Understanding Behaviour

TMfS High Occupancy Vehicle Lane: Stated Preference Research

Report for Transport Scotland

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Summary

This study reports the findings of a Stated Preference (SP) study aimed at understanding the value that car drivers put on car sharing as opposed to single occupancy trips. The aim was to develop parameters and associated Alternative Specific Constants (ASCs) and/or alternative-specific In-Vehicle Time (IVT) factors for use in the modelling and appraisal process, which would capture the relative step change in the travel experience brought about my a move from single occupancy to a car sharing trip. In addition, in order to assist in more detailed demand forecasts and understanding of the potential travel market, the opportunity was taken to enrich the findings with analysis of individual market segments. All impacts are considered in terms of their relative contribution to the (dis)utility of travel.

Following an initial pilot period, 673 responses were received from a web-based survey conducted in June 2008 amongst car driving commuters in Scotland. Representative samples were achieved across all key market segments allowing for the specification of robust and reliable parameters for demand forecasting, modelling and appraisal across Scotland.

A series of choice models were estimated to the market research data with the resultant models showing a good degree-of-fit. In addition, as hypothesised, significant variations in tastes and preferences across market segment, particularly for household car ownership, gender, age group, interest in car pooling, current journey time, and sharing with a stranger (as opposed to family member/friend). Comparing the sensitivity of demand to a change from a single occupancy to a car sharing trip, it can be seen that the latter imposes a 'penalty' equivalent to **28.45** IVT minutes. Segmenting this value according to the number of cars owner per household results in 'penalties' equivalent to **46.51** and **26.42** IVT minutes for one and two plus car owning households respectively.

1 Introduction

1.1 Background

1.1.1 MVA Consultancy was commissioned by Transport Scotland to undertake a Stated Preference (SP) study on High Occupancy Vehicle (HOV) lanes in Scotland. The study was used to inform the modelling and appraisal of potential car sharing initiatives within the Transport Model for Scotland (TMfS).

High Occupancy Vehicle Lanes

1.1.2 High Occupancy Vehicle (HOV), or carpool, lanes are reserved for the use of vehicles with two or more occupants (ie the driver plus one or more passengers), including buses. Interest in their deployment has grown in recent years as Central and Local Governments seek initiatives for more efficient use of the highway network. By encouraging car sharing, as opposed to single occupant car trips, they have the potential to reduce the total volume of traffic on the network. Typically they are created through the widening of existing alignments or the use of the hard shoulder on the motorway network. In recent years interest in their deployment from scheme opening has also grown. The Scottish Executive's *National Transport Strategy* sets forward the aim of providing more reliable journey times on the trunk road network in the face of anticipated traffic growth and tackling congestion where it affects journey time reliability:

> *"On some routes we may prioritise improvements for all or certain users, such as buses or multi occupancy vehicles, to reduce their optimum journey time as well as improve reliability."*

1.1.3 Figure 1.1 presents the assumed change in car occupancy from the base year (2000[1]) for commuting trips from Scottish Transport Analysis Guidance (STAG) Unit 9.5.14. It can be seen that without intervention, the assumed commuting trip occupancy is forecast to decline markedly, with the weekday average falling from 1.15 to 1.03. In effect this trend suggests that by 2020 there will be virtually no car sharing trips.

[1] Base year levels have been derived from the National Travel Survey (NTS).

Figure 1.1: Assumed Change in Commuting Trip Vehicle Occupancy 2000 - 2020

Decision-Making Theory

1.1.4 Understanding the propensity for using HOV lanes amongst the existing travelling population requires an appreciation not just of traditional attributes such as time and cost, but also the impact sharing with an acquaintance or stranger has on these attributes. Additionally, there may be 'penalties' to the car driver which cannot be captured in using these simple attributes.

1.1.5 As discussed, whilst a number of 'attributes' associated with different modes of travel are quite readily quantifiable (ie monetary cost for parking and fuel, travel time etc) other attributes do not lend themselves to such ready quantification. For example, comfort, convenience, reliability and security are all considered to be significant contributors to the mode choice decisions. However, differing perceptions amongst travellers, and the difficulties in readily quantifying these attributes, mean that they are rarely included (directly) within modelling and appraisal process(es), or the associated utility computation.

1.1.6 In terms of the choice between a single occupant trip and car sharing, by considering their utilities we can evaluate the key differences between the two options:

$$V_{ij}^{k} = \alpha_1 IVT_{ij}^{k} + \alpha_2 Cost_{ij}^{k} + \alpha_3 Fuel_{ij}^{k} + \delta^{k} \quad (1)$$

where:

V_{ij}^{k} = the utility of travelling by alternative k between i and j

IVT_{ij}^{k} = the In-Vehicle Time (IVT) or journey time by alternative k between i and j

$Cost_{ij}^{k}$ = the parking charge and all other non-fuel costs associated with travel by alternative k between i and j

$Fuel_{ij}^{k}$ = the fuel cost (resource plus duty and VAT) associated with travel by alternative k between i and j

δ^{k} = a 'modal penalty' or Alternative-Specific Constant (ASC) for alternative k

α_1 , α_2 , and α_3 are parameters to be estimated.

1.1.7 The choice to car share, as opposed to single occupancy, has the potential to impact upon the monetary costs associated with car travel. For example, we could make the assumption that such costs are evenly distributed between the driver and the total number of passengers in the car. Consequently, monetary costs of £12 per trip would, all else being equal, reduce to £4 per person if a previous single occupant car driver decided to car share with two passengers.

1.1.8 Similarly, a decision to car share may result in a net increase in journey time. Consider, for example, the need to now detour from the previously chosen route for the journey in question in order to pick-up one, or more, passengers and the additional journey time 'penalty' this may bring. Conversely, a demand management measure such as a HOV lane would be designed to reduce total journey times for those electing to car share.

1.1.9 It is common for the more qualitative attributes of travel to be considered as part of the Alternative Specific Constant (sometimes referred to as the ASC or 'mode penalty'[2]). The ASC is considered to be uniform across all journeys (ie it does not vary by journey time, cost or distance) by a given alternative form of transportation, although it may be segmented by journey purpose and other market segments such as demographic and socio-economic characteristics. Hypothesised components of the ASC construct in the context of this study include:

- **convenience** in terms of the additional penalty associated with not being able to perform a 'door-to-door' journey or having to share personal space with other passengers;
- **reliability** in that additional journey time and detour is likely to add a real, or perceived, additional element of (un)reliability to journey time. Additionally, passengers may have concerns regarding the reliability of their 'pick-up';
- **security**, particularly in relation to having to share confined space with other travellers with whom the traveller in question may not be familiar;
- **comfort**, whereby the ergonomics, cleanliness and privacy of the traveller's immediate environment is compromised in some way; and
- **autonomy**, typically a greater feeling of autonomy is generated by the feeling of being in control over one's own life. Adherence to a fixed schedule, ie a pick-up time, may compromise or adversely affect such feelings. The opposite affect would be one of **affinity** or liking for social interaction with fellow passengers.

1.1.10 Other aspects of car sharing that may impact on the construct include:

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[2] Hereafter we discuss this construct solely in terms of the ASC.

- information provision, particularly pre-journey with regard to pick-up times and points;
- promotion and awareness; and
- experience and familiarity, particularly as formal car sharing and HOV lanes are a relatively new concept.

1.1.11 In addition to these less readily quantifiable factors, the ASC is also liable to include the net influence of any characteristics of the individual that are not explicitly included in the utility function. It is uniform across all journeys by a given mode, but segmented values may be produced for individual markets.

1.1.12 Another means of considering the less tangible factors is via the inclusion of alternative-specific In-Vehicle (IVT) factors, which quantify the relative (dis)utility of time spent in alternatives.

1.2 Study Objectives

1.2.1 The evidence base for the value of ASCs or IVT factors for new and innovative alternative is, by their very nature, more limited than longstanding measures. This restricts the ability to use values from other studies. It is therefore the aim of this study to gain a better understanding of the value that travellers place on different aspects of car sharing, to estimate the value of the modal penalty (ASC) or equivalent IVT factor, so that the implementation of HOV lanes can be robustly appraised.

1.2.2 The primary objectives of this study are to:

- develop ASCs relative to single occupancy for car sharers;
- derive ASCs for certain key market segments, according to their relative importance in the model process;
- examine the potential for deriving IVT factors for car sharing as opposed to single occupancy (normalising the IVT factor of drive alone to one);
- examine the impacts of sharing with an acquaintance as opposed to a member of a car pool or a work colleague; and
- develop a forecasting tool to assess the relative market share (probability) for car sharing under a number of hypothetical scenarios.

1.3 Study Tasks

1.3.1 To address the requirements of the project, the study was divided in to the following tasks:

- define the attributes of interest, ie journey time, monetary cost and the person shared with;
- define the level(s) of the variables (attributes) and appropriate SP experiment design;
- design and implementation of a pilot SP survey, incorporating qualitative feedback from respondents;
- design of the final SP surveys and appropriate fieldwork strategy;
- implementation of the final SP survey(s);

- data input and cleaning;
- data manipulation in order to provide inputs into the choice modelling process and model estimation;
- choice of modelling framework(s) and application; and
- final reporting, including production of recommendations and guidance regarding the use of ASCs and IVT factors for HOV land and car sharing schemes in Scotland.

1.4 This Report

1.4.1 Following this introductory chapter, this report continues with the following structure:

- Chapter 2 – Stated Preference Design;
- Chapter 3 – Market Segments and Attribute Importance;
- Chapter 4 – Preferences and Parameter Estimation; and
- Chapter 5 – Conclusions and Recommendations.

2 Stated Preference Design

2.1 Introduction

2.1.1 The estimation of the willingness-to-pay or valuation for a product or service is usually undertaken through the observation and analysis of individuals' revealed and/or stated preferences.

2.1.2 Revealed Preference (RP) refers to observations of actual behaviour, for example the mode choices that decision-makers currently make or made in the past, and Stated Preference (SP) refers to observations of hypothetical behaviour under controlled experimental conditions.

2.1.3 Although RP data is inherently more credible than SP data, the collection of RP data is not without problems, especially when dealing with a relatively new concept such as HOV lanes, when there is limited scope for observing actual choices and assigning realistic valuations. In addition, the number of contributory factors to the mode choice decision is large, and it becomes increasingly difficult to isolate the effect of individual factors. In such instances SP data can provide a valuable insight into individuals' tastes and preferences, as it reduces the number of contributory factors to a finite set of attributes. This is achieved through the limitation of the numbers of factors within the choice context, and by controlling for any remaining influential factors within the SP experiment.

2.2 Survey Methodology

2.2.1 In order to maximise the number of people within the target market reached, a web-based self-completion survey was employed. Piloting was undertaken with City Centre businesses using a paper-based self-completion survey. Appendix A contains full details of the pilot analysis undertaken with a paper-based version of the final survey.

2.2.2 The survey form was designed to be generic, so that responses could be elicited from respondents all across Scotland. This sampling strategy ensures that the valuations and recommendations regarding car sharing are transferable between different contexts and localities.

2.2.3 The survey was designed in such a way as to ensure that the decision context related to an actual journey likely to experienced by the respondent, and the 'response space' allows the respondents to describe their hypothetical behaviour. Screening questions at the beginning of the surveys ensured that respondents were able to provide a response relevant to the car sharing context. Users of non-car modes were automatically routed past the SP choice scenarios, and solely provided information regarding their current travel patterns, demographics and socio-economic characteristics.

2.3 Stated Preference Design

2.3.1 In designing an SP experiment to elicit car users' preferences towards car sharing initiatives, consideration needs to be given towards two important aspects, namely:

- the definition of the set of alternatives from which the individuals selects their preferred option; and

- the way in which alternatives are described/presented to the individual.

2.3.2 With regard to the former, the choice alternatives are described in terms of a number of ‘attributes’ which were judiciously chosen to represent the most salient aspects of the concept(s) on offer.

2.3.3 In order to cater for a variety of journey times/distances and costs, brought about by the sampling frame and its geographic spread, attribute levels were presented to the respondent in terms of their difference from the base level (today’s journey). This ensured that the attributes of each alternative were presented in terms which would be familiar to all respondents (ie variations around their current experience), thus offering a realistic choice context. The selection of the alternatives and the range of attributes to include in the design is the subject of the next section.

Determination of the ‘Choice Alternatives’

2.3.4 An important stage in any SP design is to identify the range of alternatives and attributes to be tested. A range of possible choice contexts were considered in the design and piloting of the SP experiment. These included the presentation of competing modes (to car driver or car share), ie bus or rail; however, this approach was discounted due to the potential unavailability of one or more of these competing modes and the difficulty in defining appropriate attribute levels which would be realistic to the respondent. Table 2.1 presents the results of a paper-based pilot survey undertaken with employees in Edinburgh.

