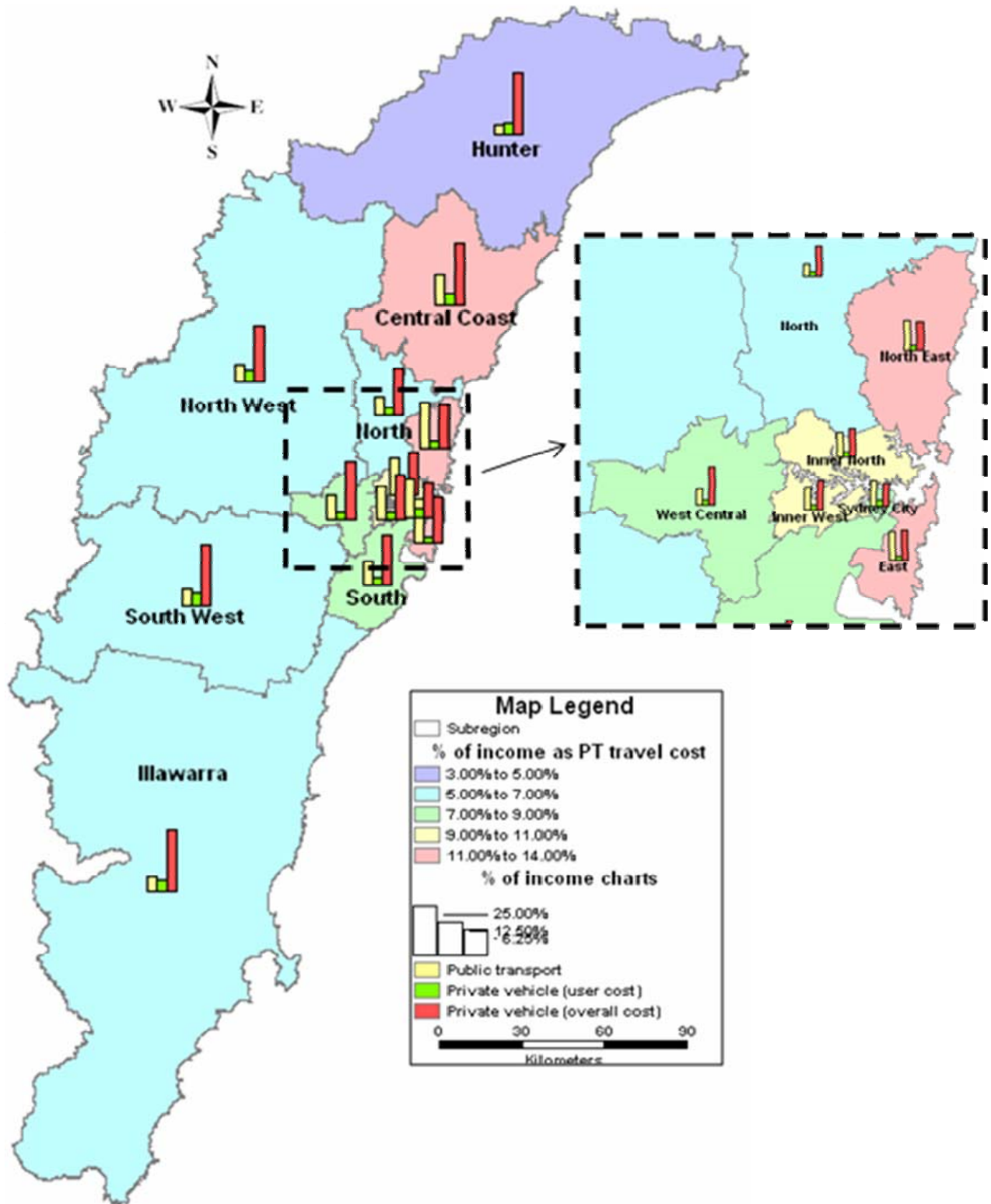


Figure A1.2: Share of annual personal income allocated to travel by public transport and private vehicle (%)

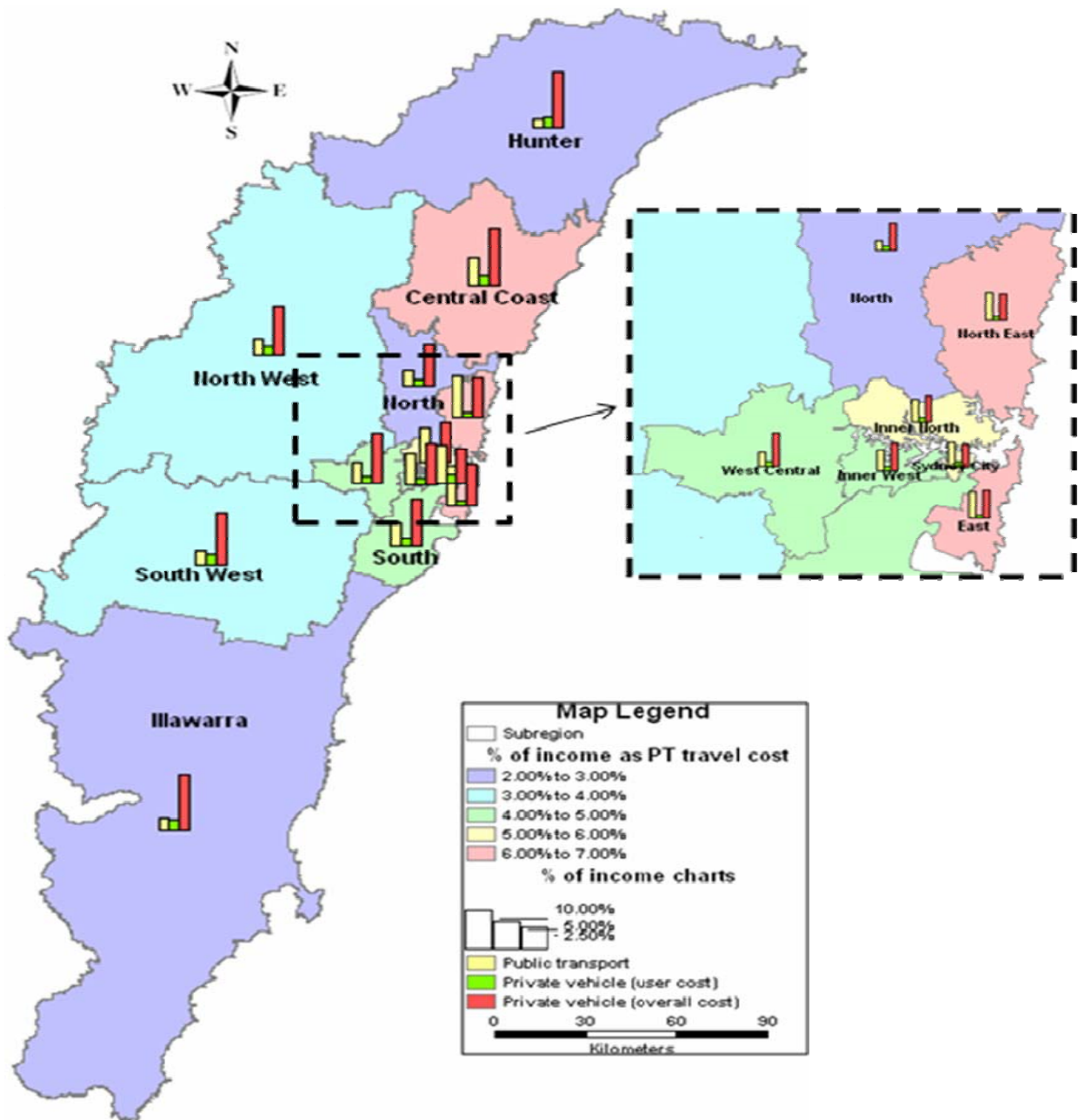


Figure A1.3: Share of annual household income allocated to travel by public transport and private vehicle (%)



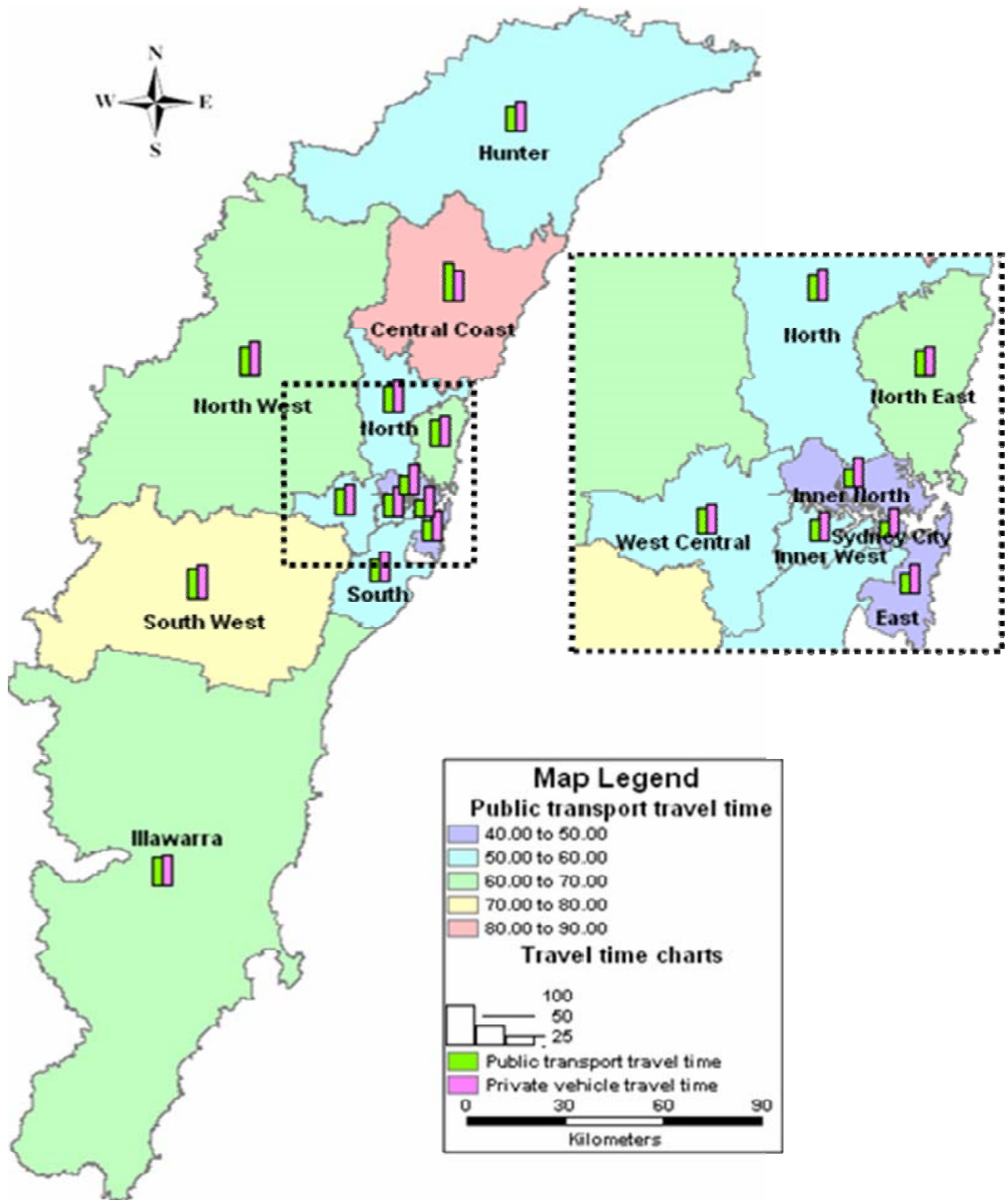


Figure A2.1: Travel time spent on public transport and private vehicle, minute per person per day

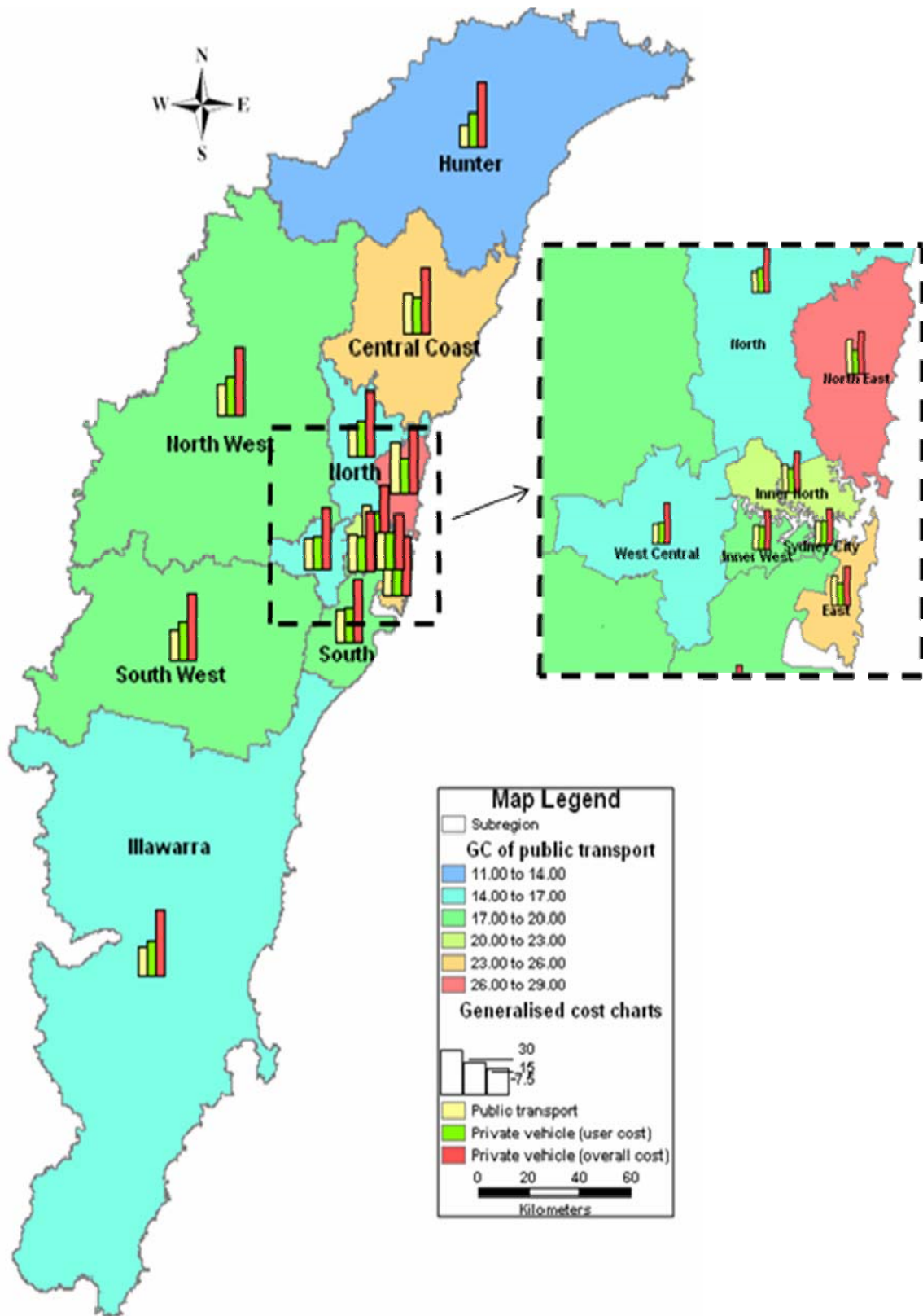


Figure A3.1: Generalised cost by public transport and private vehicle, dollar per person per day

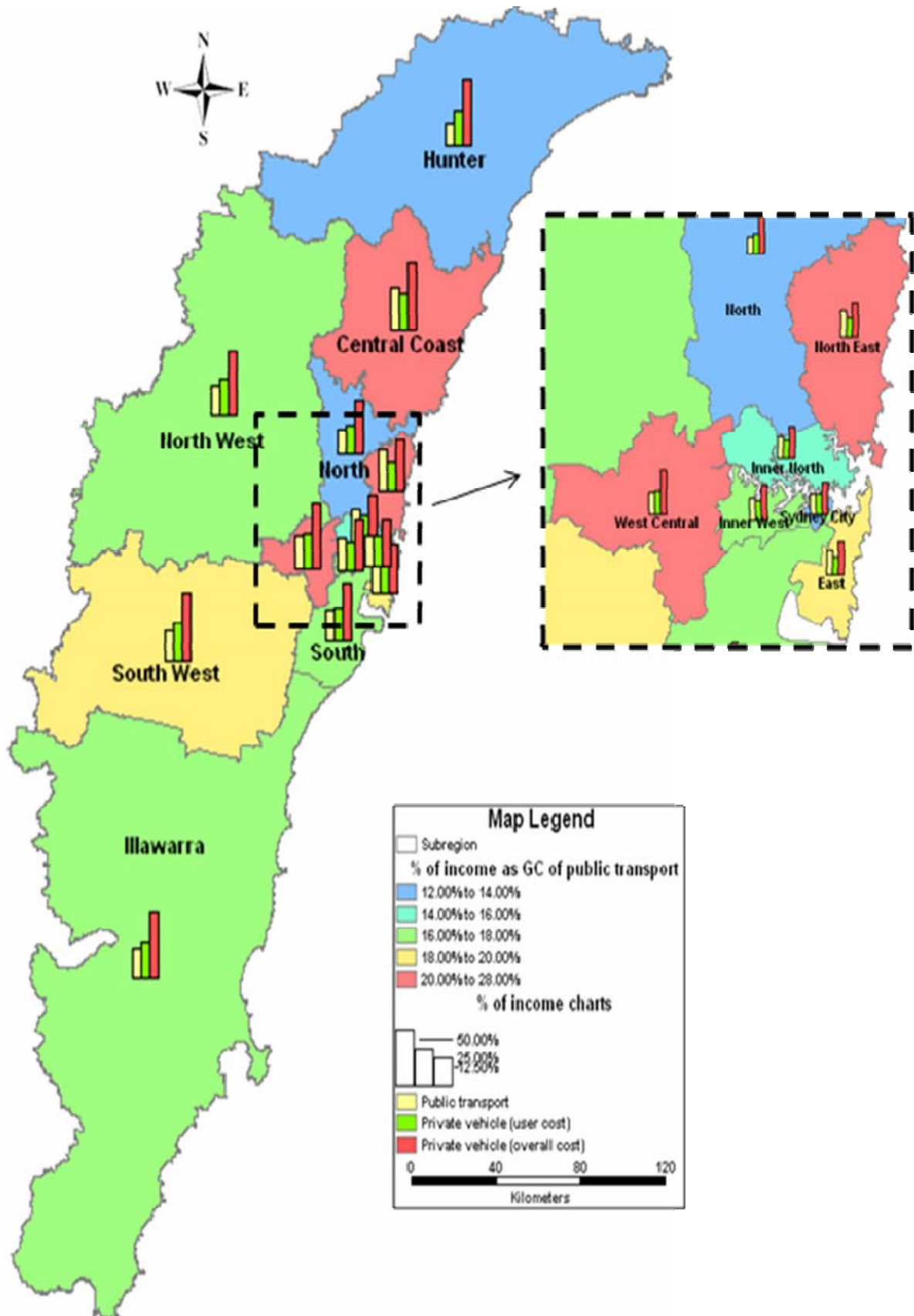


Figure A3.2: Share of annual personal income for generalised cost by public transport and private vehicle (%)