Table 2.1: Pilot SP Survey Results (N = 39)

Attribute	Coefficient	T-Stat	Implied Value	Units
ASC_{CarA}	0	Fixed	-	
ASC_{CarB}	-1.11	-2.41**	57.51	min
ASC_{PTA}	-0.606	-1.93	31.40	min
ASC_{PTB}	-0.567	-1.37	29.38	min
ASC_{Not}	-1.84	-4.35**	95.34	min
Cost	-0.00302	-2.23**	-	-
Time	-0.0193	-2.4**	6.39	p/min
Share	-0.71	-1.77	235.10	p
Park	0.4380	1.12	-145.03	p
Walk	-0.0209	-0.80	6.92	p/min
Null Log Likelihood	-312.231			
Log Likelihood	-272.535			
Rho Bar Squared	0.098			
Respondents	195			
Observations	194			

Notes: t-statistics are shown relative to zero. ** indicates significance at the 5% level.

2.3.5 The Rho Bar Squared value represents the goodness-of-fit of the model. In SP work, a value of 0.20-0.30 for the Rho Bar Squared shows the model is good, while more normal models are around 0.10-0.20. The Rho Bar Squared of this model is a little low, at 0.098, but still shows that model is a reasonable good fit, and especially so for such a small sample size.

2.3.6 The signs of all the estimated values are intuitively logical, and while the absolute numbers are not relevant, the relationship between them shows the value respondents place on them. The T-stats for the attributes show how significant the result is - if the value of the t-stat is less than 1.96, it is insignificant. Just less than half of the estimated parameters in the model have significant values.

2.3.7 The relative ease with which the pilot could be completed is presented by current mode in Table 2.2. It can be seen that even though almost 60% of respondents thought that making the choices were either 'very' or 'moderately easy', the most popular response was 'moderately difficult'. This suggested that there was a need for some simplification of the final design.

Table 2.2: Breakdown of Ease of Completion by Respondent Group (N = 39)

Ease	Car Driver	Car Passenger	Public Transport	Total
Very easy	8 (36%)	0 (0%)	4 (36%)	12 (31%)
Moderately easy	7 (32%)	3 (50%)	1 (9%)	11 (28%)
Moderately difficult	5 (23%)	3 (50%)	6 (55%)	14 (36%)
Very difficult	2 (9%)	0 (0%)	0 (0%)	2 (5%)
Total	**22**	**6**	**11**	**39**

2.3.8 The central tenet of the experiment was the determination of the value placed on car sharing against driving alone. By screening respondents to the survey in order to identify those who currently used a car to commute to work, the potential complexity of the choice situation was significantly reduced. It was therefore determined that the potential alternative of not travelling, travelling to an alternative destination, or using another mode (ie public transport) could be captured within one alternative.

2.3.9 Respondents were therefore presented with three alternatives within the choice context in the final experiment:

- single occupancy car trip;
- car share; and
- do not travel/travel elsewhere/use another mode.

2.3.10 The presentation of three alternatives minimised the cognitive burden placed upon the respondents. This refers to the degree of task complexity and difficulty arising from the experiment. Although there is little 'hard' evidence regarding the number of alternatives and their associated level with which respondents are able to 'cope', a substantial amount can be learnt from piloting. Typically, we would expect the choice context to include no more than four or five alternatives (although greater numbers have been tested). The trade off is therefore between realism (presenting all possible alternatives) and complexity (minimising the burden and maximising the ability to respond).

2.3.11 The inclusion of the do not travel/travel elsewhere/use another mode alternative allows for the possibility that the other alternatives (single occupancy and car share) have simply become too 'unattractive' and the respondent would opt for one of these (unspecified) alternatives. A hypothetical example would be where the journey times and costs of a single occupancy car trip are presented as having risen substantially, but the respondent's attitude to car sharing is so aversive that they choose to change the place of their employment or work from home.

Determination of the 'Choice Attributes'

2.3.12 The study was concerned with the values car users place on car sharing as opposed to driving alone, expressed in terms of their attributes. Section 1.1 established the framework for determining what these attributes might be, including:

- monetary cost:
  - parking charges; and
  - fuel cost.
- journey time:
  - as a result of HOV lanes;
  - walk time;
  - waiting time due to pick-up / drop-off of all car passengers; and
  - having a designated car parking space at their workplace[3].
- car sharing context:
  - sharing with a friend or family member; and
  - a car pool member or work colleague.

2.3.13 Within the pilot experiment, parking charges and fuel cost were combined within one monetary cost attribute in order to simplify the experiment using the following definition:

- "your cost, due to cheaper parking or decreased fuel use".

2.3.14 Similarly, journey time was also encapsulated in the final experiment using a single attribute with the following definition:

- "your journey time, through using High Occupancy Vehicle (**HOV**) lanes or having a designated parking space at your workplace (similar to Parent and Child spaces at a supermarket).

2.3.15 By allowing the journey time for car sharing to be greater than it is now, allowance was also made for the extended journey times associated with pick-up and dropping-off fellow car sharers. With the removal of public transport alternatives from the choice context, there was no longer the requirement to explicitly consider walk time and the contrast between accessing/egressing a public transport stop/station and the close proximity of a designated car parking space.

2.3.16 The concept of sharing with a stranger as opposed to a family member or friend was retained in the final experiment. However, in order to simplify the experiment for the respondent, the individual attribute for the allocation of a designated parking space was removed.

2.3.17 The final attributes used within the choice experiment were:

- monetary cost;

[3] This may have the potential to reduce both egress time (at the destination end of a home-based trip), due to proximity to the place of work, or In-Vehicle Time (IVT) due to reductions in time spent seeking a parking space.

- journey time; and
- sharing.

Choice Experiment

2.3.18 The choice experiment asked the respondent to consider a journey similar to the one they undertook today where the available options were single occupancy car-trip, car share (using a HOV lane), and don't travel/travel elsewhere/use another mode. For this experiment the respondent was presented with nine scenarios and asked to indicate their preferred choice based on cost, time and who they were sharing with. An example of how this scenario was presented is shown in Table 2.1. Example final surveys are provided in Appendix B.

2.3.19 Prior to the choice scenarios, an introduction was given to the choice context and the rationale behind changes in journey time and cost.

Table 2.3: Example SP Choice Scenario

Scenario 3	Car Alone	Use HOV Lane – Car Share	Don't travel/Travel elsewhere/Use other mode
Cost	£1.25 more than now	25p less than now	
Time	25 minutes more than now	10 minutes less than now	
Sharing	Travel alone	Travel with friends/family	
Choice	❑ 1	❑ 2	❑ 3

Experiment Design

2.3.20 The selection of the number of alternatives, attributes, and their constituent levels, to be considered governs the number of scenarios (questions) required in the final experiment. The empirical basis for such designs is well established in literature such as Kocur et al[4], and ensures

[4] Kocur, G., Adler, T., Hyman, W. and Aunet, B. (1982) *Guide to Forecasting Travel Demand with Direct Utility Assessment*. United Stated Department of Transportation, Urban Mass Transportation Administration, report UMTA-NH-11-0001-81-1, Washington DC USA.

orthogonality given fractional factorial as opposed to full factorial designs[5]. This means that any estimable effect or interaction of an attribute in a given design can be estimated without the risk of correlation with other main effects and interactions, for those which are assumed to be negligible.

2.3.21 A full factorial design of two alternatives (the third alternative has no inherent levels), with three attributes of interest, one at two levels and two at three levels, necessitates nine questions (scenarios) in the overall fractional factorial statistical design[6]. Nine scenarios is, from previous MVA Consultancy research, the typical upper bound at which respondent fatigue begins to become manifest in SP experiments. The inclusion of additional scenarios, over and above this number, tends to lead to diminished value of the responses.

2.3.22 In order to ensure 'realism' in the experiment, the following constraints (assumptions) were applied in the SP experiment design:

- the monetary cost of the single occupancy car-trip is always the same or greater than now;
- the journey time of the single occupancy car-trip is always greater than now;
- the monetary cost of car share is typically cheaper than now, but can be greater due to increased fuel costs; and
- the journey time of car share is typically less than now, but can be greater due to wait times associated with pick-ups/drop-offs.

2.3.23 These latter variations, as will as providing some possible realistic scenarios, also prevented respondents becoming accustomed to car share being quicker and cheaper than car alone, and thus potentially excluding it from their choice context in later scenarios.

2.3.24 The final design went through a series of simulations using a bespoke program in Excel in order to ensure that they were able to estimate a range of expected values of time and ASCs, which could be considered to be representative of the likely values of time of respondents to the survey. Scottish Transport Analysis Guidance (STAG) presents standard VoTs and the factors for uprating them[7]. Table 2.2 presents the base value of non-working time per person in 2002 values and prices, and the growthed 2008 values. For the purposes of SP analysis, the comparative value is the market price, ie their willingness to trade money for time.

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[5] A full factorial design involves each level of each attribute being combined with every level of all other attributes. However, they are only practical for small problems involving either small numbers of attributes or levels or both. Fractional factorial designs involve the selection of particular subset or sample (ie fraction) of complete factorials, so that particular effects of interest can be estimated as efficiently as possible. For a wider discussion on factorial design issues, see, for example: Louviere, J. J., Hensher, D. A, and Swait, J. D. (2003) *Stated Choice Methods: Analysis and Application*. Cambridge University Press, Cambridge UK.

[6] A full factorial design would, under this design, require the asking of 18 questions scenarios – $2^1 \times 3^2$.

[7] Available at: http://www.transportscotland.gov.uk/stag/td/Part2/Economy/9.5.12 [Accessed: 18/08/08].

Table 2.4: Values of Non-Working Time per Person (Source: STAG, 2008)

Year	Vehicle Occupant	Resource Cost (£/hour)	Perceived Cost (£/hour)	Market Cost (£/hour)
2002	Driver	4.17	5.04	5.04
	Other Occupant	3.68	4.46	4.46
2008	Driver	4.70	5.68	5.68
	Other Occupant	4.15	5.02	5.02

2.3.25 Table 2.3 presents the results of this simulation process in terms of the VoT entered into the model, and that estimated after the simulation process was run. Simulations were run for a full range of potential VoTs. The results show that the underlying design for the SP experiment was robust. This is especially true at the lower values that would be expected in accordance with STAG guidance.

Table 2.5: Stated Preference Choice Simulation Model Results

Scenario	Value of Time		Share with Family		Share with Stranger	
	Actual	Estimated	Actual	Estimated	Actual	Estimated
1	-2	-2.1	-145	-144.7	-250	-253.9
2	-4	-3.6	-145	-137.5	-250	-220.7
3	-6	-5.9	-145	-147.6	-250	-235.6
4	-8	-8.5	-145	-166.9	-250	-241.5
5	-10	-9.7	-145	-147.5	-250	-252.2
6	-12	-11.3	-145	-147.8	-250	-246.0
7	-14	-12.1	-145	-142.0	-250	-232.3
8	-16	-15.1	-145	-172.3	-250	-262.6
9	-18	-16.2	-145	-159.8	-250	-245.5
10	-20	-17.5	-145	-150.2	-250	-252.3

Additional Data Collection

2.3.26 The survey gathered information on respondent characteristics, information related to their most recent journey to work, usual commute trip-making characteristics, interest in car sharing/pooling and indicators of tastes and preferences. To this end, it asked for information on a general set of background questions including:

- respondents' demographic and socio-economic characteristics;
- the general importance of the attributes involved in car sharing; and
- respondents' current travel patterns and their daily expenditure and monetary cost associated with travel.

2.3.27 In order to ensure that the survey was representative of the desired target audience, demographic and socio-economic characteristics were collected from each respondent. The information collected included:

- employment status;
- age;
- car availability by household;
- total household income; and
- gender.

2.3.28 It was recognised that some of the above information was potentially sensitive to the respondent. There was therefore no obligation to provide this information, and it was requested during the concluding component of the survey in order to ensure that respondents were not deterred from completion at the start.

2.3.29 In order to provide a consistency check on the responses produced in the SP experiment, respondents were asked to rate (out of ten) the importance of the individual attributes considered within the experiment when making their choice.

2.3.30 Respondents were also questioned on their existing travel patterns, including the:

- origin and destination of the last journey to work;
- departure time;
- day of travel;
- journey purpose (screening);
- trip end of the journey (inbound to work or return);
- frequency of travel;
- mode choice (screening);
- mode choice frequency (last ten journeys);
- journey time and duration;
- journey cost (fuel and parking);
- travel alternatives;
- consideration of public transport and sharing alternatives;
- group travel (number of adults/children); and
- interest in joining in a car pooling/sharing scheme.