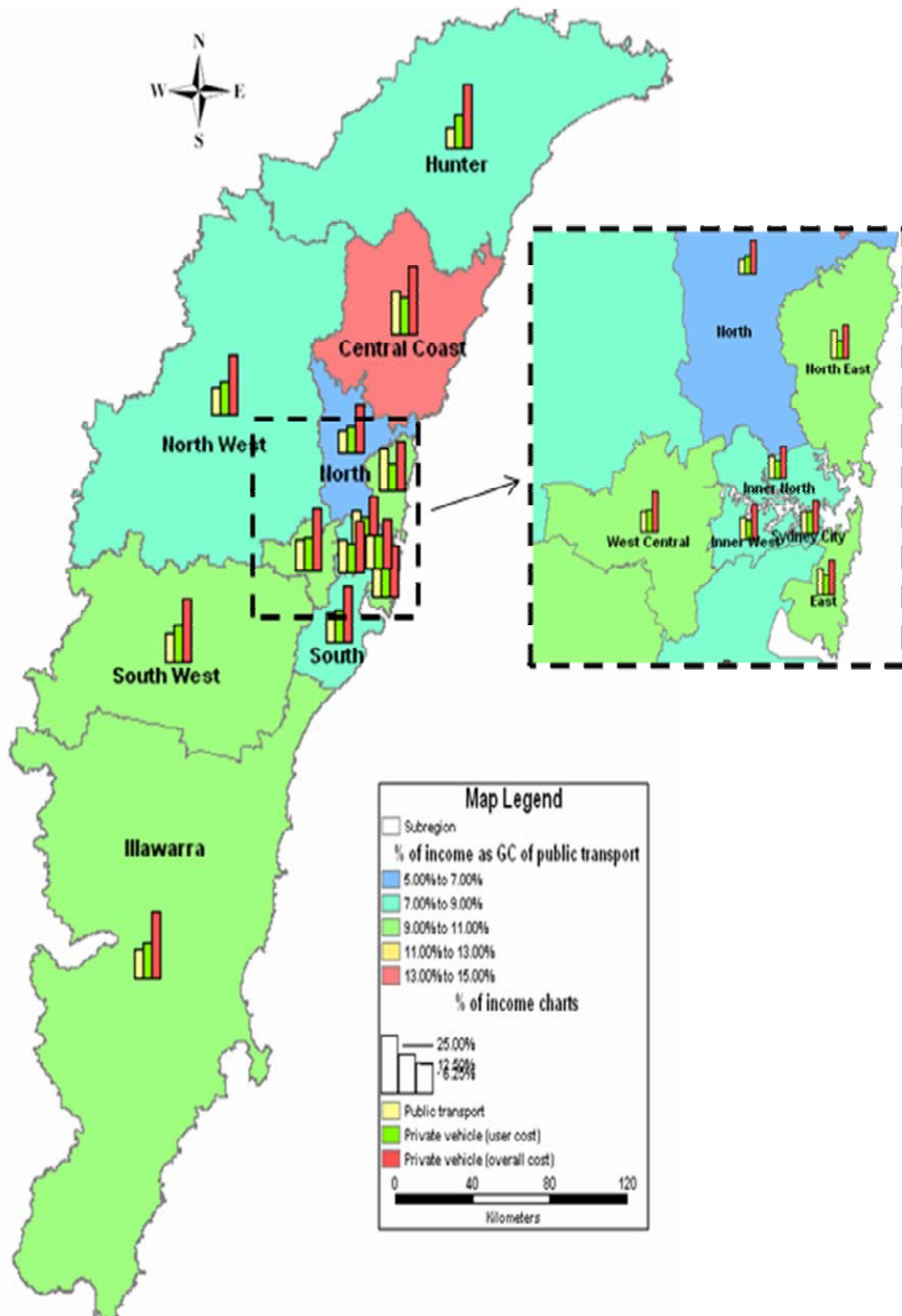
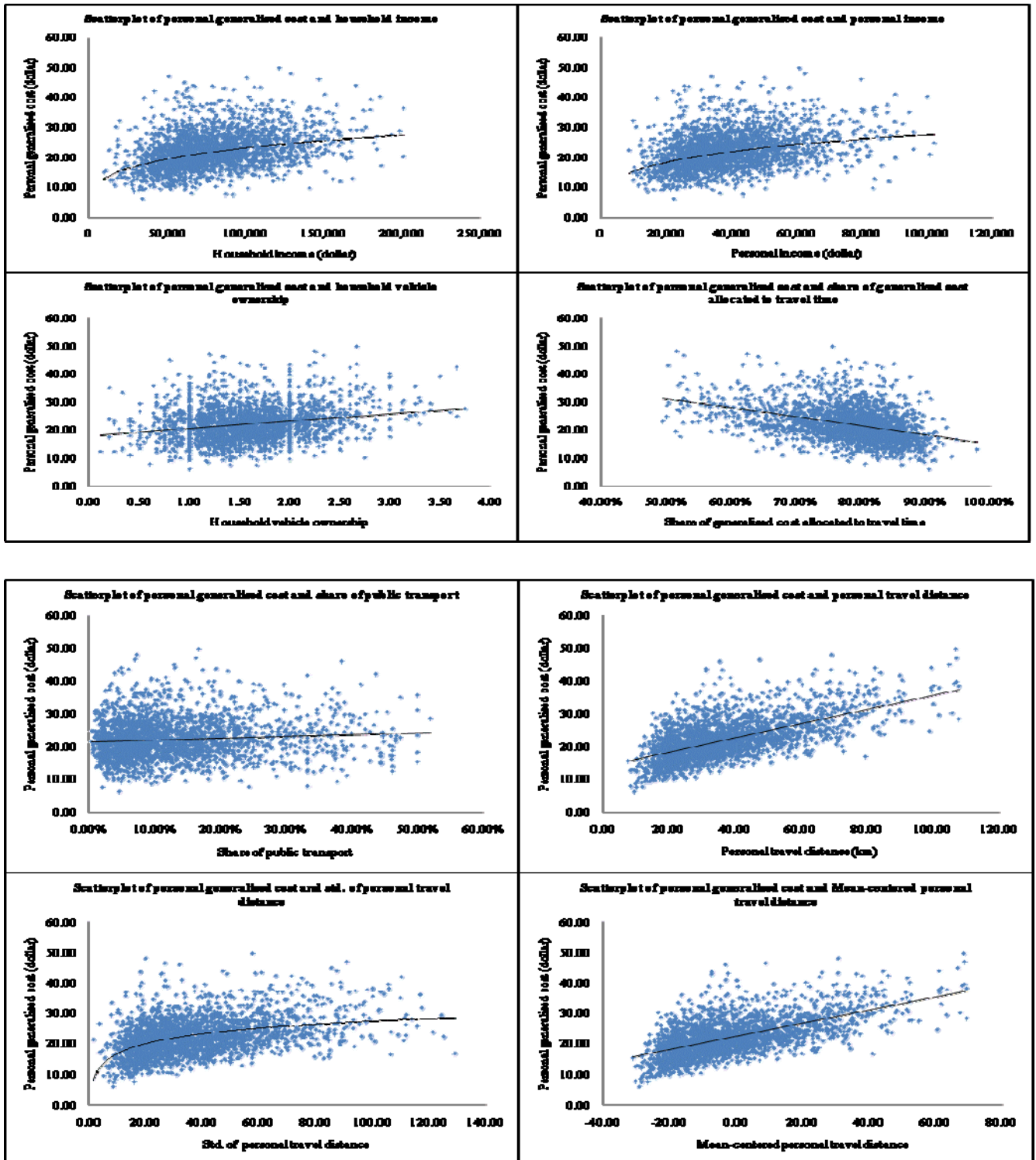


Figure A3.3: Share of annual household income for generalised cost by public transport and private vehicle (%)

### Appendix 3: Scatterplots for personal average daily generalised cost



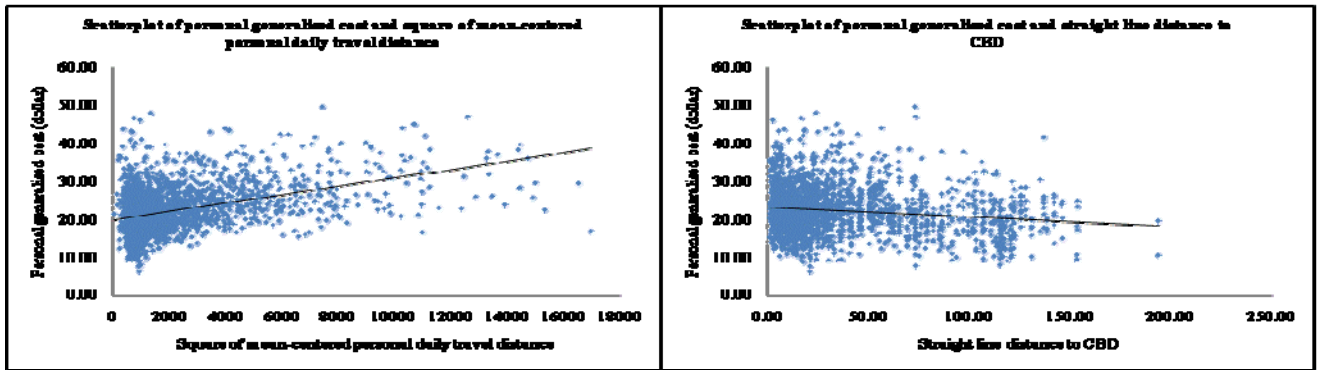
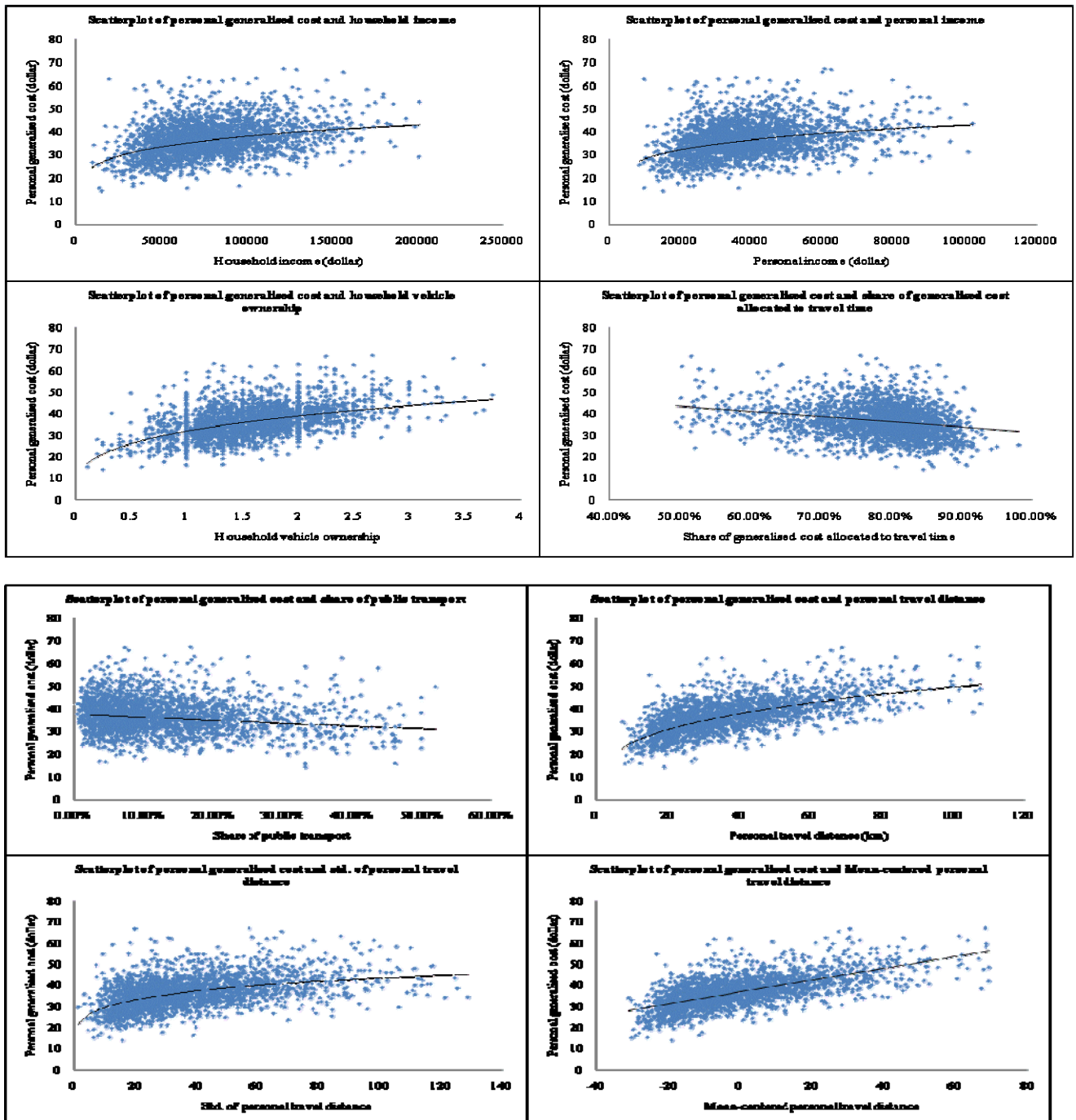


Figure A1: Scatterplots for personal average daily user generalised cost



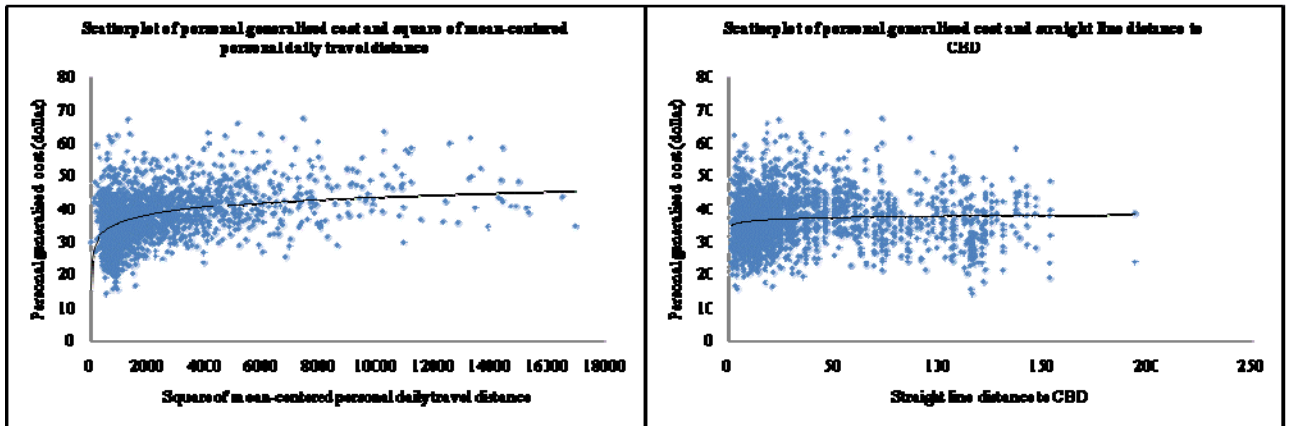
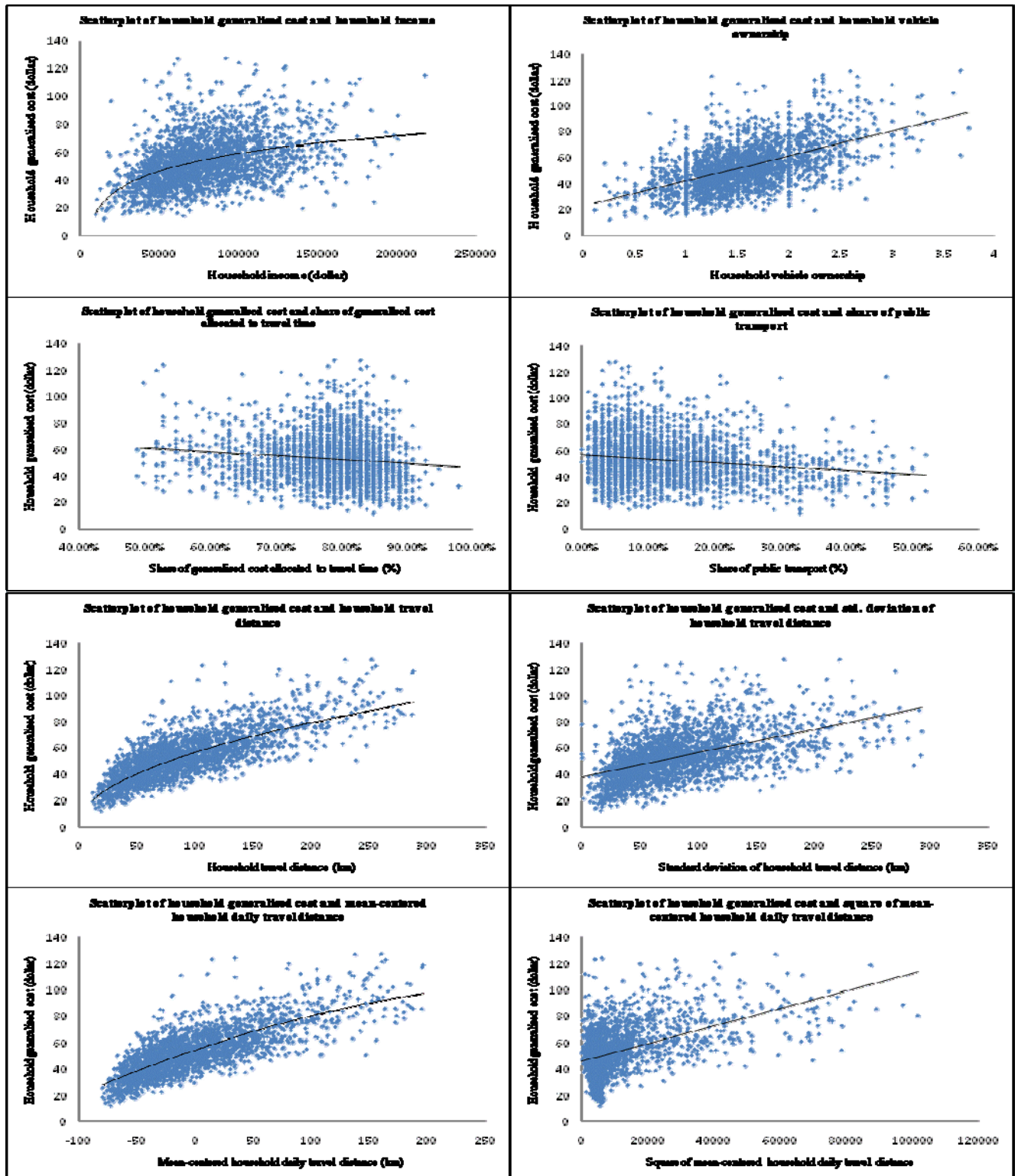


Figure A2: Scatterplots for personal average daily overall generalised cost

### Appendix 4: Scatterplots for household average daily generalised cost





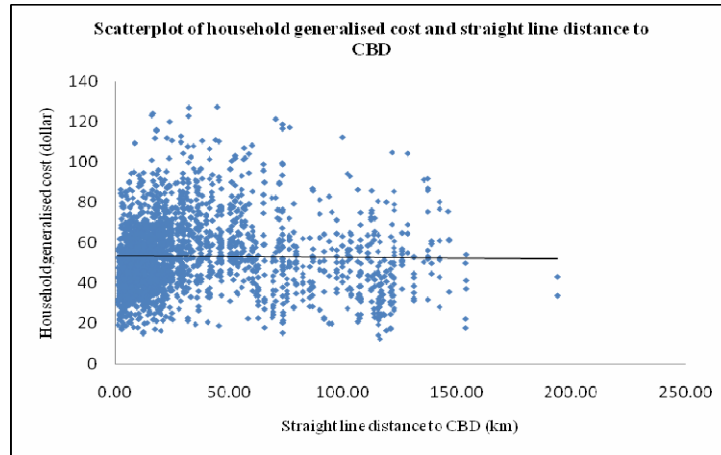
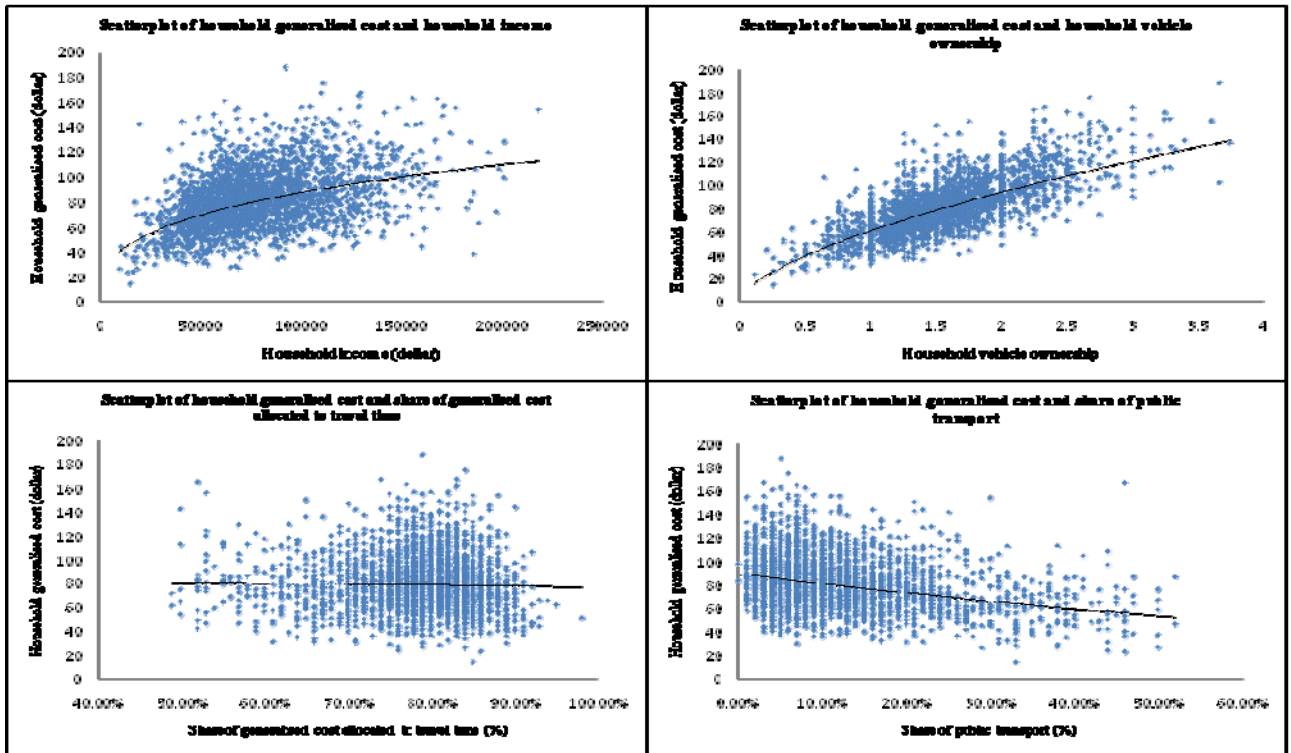