2.4 Final Surveys

2.4.1 Pilot analysis identified that the survey design was producing plausible and reliable results. Consequently, it was decided, barring a few cosmetic changes, to pursue the final survey using the piloted designs.

2.4.2 Final surveys were administered during June 2008.

2.5 Sampling

2.5.1 Out target was to achieve at least 500 commuters who regularly drove or shared a car, in order to produce a representative and statistically robust analysis. The sampling frame was selected in order to provide a geographic spread of respondents from across Scotland. A total of 659 SP surveys were achieved.

2.5.2 Data collection was undertaken using a web-based survey form. Recruitment of a wide group of 'commuting' respondents from companies based in Edinburgh, Glasgow, and other location throughout Scotland was undertaken during late May 2008. This was achieved by 'cold calling' companies and obtaining permission via each company's Human Resources / Travel Plan Co-ordinator. Employees at each recruited company were then directed to the survey website to complete the form.

3 Market Segments and Attribute Importance

3.1 Introduction

3.1.1 A total of 673 responses were achieved from respondents whose most common mode of travel was to drive a car/van to work. Appendix C contains a set of crosstabulations for the data collected.

3.2 Travel Profile of Respondents

3.2.1 The surveys collected data on a range of characteristics associated with the respondent's regular commute trip to work, including:

- usual origin and destination;
- start time;
- current journey time and cost;
- group travel;
- trip chaining undertaken on the journey to work;
- days worked;
- modes regularly used; and
- the possibility of using public transport.

Origin and Destination

3.2.2 Figure 3.1 illustrates the distribution of the respondents' home addresses by post district. The majority of the sample was recruited from employers in and around Edinburgh, and this is reflected in the spatial distribution. The only other significant clusters of respondents' home addresses were:

- Glasgow;
- Dundee;
- South Fife (Dunfermline area); and
- Inverness.

3.2.3 Figure 3.2 illustrates the corresponding spatial distribution for the respondents' typical workplaces by post district. As would be expected the most significant clusters are consistent with respondents' origins and include:

- Edinburgh, and in particular areas in and around Edinburgh Park and the A720 outer ring road;
- Glasgow;
- Dundee; and
- Inverness.

3.2.4 Figures 3.1 and 3.2 show that the sample achieved can be considered to be representative of Scottish commuters who travel to work by car and are likely to experience some degree of congestion (and therefore may be amenable to car sharing).

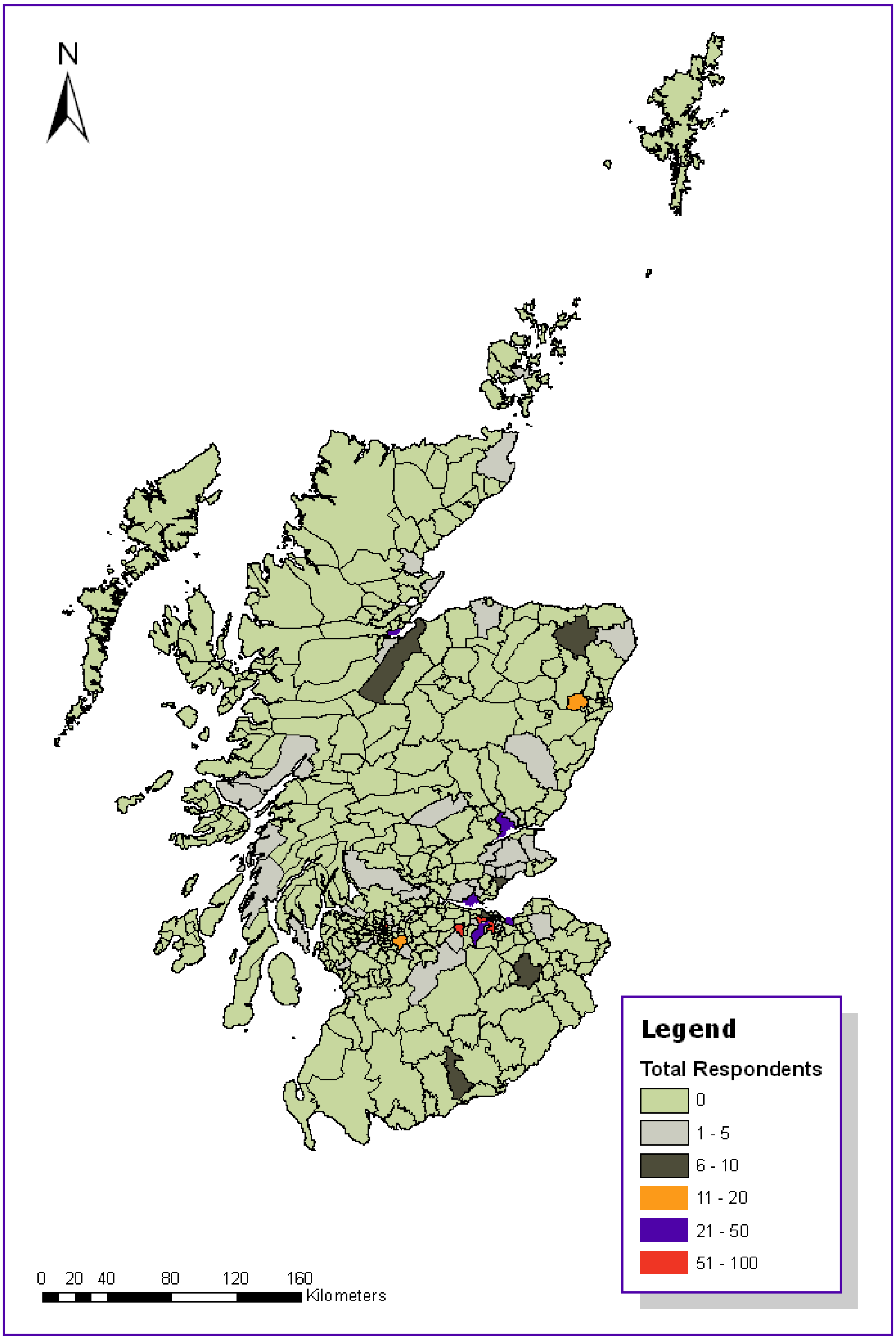

Figure 3.1: Distribution of Respondents' Origins (Home Addresses) by Post District

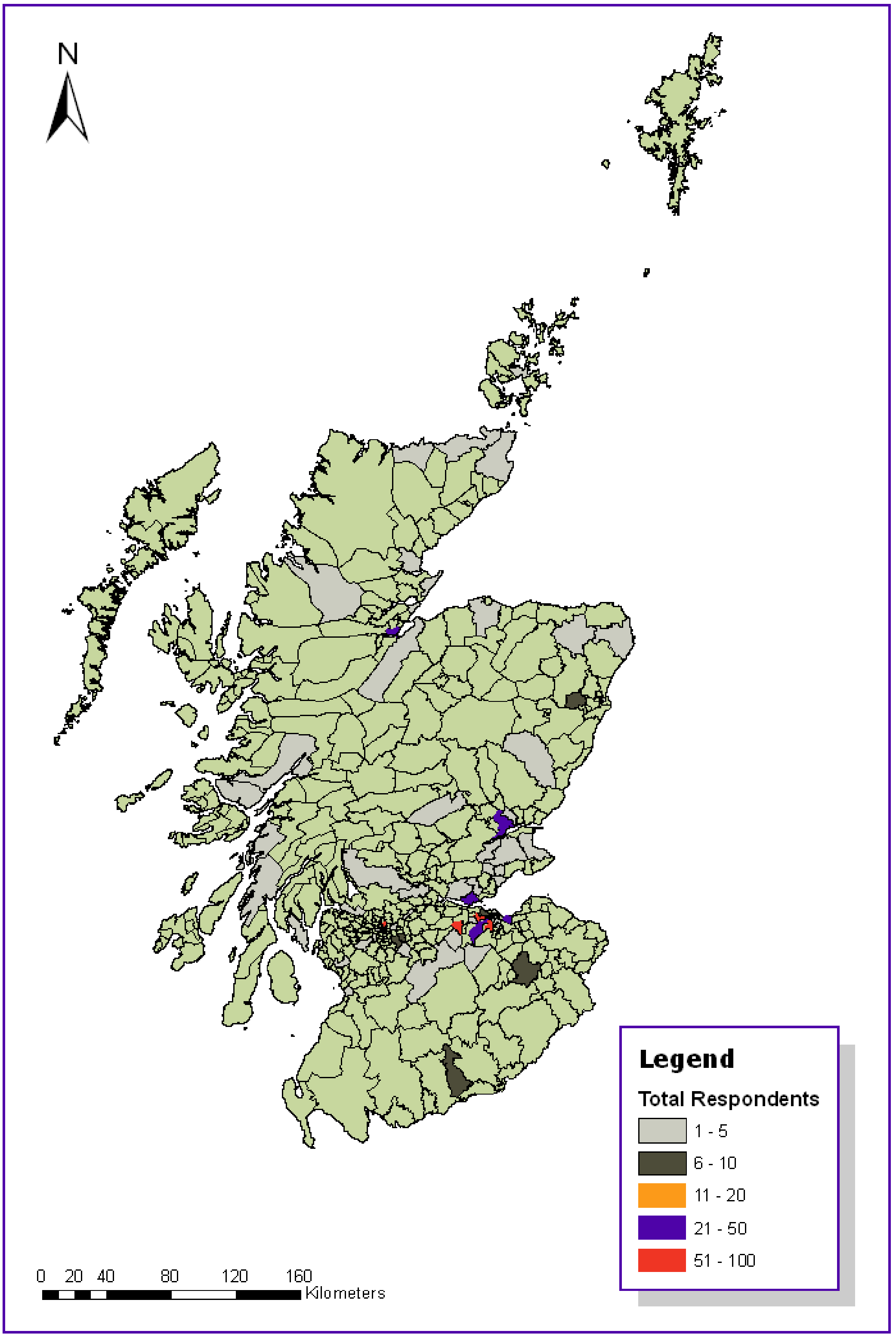

Figure 3.2: Distribution of Respondents' Destinations (Workplaces) by Post District

Time Period

3.2.5 Figure 3.1 illustrates the distribution of start times amongst the sample. The vast majority of respondents commence work between 08:00 and 09:29 (82%), indicating that, based upon start times alone[8], there is a potential market for car sharing with the ability to coordinate start times.

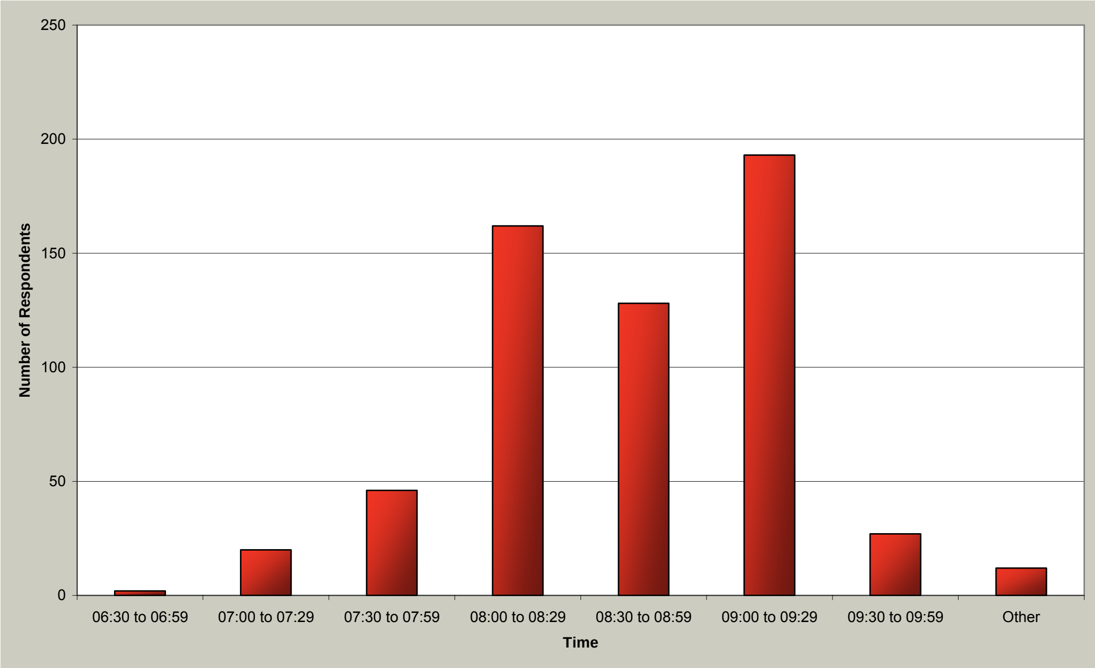

Figure 3.3: Work Start Time of Respondents (N = 590)

Working Week

3.2.6 Figure 3.4 shows that there is no significant discrepancy in the typical days worked per week outside of the weekend. The vast majority of respondents work Monday to Thursday (96.5 to 97.5%), with a marginally smaller number typically working on a Friday (93.6%). Only a small number work on either a Saturday or a Sunday (3%). Again, as for the typical start times, it would appear that the days worked per week do not present a significant barrier to the uptake of a car sharing scheme or initiative.