Figure B1: Scatterplots for household average daily user generalised cost



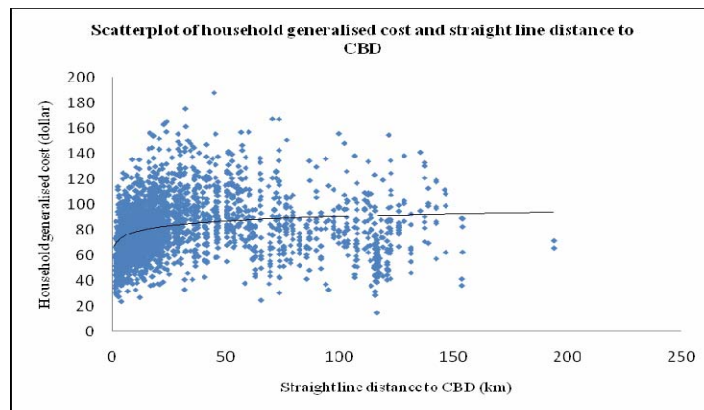
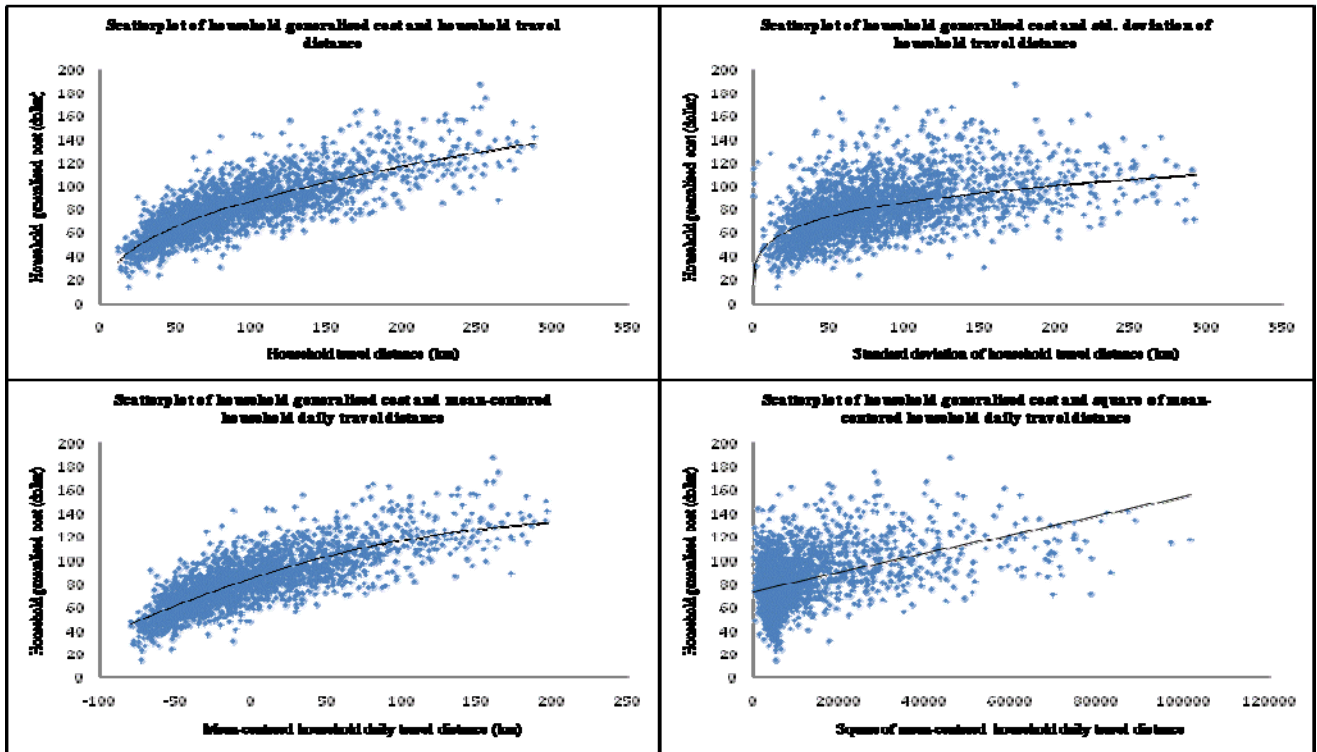


Figure B2: Scatterplots for household average daily overall generalised cost

## Appendix 5

**Table B1: Personal daily travel cost by mode and residential subregion, and percentage of annual income allocated to travel, HTS 1997-2008**

Residential Subregion	Travel cost, \$ per person per day					% of annual household income allocated to travel					% of annual personal income allocated to travel				
	Public transport	Private vehicle		All modes		Public transport	Private vehicle		All modes		Public transport	Private vehicle		All modes	
		Usage	All cost	Usage	All cost		Usage	All cost	Usage	All cost		Usage	All cost		
Sydney City	11.56	2.78	10.81	6.51	14.55	5.18%	1.25%	4.84%	2.92%	6.52%	8.79%	2.11%	8.23%	4.96%	11.07%
East	15.28	2.50	15.39	6.61	19.50	6.43%	1.05%	6.47%	2.78%	8.20%	11.95%	1.95%	12.03%	5.17%	15.24%
South	8.60	2.79	16.69	4.33	18.22	4.22%	1.37%	8.18%	2.12%	8.94%	8.51%	2.76%	16.52%	4.29%	18.04%
Inner West	11.53	2.53	14.94	5.34	17.74	4.99%	1.09%	6.46%	2.31%	7.67%	9.94%	2.18%	12.87%	4.60%	15.29%
Inner North	14.75	2.90	16.24	6.75	20.09	5.20%	1.02%	5.72%	2.38%	7.07%	9.74%	1.92%	10.73%	4.46%	13.27%
North	7.54	3.12	18.63	4.70	20.21	2.55%	1.05%	6.30%	1.59%	6.83%	5.74%	2.38%	14.19%	3.58%	15.39%
North East	17.85	2.95	17.15	5.90	20.10	6.83%	1.13%	6.56%	2.26%	7.68%	13.73%	2.27%	13.19%	4.54%	15.45%
West Central	7.17	2.59	16.72	3.54	17.67	4.14%	1.49%	9.65%	2.04%	10.20%	8.79%	3.17%	20.49%	4.33%	21.65%
North West	6.49	3.98	19.76	4.69	20.47	3.01%	1.85%	9.17%	2.17%	9.49%	6.44%	3.95%	19.61%	4.65%	20.31%
South West	5.91	4.26	19.87	4.81	20.42	3.13%	2.26%	10.54%	2.55%	10.83%	6.72%	4.84%	22.58%	5.46%	23.20%
Central Coast	9.66	3.97	19.67	4.92	20.62	6.08%	2.50%	12.37%	3.10%	12.97%	11.44%	4.70%	23.29%	5.83%	24.41%
Hunter	3.41	3.74	19.65	3.80	19.72	2.03%	2.23%	11.71%	2.27%	11.75%	3.99%	4.37%	22.97%	4.45%	23.05%
Illwarra	4.85	3.90	19.95	4.14	20.19	2.87%	2.31%	11.82%	2.45%	11.96%	5.68%	4.57%	23.39%	4.85%	23.67%

**Table B2: Personal daily travel time by mode and residential subregion, HTS 1997-2008**

Residential Subregion	Travel time, minute per person per day		
	Public transport	Private vehicle	All modes
Sydney City	40.25	68.27	83.59
East	49.16	66.39	81.39
South	55.77	69.74	82.55
Inner West	51.66	66.36	82.79
Inner North	46.12	68.57	84.78
North	59.62	71.22	88.19
North East	61.38	69.14	84.74
West Central	59.96	66.81	77.64
North West	66.65	76.44	85.76
South West	72.20	77.22	86.83
Central Coast	84.85	71.78	84.51
Hunter	55.41	66.31	73.96
Illawarra	64.63	66.20	75.54

**Table B3: Personal daily generalised cost by mode and residential subregion and percent of annual income for GC of travel, HTS 1997-2008**

## What does it cost to travel in Sydney? Spatial and equity contrasts across the metropolitan region

Hensher & Chen

Residential Subregion	Generalised cost, \$ per person per day					GC as a % of annual household income					GC as a % of annual personal income				
	Public transport	Private vehicle		All modes		Public transport	Private vehicle		All modes		Public transport	Private vehicle		All modes	
		Usage	All GC	Usage	All GC		Usage	All GC	Usage	All GC		Usage	All GC	Usage	All GC
Sydney City	18.00	18.23	26.26	22.10	30.14	8.06%	8.17%	11.77%	9.90%	13.50%	13.69%	13.87%	19.98%	16.82%	22.93%
East	23.15	17.32	30.21	22.70	35.59	9.74%	7.28%	12.70%	9.55%	14.97%	18.10%	13.54%	23.62%	17.75%	27.83%
South	17.57	18.75	32.65	21.35	35.24	8.61%	9.19%	16.01%	10.47%	17.28%	17.39%	18.56%	32.32%	21.13%	34.89%
Inner West	19.68	17.64	30.05	21.82	34.23	8.51%	7.63%	12.99%	9.44%	14.80%	16.96%	15.20%	25.89%	18.80%	29.50%
Inner North	22.07	18.30	31.64	23.79	37.13	7.77%	6.45%	11.14%	8.38%	13.08%	14.58%	12.09%	20.90%	15.72%	24.53%
North	16.98	19.04	34.55	22.83	38.34	5.74%	6.44%	11.68%	7.72%	12.96%	12.94%	14.51%	26.32%	17.39%	29.21%
North East	27.55	18.79	32.99	23.55	37.75	10.53%	7.18%	12.61%	9.00%	14.43%	21.18%	14.45%	25.37%	18.11%	29.02%
West Central	16.73	18.05	32.18	19.82	33.95	9.66%	10.42%	18.57%	11.44%	19.59%	20.51%	22.12%	39.44%	24.29%	41.61%
North West	17.39	21.85	37.63	23.49	39.27	8.07%	10.13%	17.45%	10.90%	18.22%	17.25%	21.68%	37.34%	23.31%	38.97%
South West	17.40	22.35	37.96	23.81	39.42	9.23%	11.85%	20.13%	12.63%	20.91%	19.77%	25.40%	43.14%	27.06%	44.80%
Central Coast	23.10	20.37	36.07	22.77	38.46	14.53%	12.81%	22.69%	14.32%	24.20%	27.35%	24.12%	42.70%	26.96%	45.54%
Hunter	11.94	18.63	34.54	19.35	35.26	7.12%	11.10%	20.59%	11.53%	21.02%	13.96%	21.78%	40.37%	22.61%	41.21%
Illwarra	15.33	18.90	34.95	20.07	36.13	9.08%	11.19%	20.70%	11.89%	21.40%	17.97%	22.15%	40.97%	23.53%	42.35%

*Table B4: Daily travel cost per household by mode and residential subregion, and percentage of annual income allocated to travel, HTS 1997-2008*