[8] For example, taking no account of end times or employee origins.

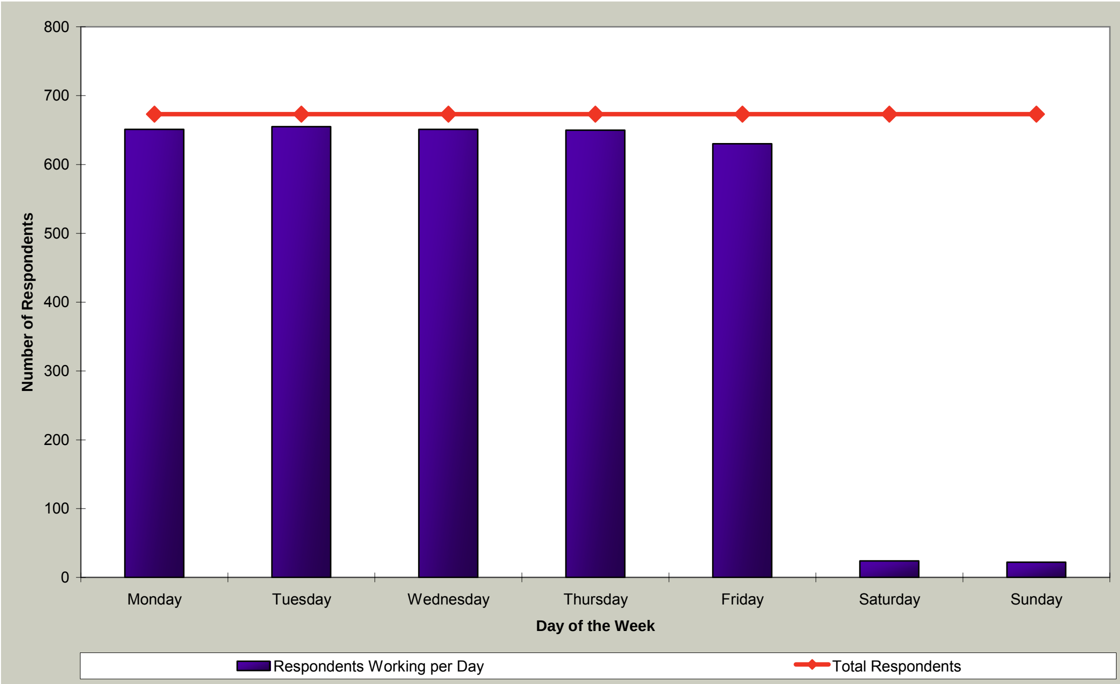

Figure 3.4: Days Worked per Week (N = 673)

Mode Choice

3.2.7 Respondents were questioned with regard to which modes, other than the private car, were regularly used to commute to and from work. In addition to the 669 respondents who indicated that they most regularly drove to work (four indicated that they were most regularly a passenger in a car), 156 alternatives modes were indicated. On average, this indicates that around one in four respondents used an alternative mode to the car for their commute journey on a regular basis; although, a number of respondents provided numerous alternative modes, suggesting that the 'true' proportion is somewhat less than one in four.

3.2.8 Figure 3.5 shows that the most common alternative modes are as a car passenger, on a motorcycle, or using rail or a work's bus. By comparison, very few car drivers use the conventional bus network as an alternative for the journey to work.

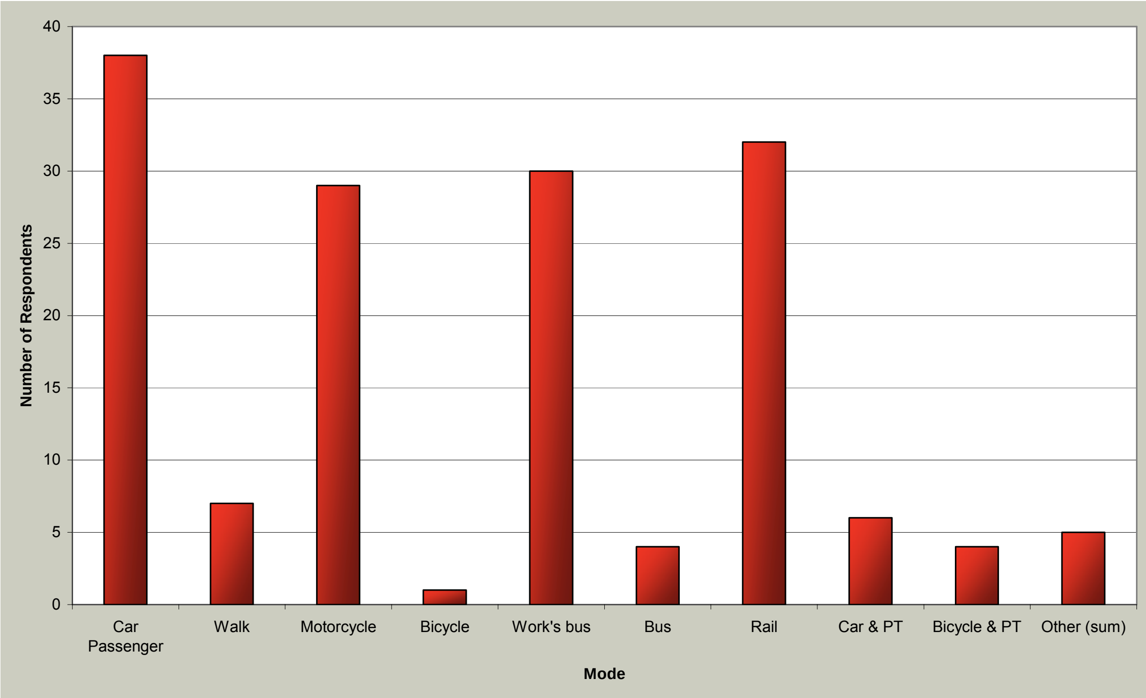

Figure 3.5: Alternative Modes for the Commute to Work (N = 673)

Car Occupancy Levels

3.2.9 The presence of other family members, friends, colleagues or car pool members provides an indication of current car sharing levels and the propensity for the car driver to have access to multiple destinations on their journey to work. This latter factor is dealt with more fully in the following paragraph, and can be considered to be a proxy for the need for flexibility and convenience, two travel factors on which the car is perceived to score highly in comparison to alternative modes.

3.2.10 Figure 3.6 illustrates the propensity to travel with another occupant amongst the respondents. In total, 10% of respondents travel with one other adult and 5% travel with one child. 7% travel with two or more occupants (who may be a mix of adults and children).

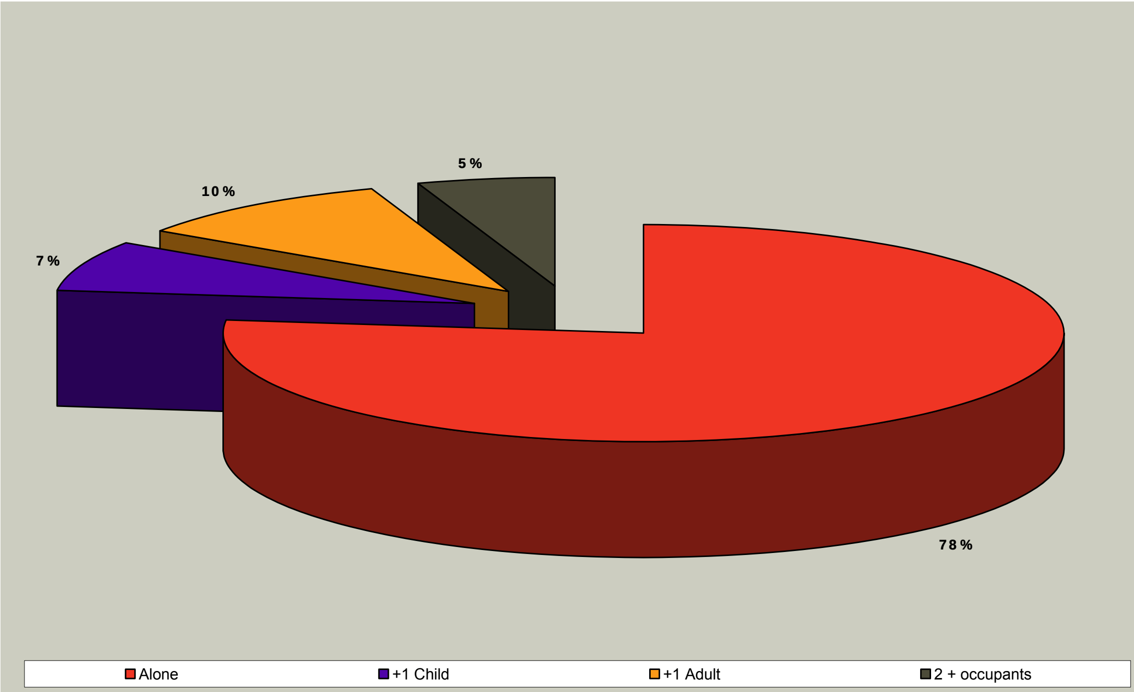

Figure 3.6: Propensity to Travel with another Occupant (N = 673)

Other Activities

3.2.11 Increasing attention has been devoted to the concept of trip chaining/tours, or activity modelling/sojourns, in transport planning. Instead of defining a fixed number of trips which are undertaken on a strict single Origin-Destination (O-D) pair basis, the individual is assumed to follow a three-component framework for trip generation (Daly, 1997[9]):

- the individual in his/her household context formulates an activity pattern for the period to be modelled, say a day. Out-of-home activities are of course the only activities that generate trips.
- the out-of-home activities are organised into ‘sojourns’, which are defined as stays at a specific location, each of which has a primary purpose (and possibly secondary purposes at the same location too).
- a travel plan is formulated to link the sojourns, in particular deciding which require to be visited by separate home-based tours (two or more trips) and which can be linked with other sojourns by non-home based trips.

3.2.12 It can be seen that in the context of the journey to work there is the potential for multiple stays and alternative purposes which may exert an important influence on the mode choice decision. Respondents were presented with a number of alternative options for activities undertaken on the journey to work, including to:

- take their spouse/partner to work;
- take children to school;

[9] DALY A. J. (1997) Improved methods for trip generation. *Proceedings 25th European Transport Conference*, Vol. P415, pp. 207-222, PTRC, London.

- take friend/family member to work/education;
- go shopping/other errands;
- buy things; or
- other.

3.2.13 On average, respondents engaged in 1.16 activities per tour (respondents could select multiple options). Approximately 48% of respondents travelled to and from work without engaging in other activities. The most popular activities were to go shopping/undertake other errands (21%) and taking children to school (15%). The undertaking of any additional activity may have a significant bearing on the propensity to partake in a car sharing scheme, due to potential concerns regarding the compromising of these activities.

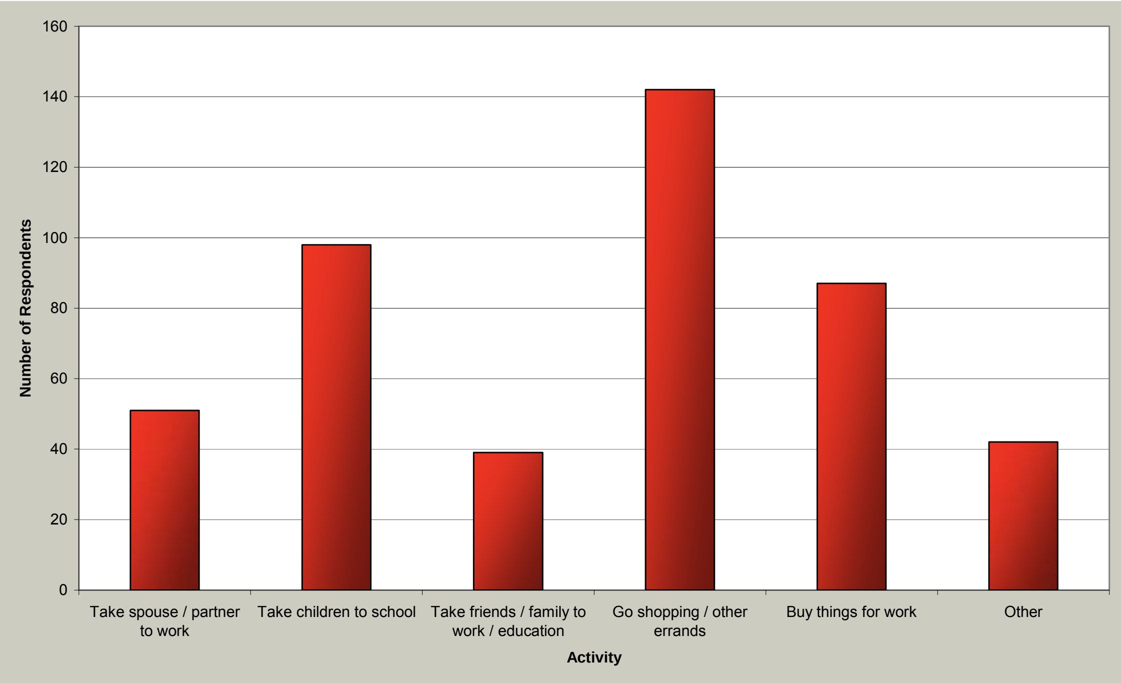

Figure 3.7: Other Activities Undertaken on the Journey to Work (N = 673)

Current Journey Times

3.2.14 Figure 3.8 illustrates the (normal) distribution of journey times amongst the sample. 82% of commuting journey times are 45 minutes or less, with approximately a third being between 16 to 30 minutes. This provides an indication that any significant deviations in order to pick-up car pool member/colleagues from the respondent's existing route may have a substantial proportionate effect on overall journey time; and therefore their propensity to partake in a car sharing scheme. Conversely, any priority measure for car sharers must counteract this additional time plus any perceived 'penalty' for car sharing that the individual has in order for the alternative to be chosen.

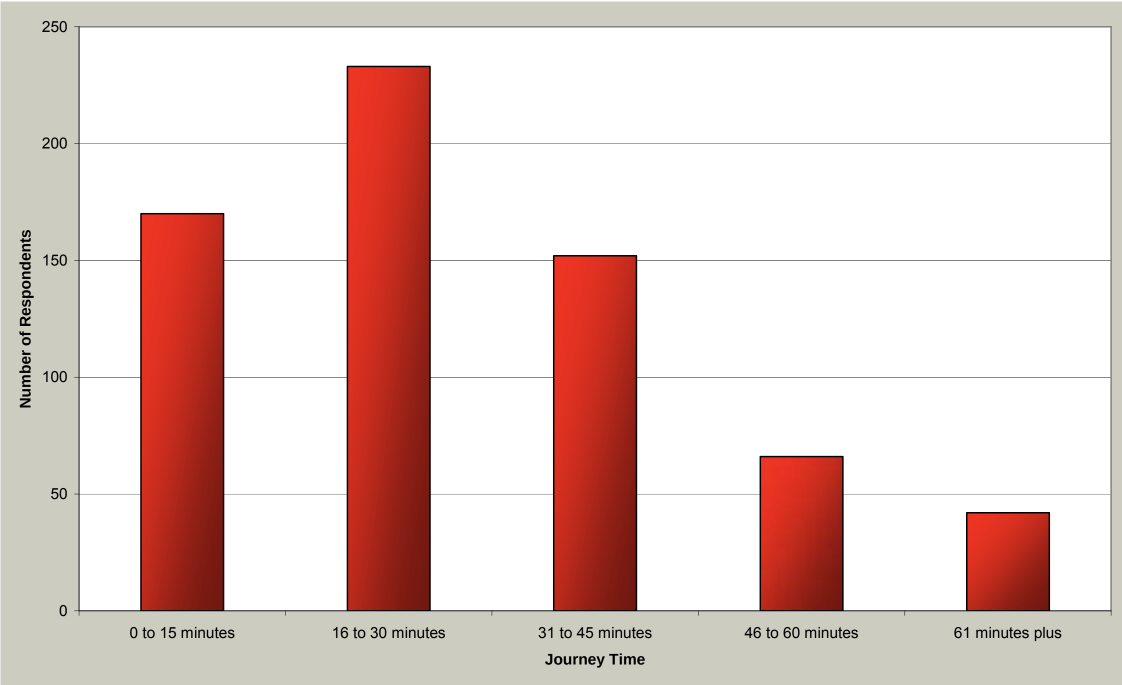

Figure 3.8: Current Journey Times (N = 663)

The Possibility of Using Public Transport

3.2.15 Respondents were questioned with regard to the possibility of using public transport, and why, if it was available, they chose not to. In total, 54% of respondents indicated that public transport was an alternative for the journey to work. It should be noted that this figure may not represent the 'true' proportion who have a public transport alternative, but rather those who perceive themselves to have that alternative. It is hypothesised that this figure may be higher, due to lack of information or knowledge regarding the public transport alternatives, although there is no sound evidence to suggest that the figure could in fact be lower.

3.2.16 Figure 3.9 provides a summary of the reasons given by respondents for not choosing public transport. They provide an important indication of why competing modes to a single occupancy car trip are currently unattractive to the respondent, and therefore key factors that are (perceived to be) influencing the modal choice decision. An understanding of these factors contributes to the knowledge base regarding the potential market for a car sharing initiative.

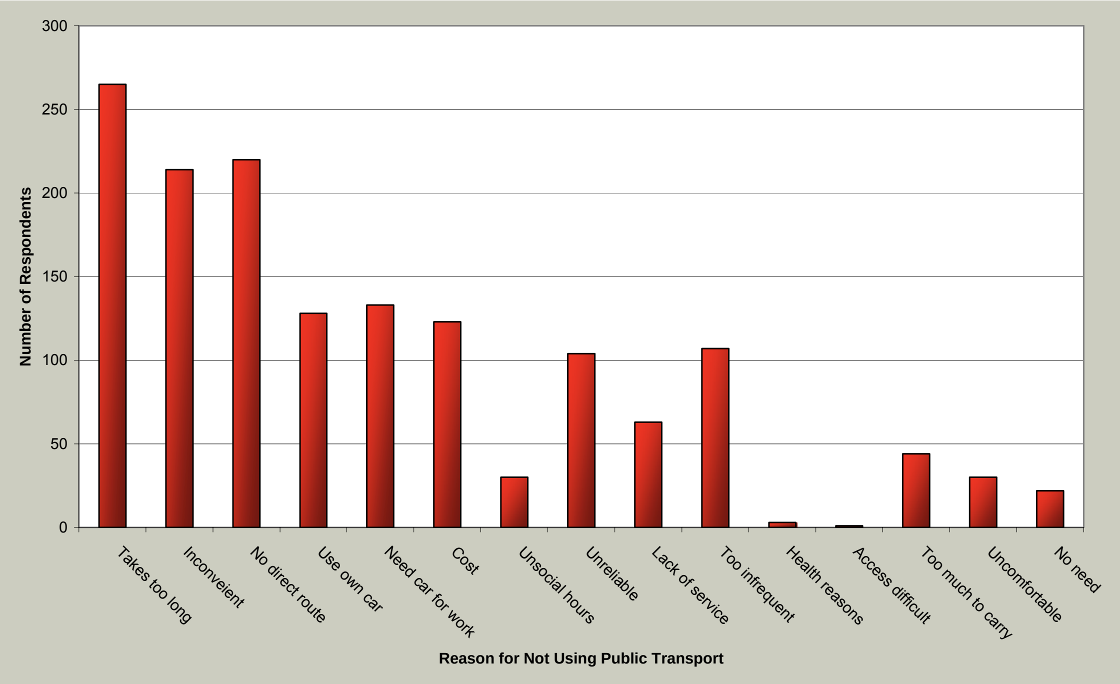

Figure 3.9: Reason for Not Using Public Transport (N = 673)

3.2.17 Respondents were available to provide more than one reason why public transport was not chosen and, on average, 2.2 reasons per respondent were provided. 221 respondents provided more than three reasons why public transport was not considered to be a viable alternative. The principal reasons included:

- "takes too long" (39.4%);
- "no direct route" (32.7%);
- "inconvenient" (31.8%);
- "need car for work" (19.8%);
- "use own car" (19.0%);
- "cost" (18.3%); and
- "too infrequent" (15.9%).

Interest in Car Sharing and Car Pooling Initiatives

3.2.18 Respondents were questioned with regard to their general interest in a car pooling initiative and, more specifically, their interest if a High Occupancy Vehicle (HOV) lane was in operation. Figure 3.10 shows that without a dedicated HOV lane, 36% were interested in a car sharing initiative. 3% indicated that they were already a member of a scheme. A full set of specific reasons why car pooling was unattractive is presented in Appendix D.

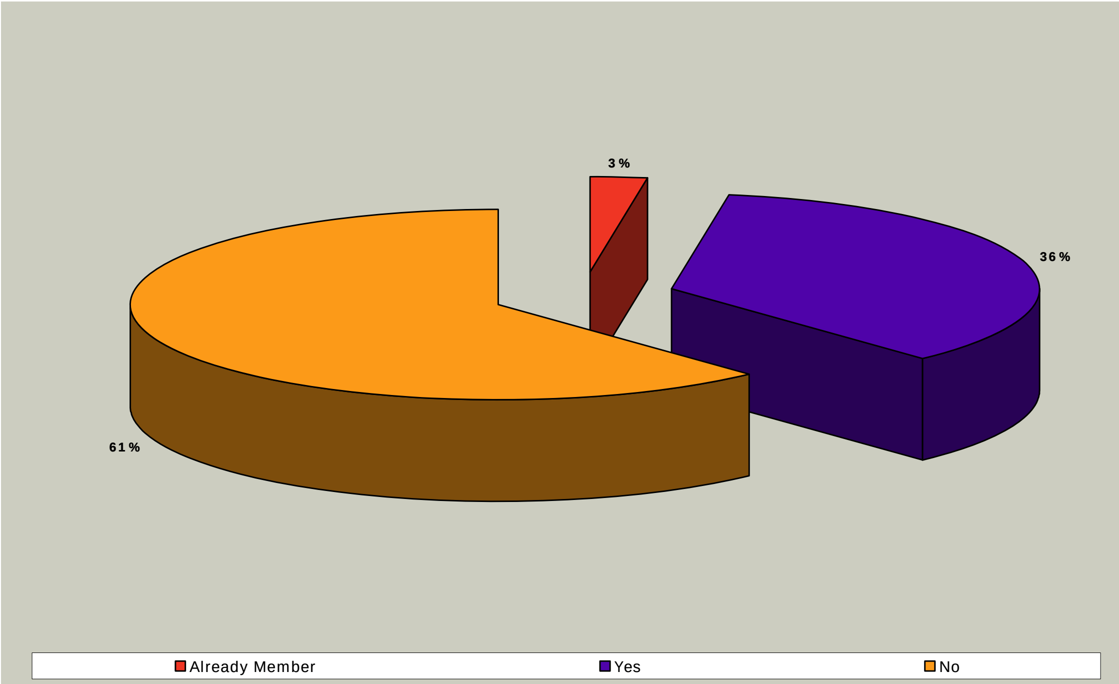

Figure 3.10: Interest in Car Pooling (N = 673)

3.2.19 Of the 415 respondents who provided a response to the potential use of car pooling should there be HOV lanes, 20% indicated that they would be interested in a car sharing initiative.