Residential Subregion	Travel cost, \$ per household per day					% of annual household income allocated to travel				
	Public transport	Private vehicle		All modes		Public transport	Private vehicle		All modes	
		Usage	All cost	Usage	All cost		Usage	All cost	Usage	All cost
Sydney City	14.89	4.44	17.75	11.43	24.74	6.67%	1.99%	7.95%	5.12%	11.08%
East	20.69	5.12	28.95	14.11	37.94	8.70%	2.15%	12.18%	5.93%	15.96%
South	11.99	6.27	34.16	10.24	38.13	5.88%	3.07%	16.75%	5.02%	18.70%
Inner West	16.54	5.41	29.92	12.21	36.72	7.15%	2.34%	12.94%	5.28%	15.88%
Inner North	19.68	6.00	30.69	14.54	39.23	6.93%	2.11%	10.81%	5.12%	13.82%
North	10.86	7.86	41.57	12.43	46.14	3.67%	2.66%	14.06%	4.20%	15.60%
North East	24.42	6.87	34.78	14.29	42.21	9.34%	2.63%	13.30%	5.46%	16.14%
West Central	10.28	6.22	36.12	8.95	38.85	5.93%	3.59%	20.85%	5.16%	22.42%
North West	9.71	10.04	43.67	12.34	45.97	4.50%	4.66%	20.25%	5.72%	21.32%
South West	8.47	10.76	43.87	12.75	45.86	4.49%	5.71%	23.26%	6.76%	24.32%
Central Coast	13.33	8.87	37.73	11.33	40.20	8.39%	5.58%	23.74%	7.13%	25.29%
Hunter	4.77	8.46	38.93	8.87	39.34	2.84%	5.04%	23.20%	5.29%	23.45%
Illwarra	6.96	8.88	39.65	9.74	40.51	4.12%	5.26%	23.49%	5.77%	23.99%

*Table B5: Daily travel time per household by mode and residential subregion, HTS 1997-2008*

Residential Subregion	Travel time, minute per household per day		
	Public transport	Private vehicle	All modes
Sydney City	51.85	108.96	146.63
East	66.55	136.14	173.78
South	77.79	156.58	195.20
Inner West	74.10	141.85	189.39
Inner North	61.53	141.74	182.76
North	85.85	179.33	233.38
North East	83.98	160.79	205.24
West Central	85.90	160.35	196.42
North West	99.64	192.69	225.76
South West	103.53	195.25	230.37
Central Coast	117.05	160.19	194.58
Hunter	77.36	149.92	172.44
Illawarra	92.64	150.78	177.91

*Table B6: Daily generalised cost per household by mode and residential subregion and percentage of annual income for generalised cost of travel, HTS 1997-2008*

Residential Subregion	Generalised cost, \$ per person per day					GC as a % of annual household income				
	Public transport	Private vehicle		All modes		Public transport	Private vehicle		All modes	
		Usage	All cost	Usage	All cost		Usage	All cost	Usage	All cost
Sydney City	23.19	29.09	42.40	38.78	52.09	10.39%	13.04%	19.00%	17.37%	23.34%
East	31.34	35.52	59.35	48.48	72.31	13.18%	14.94%	24.96%	20.39%	30.41%
South	24.50	42.09	69.99	50.48	78.37	12.01%	20.64%	34.31%	24.75%	38.42%
Inner West	28.23	37.70	62.21	49.92	74.43	12.21%	16.30%	26.90%	21.58%	32.18%
Inner North	29.44	37.82	62.51	51.28	75.97	10.37%	13.32%	22.02%	18.06%	26.76%
North	24.45	47.94	81.65	60.41	94.13	8.27%	16.21%	27.61%	20.43%	31.82%
North East	37.69	43.71	71.62	57.04	84.95	14.41%	16.71%	27.39%	21.81%	32.48%
West Central	23.97	43.33	73.23	50.14	80.04	13.84%	25.01%	42.26%	28.94%	46.19%
North West	26.00	55.08	88.71	61.84	95.47	12.06%	25.55%	41.14%	28.68%	44.28%
South West	24.95	56.52	89.62	63.18	96.29	13.23%	29.97%	47.53%	33.51%	51.06%
Central Coast	31.87	45.46	74.33	52.42	81.29	20.05%	28.60%	46.76%	32.98%	51.14%
Hunter	16.68	42.12	72.59	45.11	75.58	9.94%	25.11%	43.26%	26.89%	45.05%
Illwarra	21.97	43.05	73.82	47.28	78.05	13.01%	25.50%	43.72%	28.00%	46.23%

## Appendix 6

### *Spatial Profiles on travel cost, time and generalised cost by all modes*

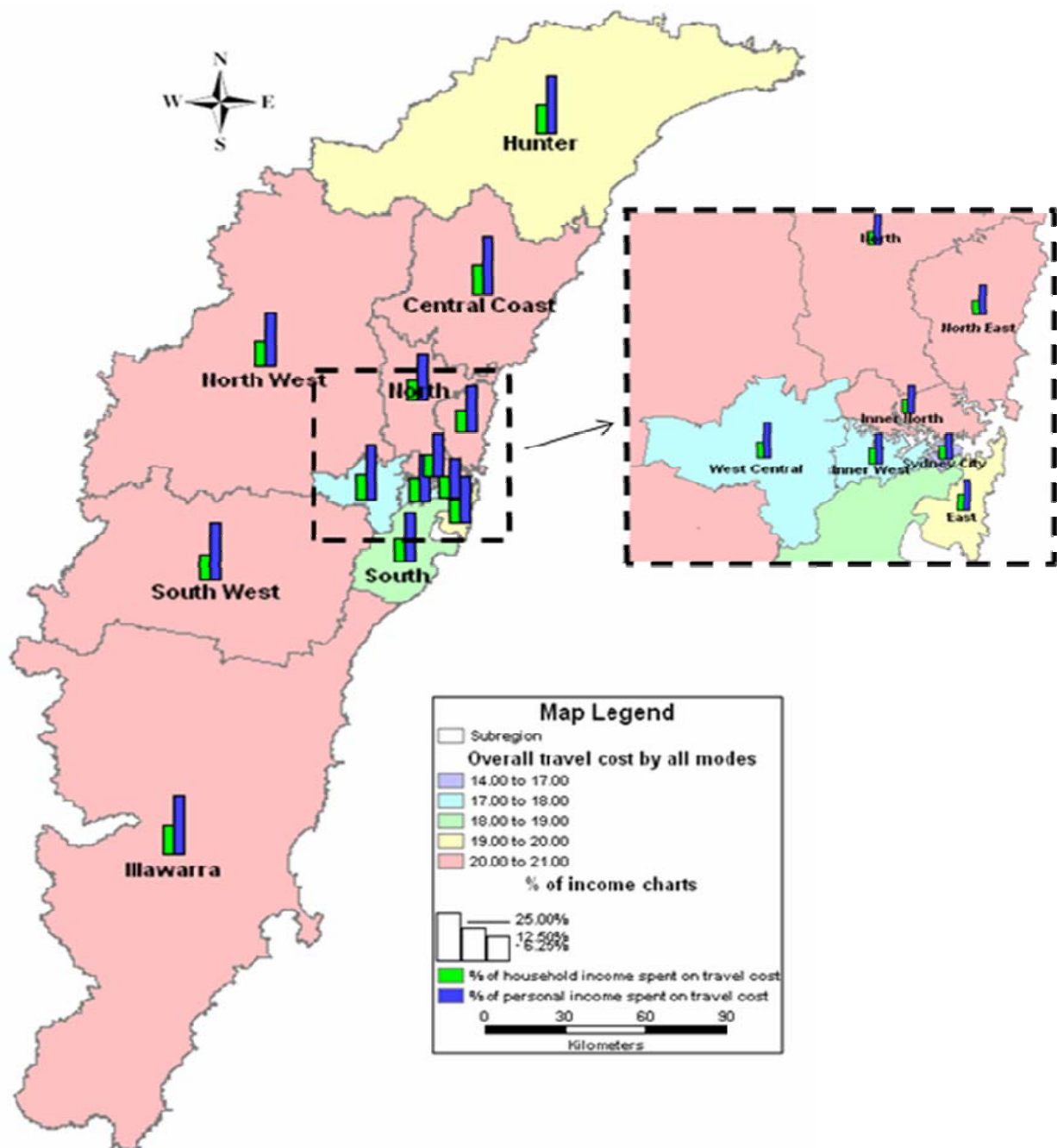


Figure C1: Overall personal travel cost by all modes (dollar per person per day) and as a percentage of income by region

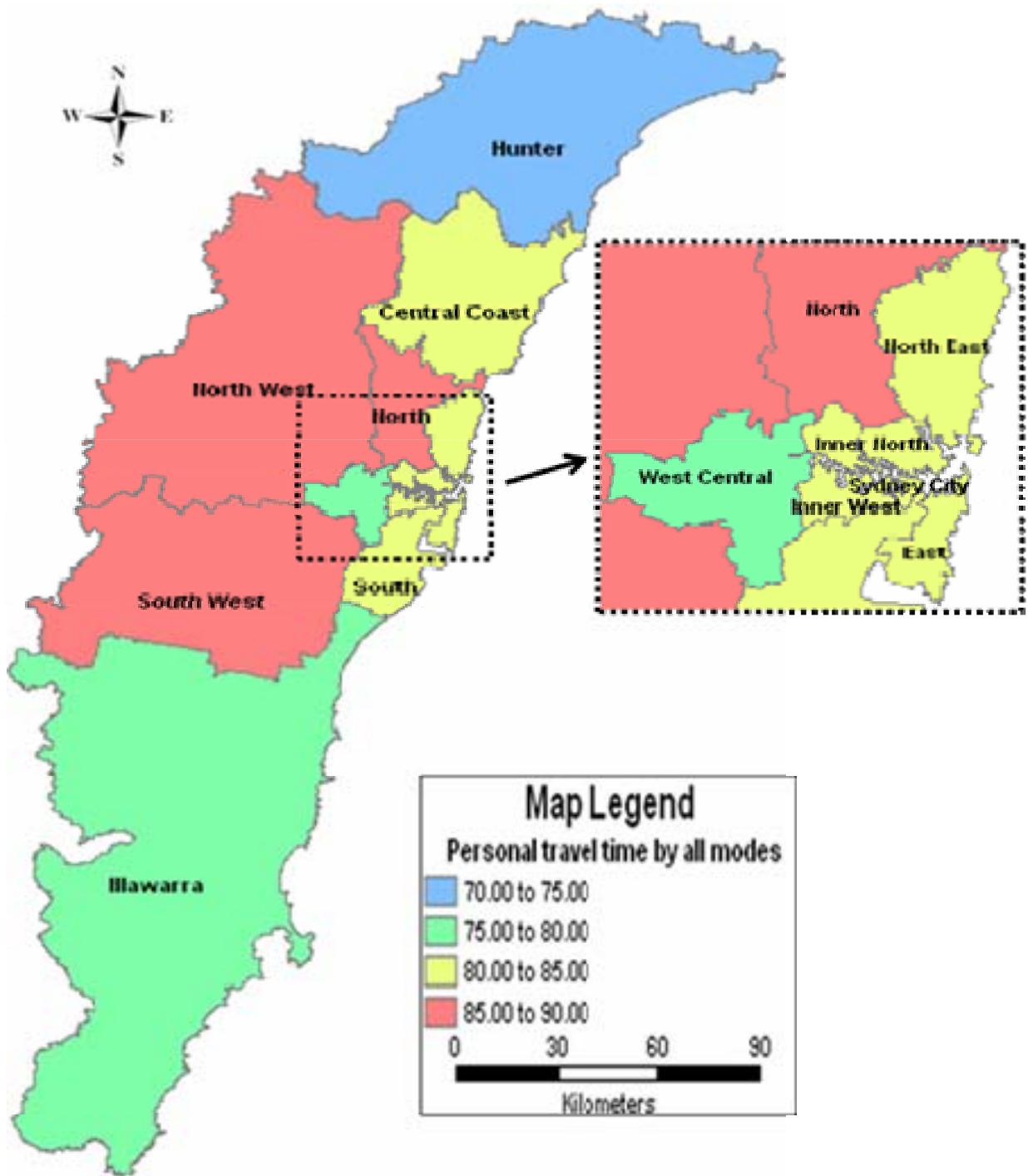


Figure C2: Personal travel time by all modes (minute per person per day)