3.3 Demographic Profile of Respondents

Gender

3.3.1 Figure 3.11 shows that 52% of respondents to the survey were male, 48% female.

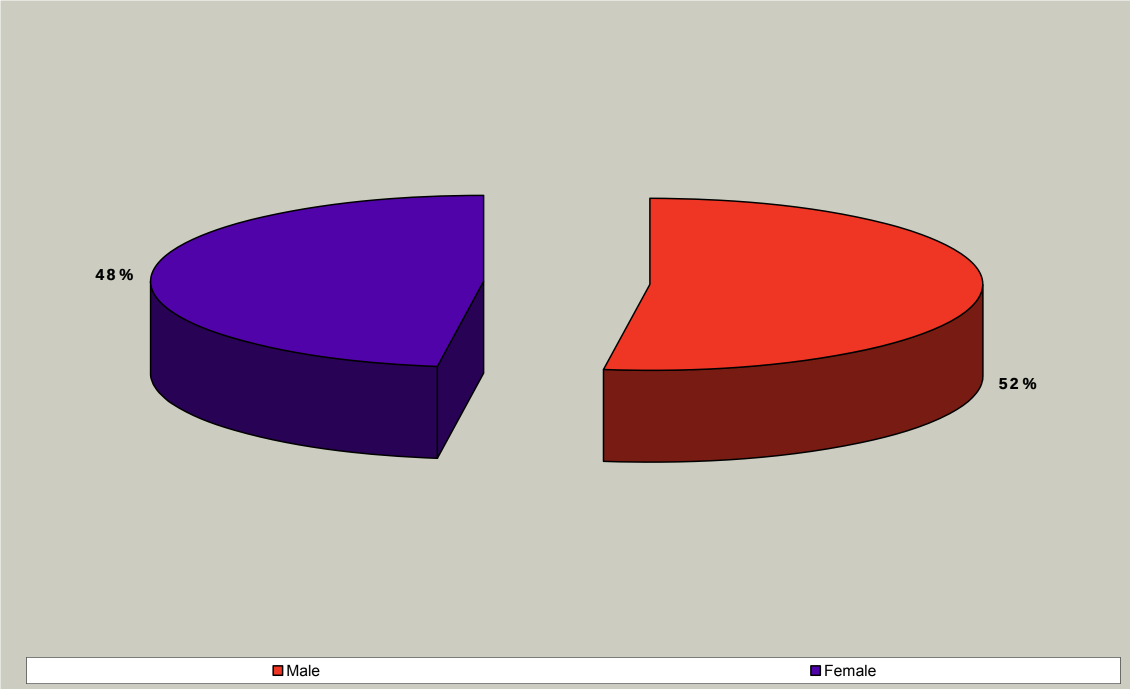

Figure 3.11: Gender Profile of Respondents (N = 636)

Age

3.3.2 Figure 3.12 illustrates the age group profile of respondents to the survey. The majority are aged 44 and under (68%), of which 6% are aged 24 and under.

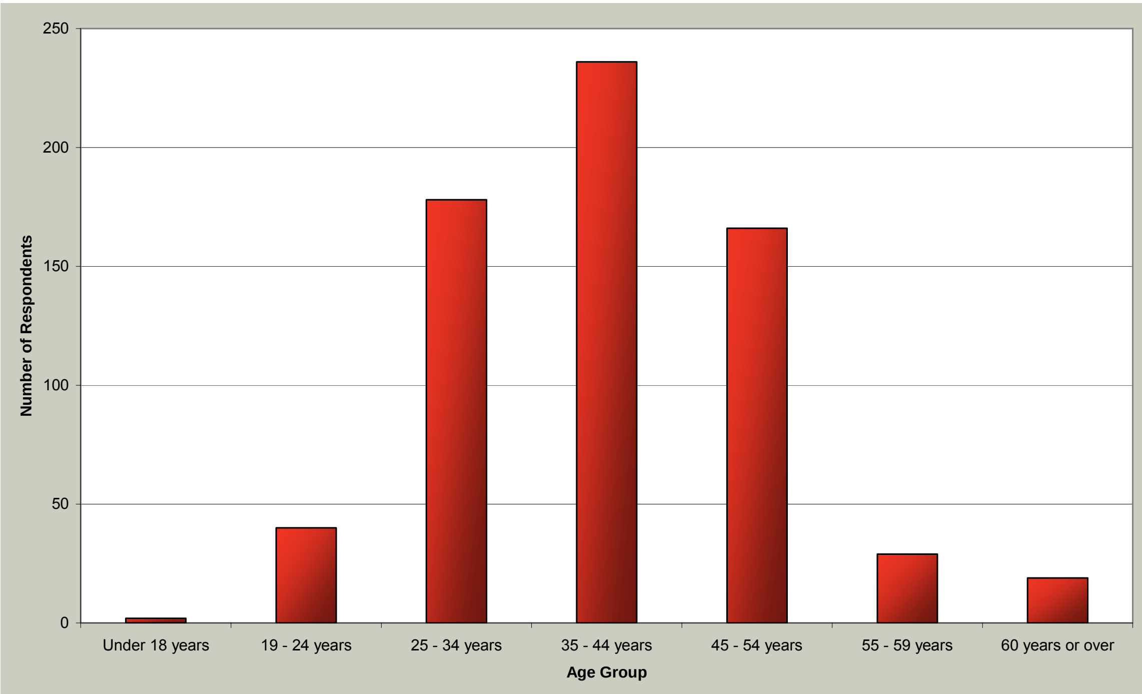

Figure 3.12: Age Group Profile of Respondents (N = 670)

3.4 Socio-Economic Profile of Respondents

Total Household Income

3.4.1 593 respondents provided an indication of their total (before tax) household income. Figure 3.13 illustrates the distribution, with the majority of respondents on mid incomes between £20,001 and £50,000 (58%).

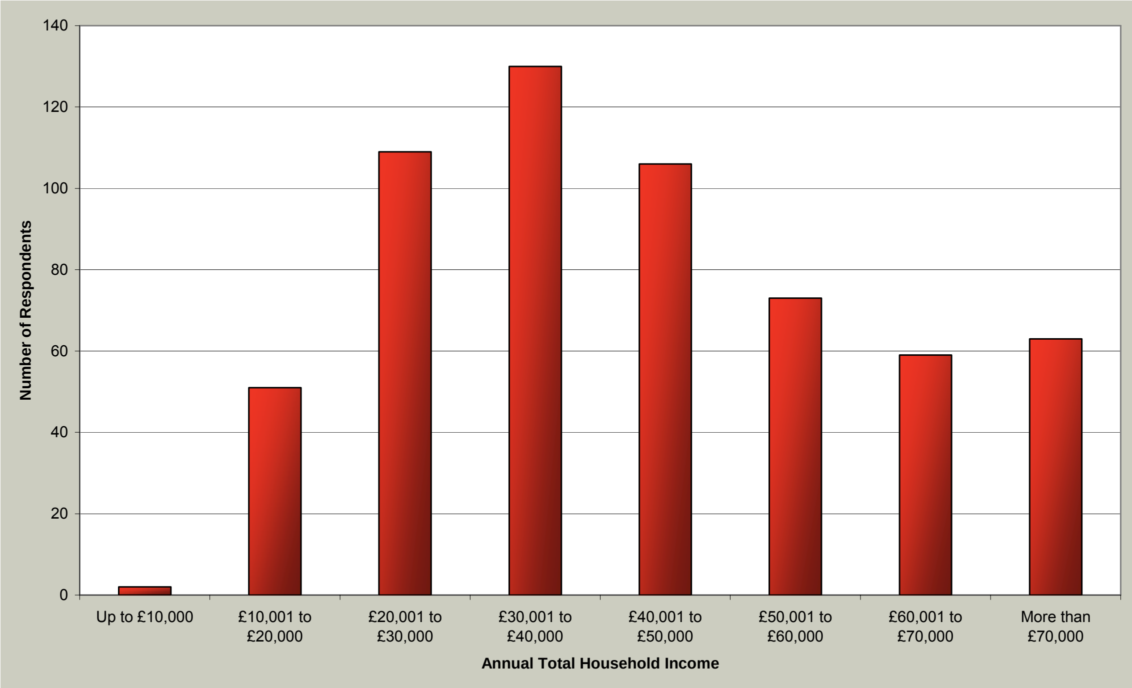

Figure 3.13: Annual Total Household Income of Respondents (N = 593)

Car Ownership

3.4.2 Car ownership amongst the sample is presented in Figure 3.14, with the majority of respondents owning two cars within their household. Approximately 60% own two plus cars, whilst 1% do not own a car (assumed to be own a company car or van, or be erroneous responses).

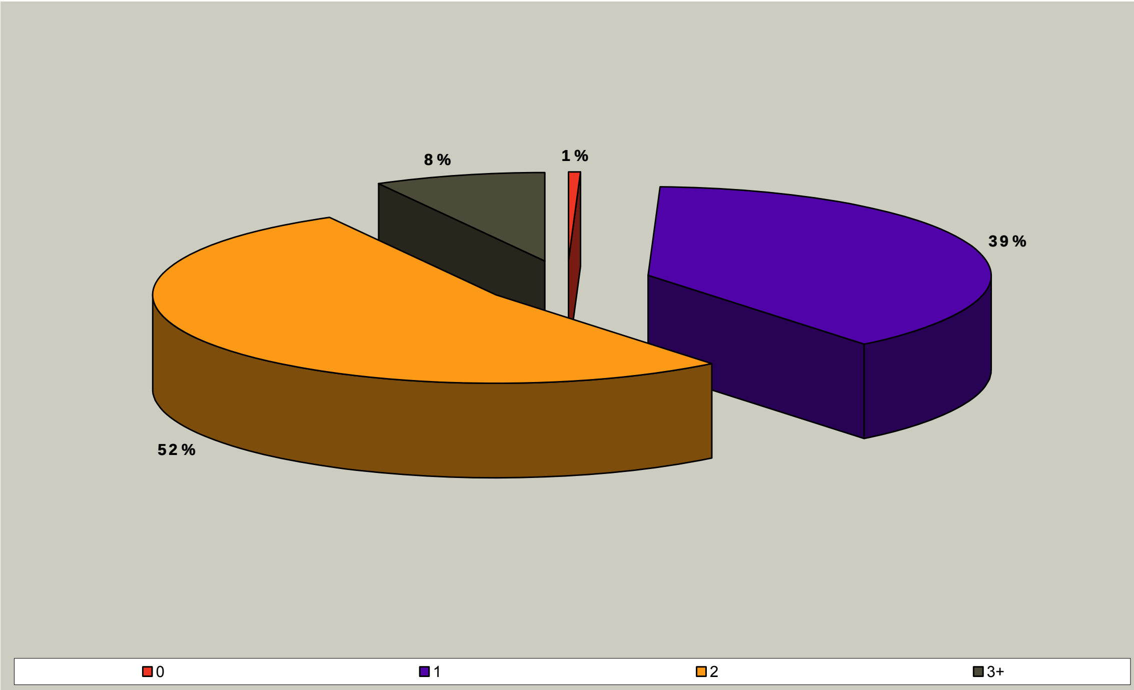

Figure 3.14: Car Ownership Distribution (N = 672)

Employment Status

3.4.3 Figure 3.15 provides the employment status of the sample. The majority on full-time (88%) or part-time (9%) employment with 3% self-employed.

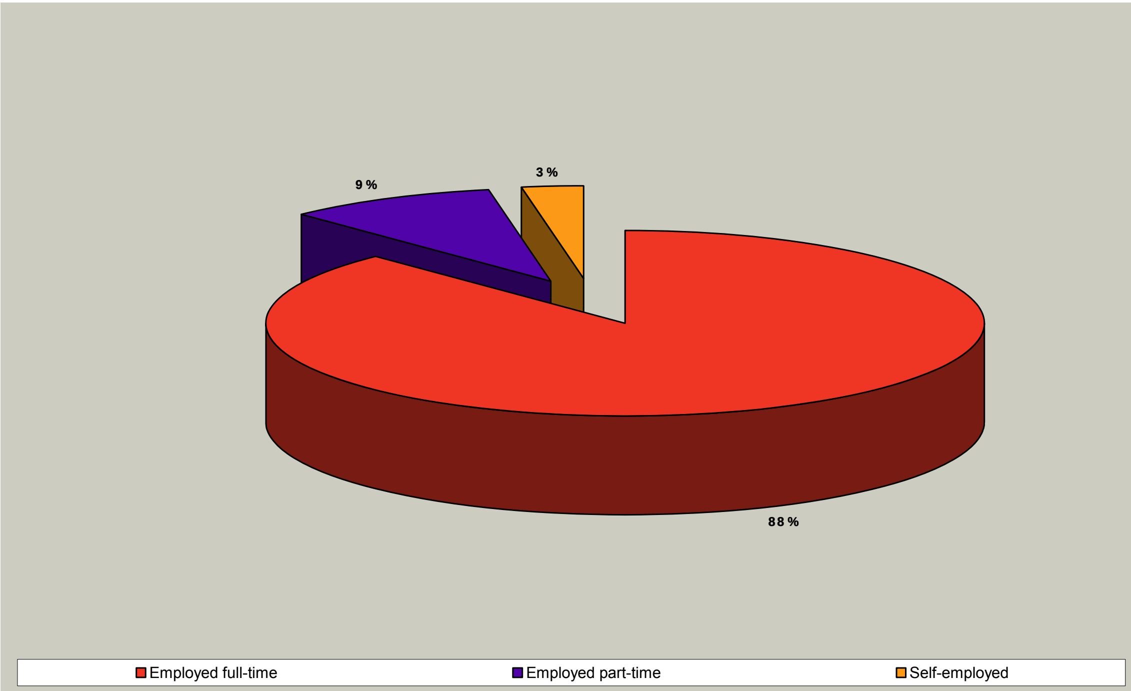

Figure 3.15: Employment Status of Respondents (N = 671)

3.5 Attribute Importance

3.5.1 The distributions of ratings of importance for the three attributes considered within the stated preference experiment are presented in Figure 3.16. The average ratings of the three attributes were:

- journey time (3.93);
- monetary cost (3.59); and
- sharing of a car (2.42).

3.5.2 It can be seen that the distribution of responses for each of the three attributes differs markedly. Journey time, considered to be the most important attribute, displays an exponential or s-shaped relationship, with a positive skew towards higher level of importance. Cost is seen to display a more consistent s-shaped function, with few disparities between the number of respondents considering it to be of average, high or very high importance. By contrast, the distribution of the relative importance of sharing a car is much less clear. Although the distribution is negatively skewed, with a slightly below average score of 2.42, there is no clear pattern in the responses provided.

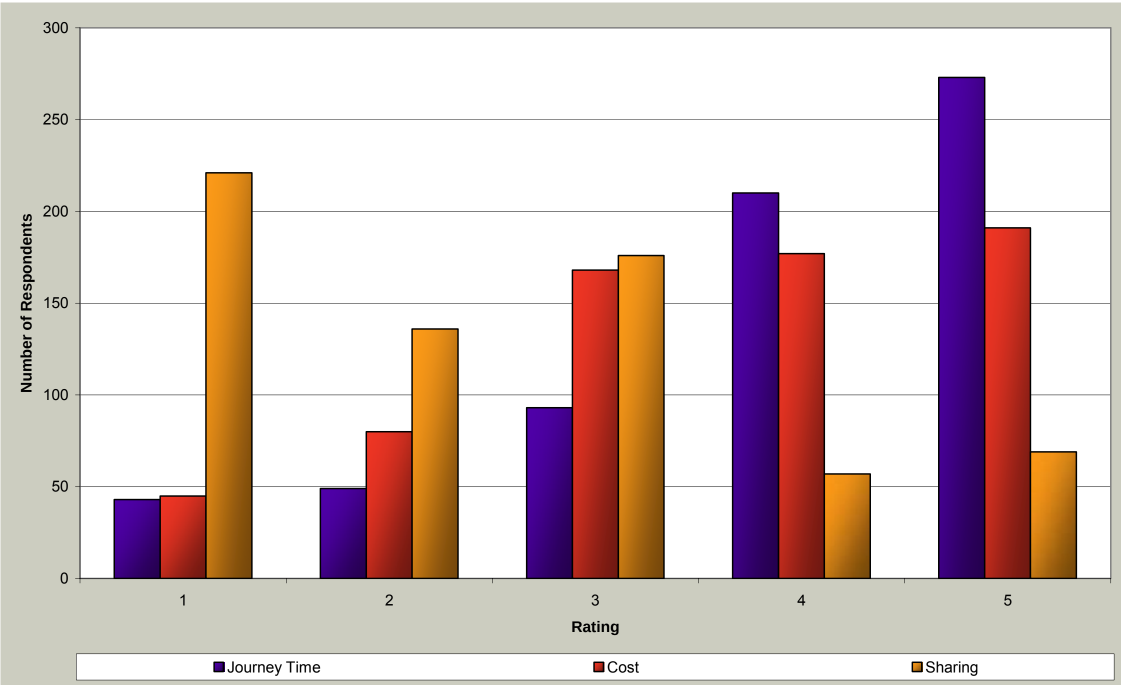

Figure 3.16: Rating of Importance of each Stated Preference Attribute

4 Preferences and Parameter Specification

4.1 Introduction

4.1.1 The data from the Stated Preference (SP) experiments was analysed under a discrete choice modelling framework.

4.1.2 This framework is based on the principle that a decision-maker (the traveller) chooses the choice alternative (mode) that yields greatest satisfaction or 'utility', where utility is taken to be related to the 'attributes' of the choice alternative (eg monetary cost, journey time and who the vehicle was shared with). The choice context is composed of a finite set of alternatives.

4.1.3 The aim was to develop a model that shows the probability that a decision-maker will choose a choice alternative and to quantify how this choice probability is influenced by changes in the attribute of the alternatives. By comparing the relative influence of one attribute against another, it is possible to infer its relative value. For example, by comparing the influence that changes in journey time have on choice compared with the influence that changes in journey cost have on choice, it is possible to estimate the implied Value of Time (VoT).

4.1.4 The objective of the study was to quantify the additional value that car drivers and passengers put on their time spent sharing their vehicle with others (friends/family or car pool member/colleague). This can be expressed as an absolute value in money or equivalent journey time units (an ASC or modal penalty), or can be related to the length of the journey by expressing the value proportionate to journey time (an IVT factor).

4.1.5 Following conventional modelling practice, we started the data analysis using a Multinomial Logit (MNL) model, followed by more complex model forms which take better account of correlation between choice alternatives and variations in tastes and preferences across travellers. Appendix E contains full details of the final models.

4.2 Main Models

4.2.1 The main models were estimated with a non-nested simple linear in the parameters form. The estimation models underwent a thorough set of econometric diagnostic tests to ensure that they were statistically robust. This included an examination of their overall level-of-fit, precision in parameter estimation and accommodation of correlation between attributes and alternatives.

4.2.2 Under the non-nested multinomial framework, the marginal probability of choosing to travel by car alone is given by:

$$P_{CarAlone} = \frac{e^{\beta V_{CaAlone}}}{e^{\beta V_{CarAlone}} + e^{\beta V_{CarShare}} + e^{\beta V_{NT}}} \qquad (2)$$

where:

$P_{CarAlone}$ = the probability of choosing to travel by car alone

$V_{CarAlone}$ = the utility of travelling by car alone

$V_{CarShare}$ = the utility of travelling by car sharing

V_{NT} = the utility of not travelling/travelling to an alternative destination/choosing an alternative mode not presented

β = a parameter to be estimated[10]

4.2.3 An important practical issue is the specification of the utility (V) of each alternative, which is taken as a function of the attributes in the SP experiment and the characteristics of the respondent.

4.2.4 Two main models were developed as follows:

- **Model 1** has a logit structure with the value of sharing (as opposed being alone) expressed as an **absolute** value; and
- **Model 2** has a logit structure with the value of time spent sharing (as opposed to alone) expressed as a **factor** of in-vehicle time.

4.3 Transport Model for Scotland (TMfS) Valuations

Model 1 – TMfS Car Sharing ASC Valuation

4.3.1 The Transport Model for Scotland (TMfS) valuation(s) requires a set of parameters which can be easily related to a given set of demand matrices. These will typically not contain disaggregated information on the proportion of car commuters who drive alone or share a car in either the base or future year scenario. In effect a single parameter or factor needs to be specified that reflects the relationship between car sharing and driver alone.

4.3.2 In the first model the utility of each mode is specified as a function of monetary cost (fuel and parking), in-vehicle time, and Alternative Specific Constants (ASCs: δ_1, δ_2, and δ_3). The ASCs capture the preferences for travel by each alternative after taking account of the other variables (attributes) in the model, and as such represent the value of car sharing as opposed to car alone.

4.3.3 The resulting utility specifications take the form:

$$V_{CarAlone} = \beta_1 Cost_{CarAlone} + \beta_2 IVT_{CarAlone} + \delta_1 \quad (3)$$

$$V_{CarShare} = \beta_1 Cost_{CarShare} + \beta_2 IVT_{CarShare} + \delta_2 \quad (4)$$

$$V_{NT} = \delta_3 \quad (5)$$

4.3.4 The model was estimated using BIOGEMEv1.5 (Bierlaire, 2003[11]). In addition, to the above a dummy variable for sharing with a stranger (car pool member/colleague) was also included in an earlier specification. However, within this model specification, the parameter was found to be insignificant and of the intuitively wrong sign. It was therefore excluded from further analysis in the aggregate model. Table 4.1 presents the results of the model estimation.

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[10] Taken as one in practice as it cannot be estimated separately from the fixed-coefficients parameter θ, which is assumed to be constant for all individuals.

[11] Bierlaire, M. (2003) BIOGEME: a free package for the estimation of discrete choice models, Conference paper STRC 2003.

Table 4.1: TMfS Model 1 Car Sharing Absolute Valuation

Attribute	Coefficient	T-Stat	Implied Value	Units
$ASC_{CarAlone}$ (δ_1)	0	--fixed---	-	min
$ASC_{CarShare}$ (δ_2)	-1.23	-23.45**	**26.68**	min
ASC_{NT} (δ_3)	-2.3	-42.99**	49.89	min
Cost (β_1)	-0.00569	-15.64**		
Time (β_2)	-0.0461	-25.15**	8.10	p/min
			4.86	£/hour
Null log-likelihood	-6555.42			
Log-likelihood	-5327.797			
Adjusted Rho Sq.	0.187			
Respondents	659			
Observations	5967	Excludes null observations		

Notes: t-statistics are shown relative to zero. ** indicates significance at the 5% level.

4.3.5 The adjusted Rho squared is high for an SP experiment (0.187) showing a good degree-of-fit to the data. T-statistics are highly significant whilst parameter estimates are of the intuitively correct sign. The Value of Time (VoT) for commuters is marginally lower than that presented in STAG (£5.68/hour for car drivers and £5.02/hour for other occupants).

4.3.6 The implied value for car sharing as opposed to drive alone is 26.68 minutes per trip.

Model 2 – TMfS Car Sharing IVT Factor Valuation

4.3.7 An alternative specification is in terms of a factor for In-Vehicle Time (IVT). Initial analysis was undertaken with no ASCs; however, this provided a positive coefficient on the IVT for single occupancy car trip, which meant a (credible) IVT factor could not be computed.

$$V_{CarAlone} = \beta_1 Cost_{CarAlone} + \beta_2 IVT_{CarAlone} + \delta_1 \quad (6)$$

$$V_{CarShare} = \beta_1 Cost_{CarShare} + \beta_4 IVT_{CarShare} + \delta_2 \quad (7)$$

$$V_{NT} = \delta_3 \quad (8)$$

4.3.8 Table 4.2 presents the resulting model estimate.

Table 4.2: TMfS Model 2 Car Sharing Factor Valuation

Attribute	Coefficient	T-Stat	Implied Value	Units
$IVT_{CarAlone}$ (β_2)	-0.0708	-14.93**	1.00	IVT Weight
$IVT_{CarShare}$ (β_4)	-0.0251	-6.14**	**0.35**	IVT Weight
$ASC_{CarAlone}$ (δ_1)	0	--fixed---		
$ASC_{CarShare}$ (δ_2)	-1.53	-20.61**	**60.96**	min
ASC_{NT} (δ_3)	-2.68	-30.66**		
Cost (β_1)	-0.00585	-15.91**	-	-
Null log-likelihood	-6555.420			
Log-likelihood	-5311.329			
Adjusted Rho Sq.	0.189			
Respondents	659			
Observations	5967	Excludes null observations		

Notes: t-statistics are shown relative to zero. ** indicates significance at the 5% level.

4.3.9 Although the adjusted Rho squared suggests a good degree-of-fit to the data at 0.189 and all t-statistics are significant at the 5% level, the parameter for sharing IVT is of a lower magnitude than single occupancy. The utility construct under this form is therefore unnecessarily complicated by the consideration of IVT factors and ASCs, whilst the combination of the two results in a distorted, and unrepresentative, distribution of sharing valuations when combined with the 'pure' IVT. IVT factor results do not therefore form an appropriate specification technique for aggregate demand models such as TMfS.

4.3.10 Subsequent analysis focuses on the specification of models which consider additional terms, market segments, and specifications.

4.4 Market Segment Analysis

4.4.1 Building on the base models, a series of additional models were estimated to examine how tastes and preferences vary across the individuals in the sample. This was achieved through a combination of approaches involving estimating separate utility parameters for key segments, including:

- income (*Inc*);
- age group;
- car ownership (*1 or 2+*);
- gender (*Female*);
- employment status (*FT* or *PT*);
- geography (Scottish Executive Sixfold Classification);
- whether the person they were sharing was a friend/family member or a stranger ($Share_{Stranger}$);
- current journey time (*JT*);
- interest in partaking in a car pool (*CarPoolInterest*); and
- current propensity to currently car share.