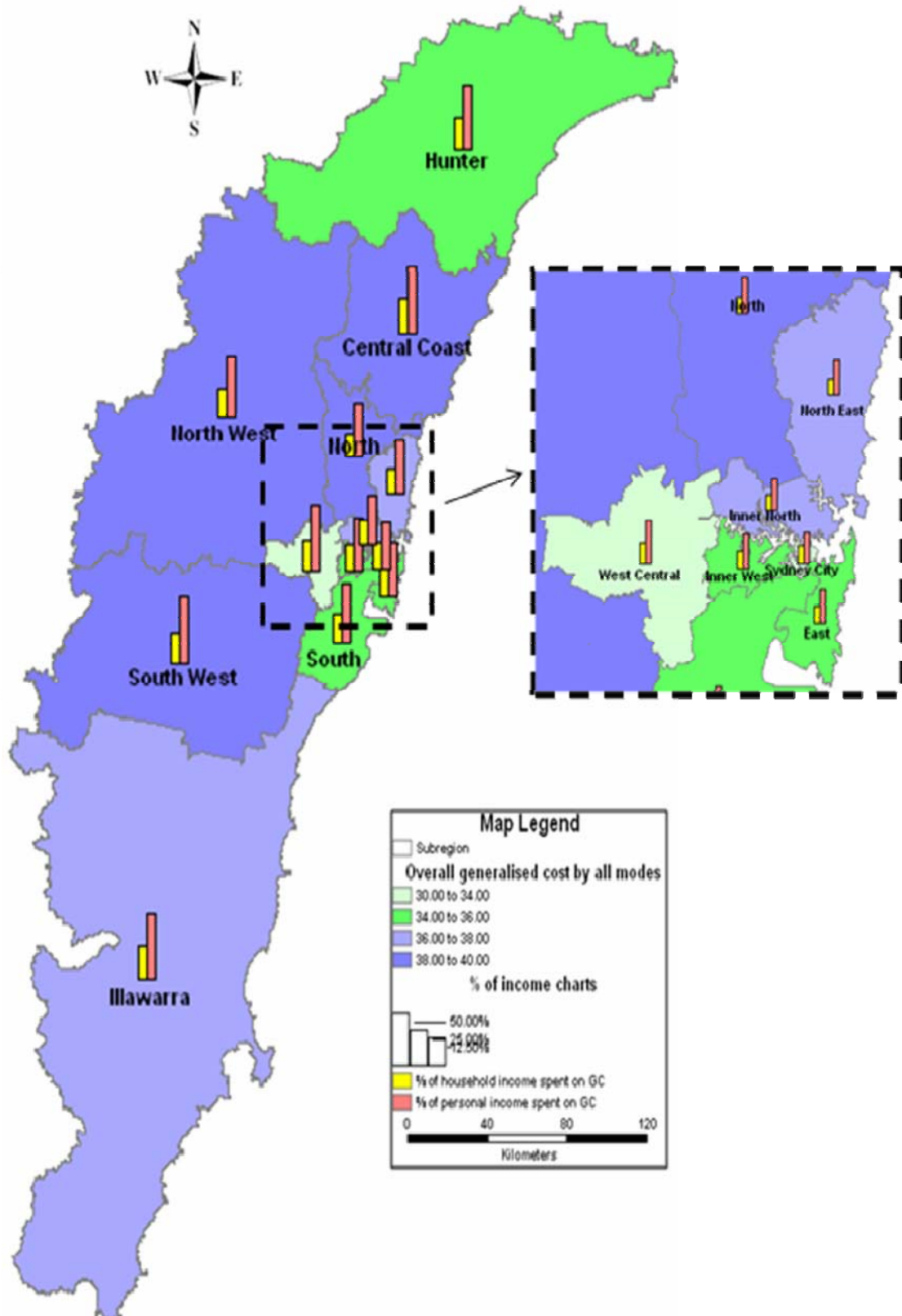


Figure C3: Overall generalised cost of travel per person by all modes (dollar per person per day) and as a percentage of income by region



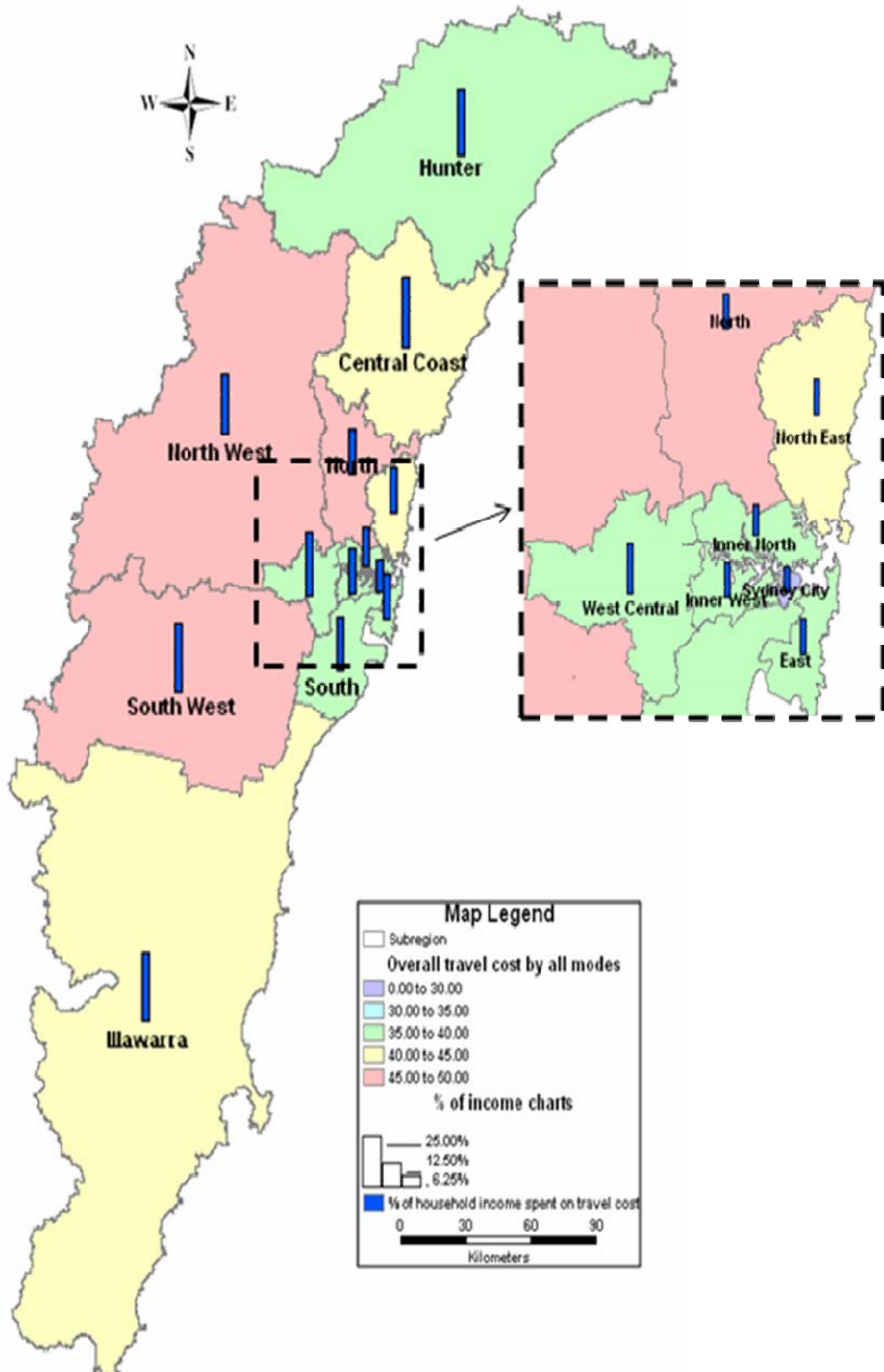


Figure C4: Overall household travel cost by all modes (dollar per household per day) and as a percentage of household income by region

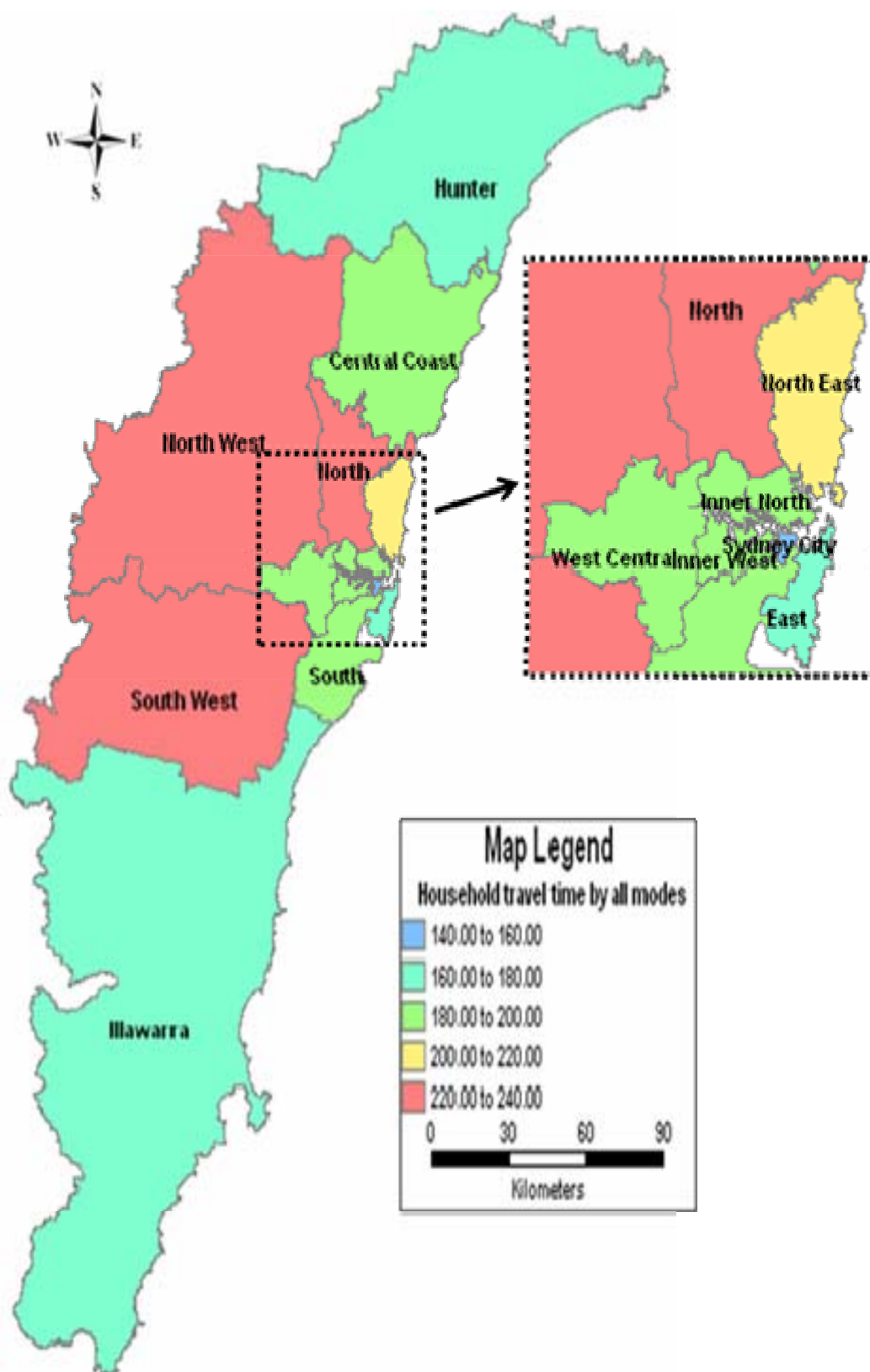


Figure C5: Household travel time by all modes (minute per household per day)

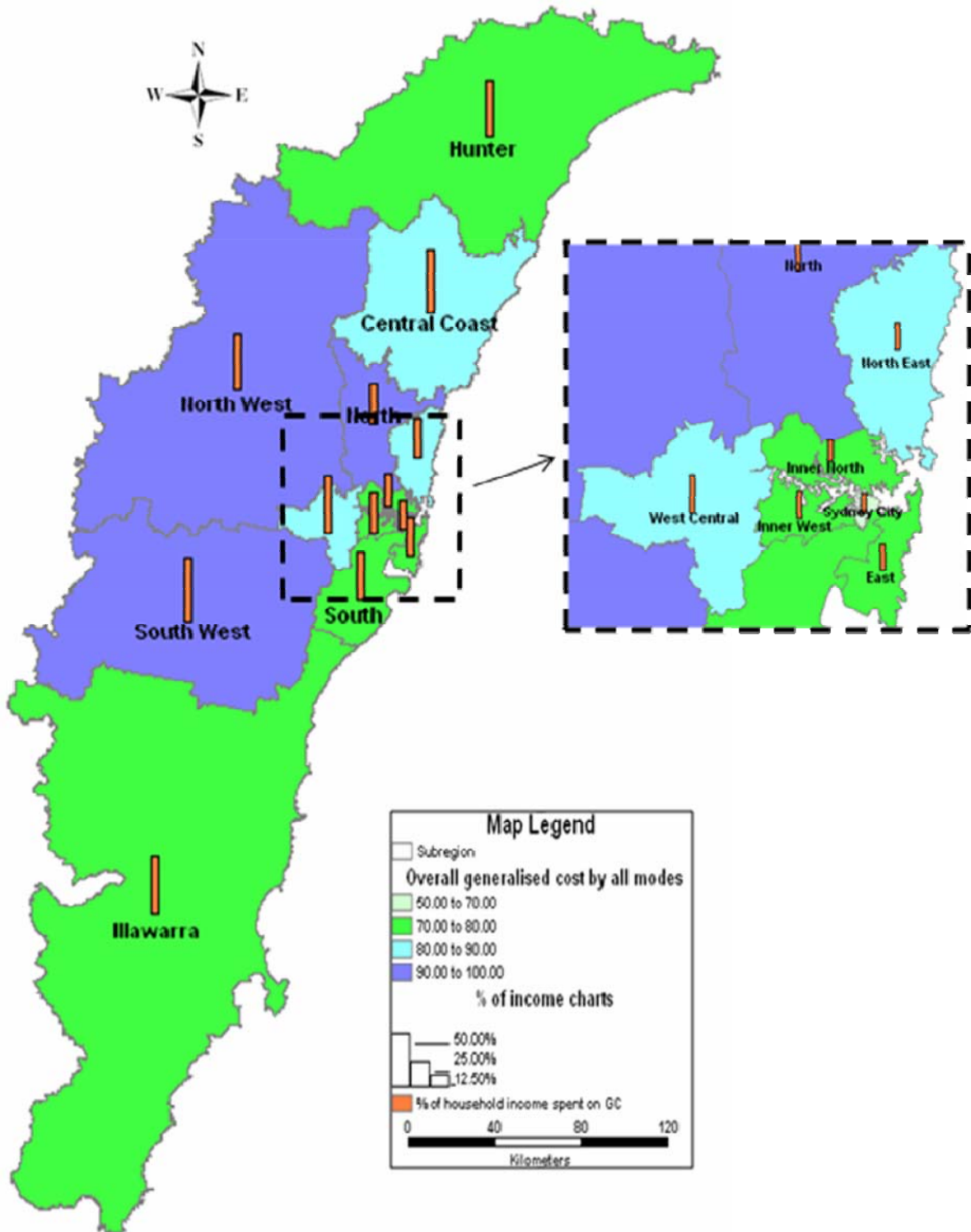


Figure C6: Overall generalised cost of travel per household by all modes (dollar per household per day) and as a percentage of household income by region

## Appendix 7: Vehicle class conversion: HTS to NRMA, and NRMA ownership costs

HTS		NRMA
Vehicle class	Engine size	Vehicle class
Motorcycle		Light
Car	< 1600 cc	Light
Car	>= 1600 cc & < 2400 cc	Small
Car	>= 2400 cc & < 3000 cc	Medium
Car	>= 3000 cc	Large
4WD	< 3000 cc	SUV Compact
4WD	>= 3000 cc & < 4000 cc	SUV Medium
4WD	>= 4000 cc	SUV Large

**Vehicle ownership cost by vehicle segment**

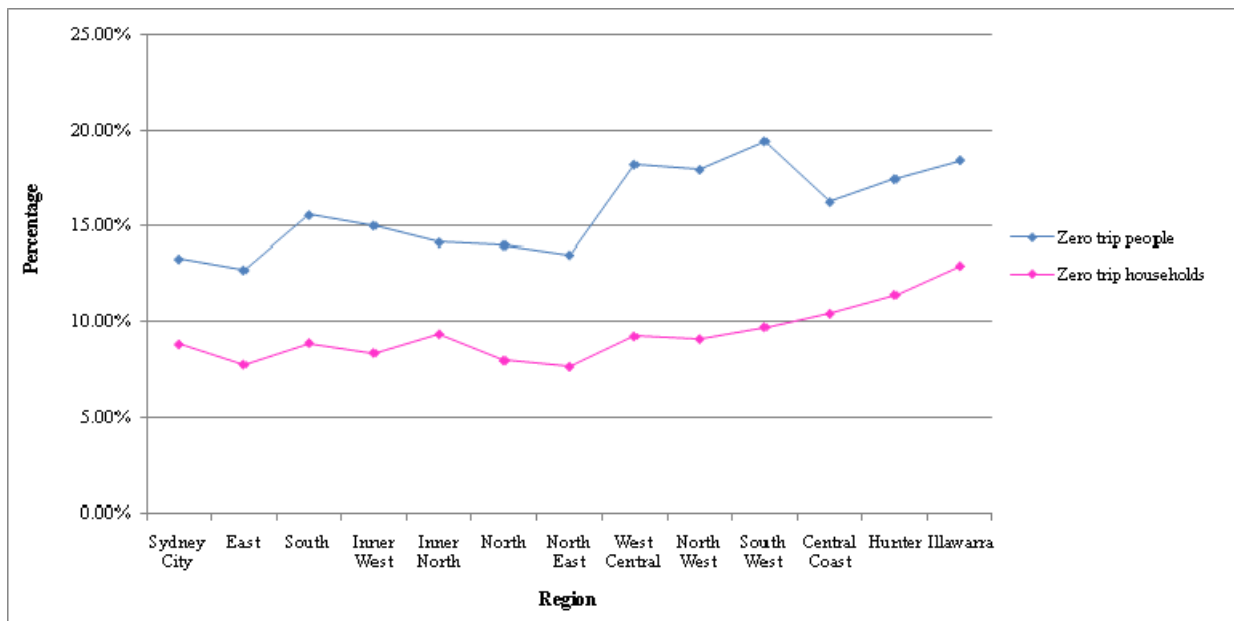
Vehicle Class	Weekly cost, per vehicle per week						Cost, per vehicle per day
	Depreciation	Opportunity cost	Annual fees and charges	Tyres	Maintenance	Total	
Light Car	53.43	15.46	28.37	4.95	13.66	115.86	16.55
Small Car	67.99	19.86	30.59	6.26	14.49	139.19	19.88
Medium Car	110.10	32.43	35.19	6.79	17.34	201.85	28.84
Large Car	129.79	38.47	35.70	6.92	9.41	220.28	31.47
People mover	117.63	34.84	32.22	5.76	16.51	206.97	29.57
SUV Compact	92.41	27.14	32.52	5.16	17.05	174.27	24.90
SUV Medium	134.75	39.94	33.62	6.03	12.64	226.97	32.42
SUV Large	138.87	41.17	36.25	5.22	17.20	238.72	34.10

Note: Daily vehicle ownership cost is calculated by dividing weekly vehicle ownership cost by 7 days per week.

## Appendix 8: Incidence of no trips on HTS survey day

### Zero trip people and household on survey day by region

Residential Subregion	Total population	Total households	Zero trip individuals	Zero trip households	Percentage of zero trip individuals	Percentage of zero trip households
Sydney City	2432	1317	324	116	13.32%	8.81%
East	6033	2671	769	207	12.75%	7.75%
South	10331	4045	1609	359	15.57%	8.88%
Inner West	5903	2393	887	200	15.03%	8.36%
Inner North	5340	2345	756	219	14.16%	9.34%
North	5383	1897	755	151	14.03%	7.96%
North East	4847	1873	656	143	13.53%	7.63%
West Central	12202	4335	2223	400	18.22%	9.23%
North West	11917	4083	2139	371	17.95%	9.09%
South West	7419	2491	1442	242	19.44%	9.71%
Central Coast	5249	2130	853	222	16.25%	10.42%
Hunter	7447	2971	1300	339	17.46%	11.41%
Illawarra	7910	3143	1459	406	18.45%	12.92%
<b>Total</b>	<b>92413</b>	<b>35694</b>	<b>15172</b>	<b>3375</b>	<b>16.42%</b>	<b>9.46%</b>



Percentage of zero trip individuals in total population and zero trip households in total households by region