Model 3 – Market Segment Absolute Valuation

4.4.2 In Model 3, analysis of differences and values by market segment was undertaken on the absolute values of the ASCs. This builds on Model 1 by provided a disaggregated valuation of δ_2 according to key market segments. Piecewise estimation of the ASCs showed a strong relationship between choice, car ownership level, age group, gender, current journey time, and interest in car pooling. The preferred specification is shown below, with the estimated model parameters presented in Table 4.3.

$$V_{CarAlone} = \beta_1 Cost_{CarAlone} + \beta_2 IVT_{CarAlone} + \delta_1 \quad (9)$$

$$V_{CarShare} = \beta_1 Cost_{CarShare} + \beta_2 IVT_{CarShare} + \delta_2^1 CarOwn2 + +\delta_2^2 Female + \delta_2^3 Age25-44 + \delta_2^4 CarPoolInterest + \delta_2^5 JT + \delta_2^6 Share_{Stranger} \quad (10)$$

$$V_{NT} = \delta_3 \quad (11)$$

4.4.3 In general, higher car ownership, whether they are female, being aged between 25 and 44, lengthier journey times, and having to share with a stranger means that respondents are more likely to choose a single occupancy car trip. All t-statistics are significant at the 5% level, whilst the implied VoT is marginally lower than that presented in STAG.

Table 4.3: Model 3 Results

Attribute	Coefficient	T-Stat	Implied Value	Units
$ASC_{CarAlone}$ (δ_1)	0	-fixed--	-	min
ASC_{NT} (δ_3)	-1.81	-36.86**	62.41	min
$ASC_{CarShare}$ * CarOwn2+ (δ_2^1)	-0.61	-11.95**	21.03	min
$ASC_{CarShare}$ * Female (δ_2^2)	-0.218	-4.01**	7.52	min
$ASC_{CarShare}$ * Age 25-44 (δ_2^3)	-0.408	-7.81**	14.07	min
$ASC_{CarShare}$ * CarPoolInterest (δ_2^4)	1.04	18.15**	-35.86	min
$ASC_{CarShare}$ * JT (δ_2^5)	-4.71E-05	-2.04**	0.00	min
$ASC_{CarShare}$ * Share (δ_2^6)	-0.396	-6.97**	13.66	min
Cost (β_1)	-0.00327	-9.46**	-	-
Time (β_2)	-0.029	-17.84**	8.87	p/min
			£5.32	£/hour
Null log-likelihood	-6555.42			
Log-likelihood	-5472.823			
Adjusted Rho Sq.	0.186			
Respondents	659			
Observations	5967	Excludes null observations		

Notes: t-statistics are shown relative to zero. ** indicates significant at the 5% level.

Model 4 – TMfS Market Segment Absolute Valuation

4.4.4 The results presented in Table 4.3 represent the most fine-grain valuations considering all attributes of interest collected in the survey. However, TMfS demand matrices are not segmented to such a degree, and the key attribute of interest for modelling and appraisal purposes is household car ownership. Model 3 found households with two plus cars to be a strong indicator of variation in taste and preference across the sample. By contrast, households with one car was an insignificant contributor to model fit when considered alongside the other market segments, ie gender, age group and car pool interest are 'better' predictors of propensity to car share. In effect, these segments can be considered to have subsumed the effect of one car owning households.

4.4.5 Table 4.4 presents the model results when one car owning households are included in the model at the expense of all other explanatory variables. It can be seen that all t-statistics are significant and of the intuitive sign and magnitude. The model fit is broadly equal to that of Model 3, indicating that this model, despite its reduction in the number of explanatory variables, remains a robust and reliable indicator of preferences for car sharing amongst the population. One car owning households place a higher penalty (46.51 IVT minutes) of having to share than two plus car owning households (26.42 IVT minutes), for which a number of possible explanatory rationales can be hypothesised, including:

- a wider geographic distribution of workplaces amongst one car owning households, potentially increasing their perception of the relative penalty for partaking in a car sharing initiative (respondent perception may be of significant route deviation in order to pick-up/drop-off);
- greater feelings of autonomy and independence associated with car driving and hence higher valuations of the penalty of having to car share (particularly with a stranger). These feelings could be accentuated by the ownership of one vehicle; and
- potential correlation between one car owning households and some of the other explanatory variables with higher penalties for car sharing identified in Table 4.3, ie females and 25-44 years olds.

Table 4.4: Model 4 Results

Attribute	Coefficient	T-Stat	Implied Value	Units
$ASC_{CarAlone}$ (δ_1)	0	--fixed--	-	min
ASC_{NT} (δ_3)	-2.29	-42.89**	50.00	min
$ASC_{CarShare}$ * CarOwn1 (δ_2^1)	-2.13	-5.21**	46.51	min
$ASC_{CarShare}$ * CarOwn2+ (δ_2^2)	-1.21	-23.2**	26.42	min
Cost (β_1)	-0.00565	-15.54**	-	-
Time (β_2)	-0.0458	-25.04**	8.11	p/min
			£4.86	£/hour
Null log-likelihood	-6555.42			
Log-likelihood	-5330.215			
Adjusted Rho Sq.	0.186			
Respondents	5967			
Observations	5967	Excludes null observations		

4.5 Mixed Logit Specification – Panel Data Models

4.5.1 A random parameters or mixed logit specification offers two principal advantages over traditional multinomial logit specifications. Firstly, it accommodates taste variation across the sample by specifying the model coefficients as distributions (eg a normal distribution) rather than fixed values. Secondly, the model takes account of potential correlations in the data introduced because of the repeat observation nature of the data. In SP experiments, each respondent typically provides choice information for many scenarios (in this experiment nine) and because these choices come from the same individual they can not be treated as independent. The random parameters model can be specified to account for such panel data effects by allowing the choices of an individual to be correlated.

4.5.2 The models developed in this study were estimated using BIOGEME and developed in accordance with webTAG Unit 3.11.5.

Model 5 – Absolute Valuation with Random Parameters

4.5.3 In Model 5, analysis was undertaken on the absolute values of the ASCs. The preferred specification is as Model 1, with parameters to the ASCs, cost and journey time specified to be normally distributed across individuals. Table 4.5 shows estimates of both the mean and standard deviation of the parameters.

Table 4.5: Model 5 Results

Attribute	Mean of Random Parameter		Std Deviation of Random Parameter	
	Coefficient	T-Stat	Coefficient	T-Stat
$ASC_{CarAlone}$ (δ_1)	---fixed---		---fixed---	
$ASC_{CarShare}$ (δ_2)	-4.04	-16.36	-4.41	-18.76
ASC_{NT} (δ_3)	-8.15	-16.60	-5.70	-12.34
Cost (β_1)	-0.0173	-15.53	0.0162	12.52
Time (β_2)	-0.142	-20.46	0.0773	11.07
Null log-likelihood	-6555.420			
Log-likelihood	-3157.488			
Adjusted Rho Sq.	0.517			
Respondents	659			
Observations	6057			

Notes: t-statistics are shown relative to zero. ** indicates significant at the 5% level. Mixed logit model estimated with a panel specification using 1,000 Modified Latin Hypercube Sampling Strategy[12] draws.

[12] There has been some discussion in the literature of the sequencing and number of draws to be employed in the calculation of probabilities. Research now points to the use of sequences constructed from number theory to be more uniformly spread in order to improve processing time. A discussion on the Modified Latin Hypercube Sampling Strategy is given in HESS, S., TRAIN, K., AND

4.5.4 As is typically experienced with mixed logit specification, the overall level of fit is substantially improved compared with the non-random parameters specification – an adjusted Rho squared of 0.517 compared with 0.187. The estimated parameters have the anticipated signs and magnitude and are generally estimated with a high degree of precision.

4.5.5 The standard deviations on the random parameters indicate a considerable degree of taste variation across the sample, although the mean estimates of the value of time are broadly similar to those from Model 1 – 8.21p/min (£4.92/hour) compared to 8.10p/min. The implied ASC for car share is 28.45 minutes, as opposed to 26.68 minutes in Model 1.

4.5.6 The ratio of the normally distributed coefficient on car sharing over the normally distributed coefficient on time generates a (Cauchy) distribution on the value of car sharing - shown in Figure 4.1. From this analysis it can be seen that although most respondents see a disbenefit to car sharing, around 13% of respondents show a benefit from sharing.

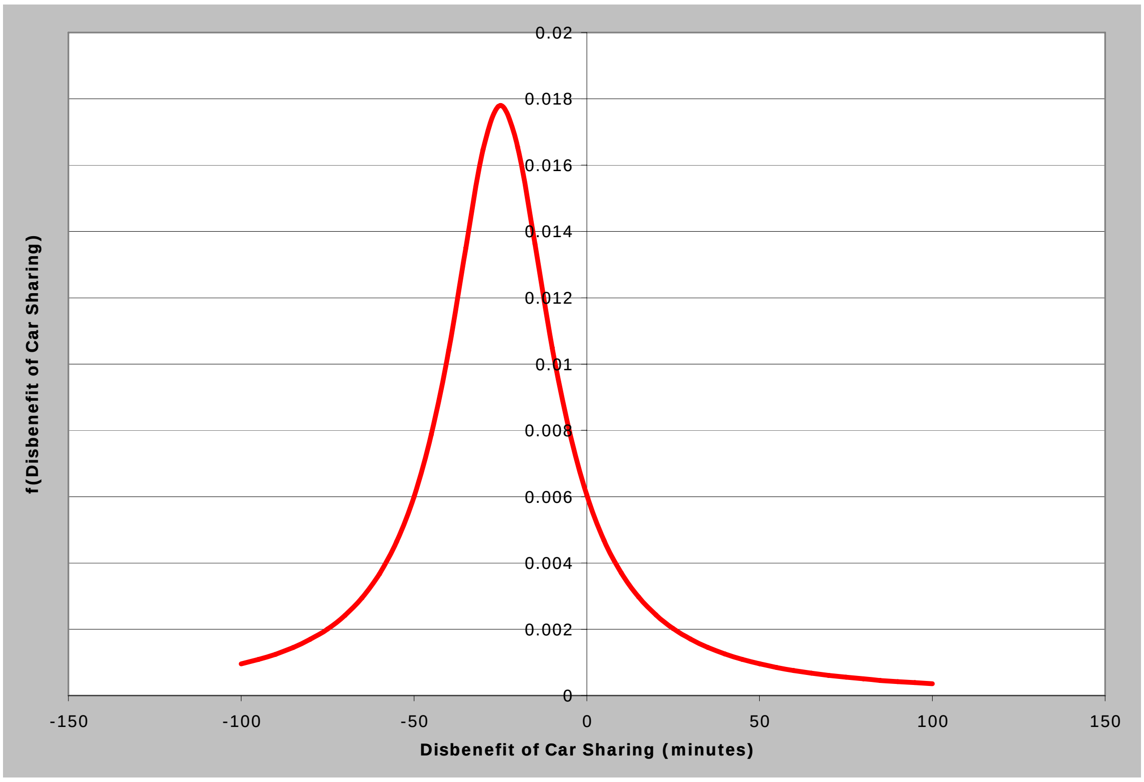

Figure 4.1: Distribution of the Disbenefit of Car Sharing

4.6 Summary

4.6.1 A variety of models have been produced based upon the SP data in order to derive valuations of car sharing in terms of adjustments to the Alternative Specific Constants (ASCs) and in equivalent alternative-specific IVT factors (relative to car alone).

4.6.2 For each of these, further analysis has been undertaken according to key market segments, namely:

POLAK, J. (2006). On the use of modified latin hypercube sampling (MLHS) method in the estimation of mixed logit model for vehicle choice. *Transportation Research Part B: Methodological, Vol. 40(2)*. pp. 147-163.

- income;
- car ownership;
- age group;
- gender;
- employment status;
- geography (Scottish Executive Sixfold Classification);
- sharing with a stranger;
- current journey time;
- interest in partaking in a car pool; and
- current propensity to currently car share.

4.6.3 All of the base models produce significant results across the modelled parameters. The accompanying recommended values and factors therefore represent a solid foundation for the modelling and appraisal of High Occupancy Vehicle (HOV) lanes in Scotland.

4.6.4 The corresponding ASC is **26.68** minutes from the multinomial specification and **28.45** minutes from the mixed logit specification with normal distributions on time, cost and the ASCs. Further segmentation according to household car ownership (in line with TMfS demand matrices) results in valuations of **46.51** and **26.42** IVT minutes for one and two plus car owning households respectively.

4.6.5 Further analysis has shown that significant parameters can also be developed for market segments, including:

- car ownership (two cars plus households);
- gender;
- age group;
- current journey time;
- sharing with a stranger; and
- interest in partaking in a car pool.

4.6.6 The impact of all of the above, barring ‘interest in partaking in a car pool’ can be considered as negative in relation to propensity to car share.

5 Conclusions and Recommendations

5.1 Summary and Conclusions

5.1.1 An SP study was undertaken using a representative sample of commuters from across Scotland to provide parameter estimates for the modelling and appraisal of car sharing initiatives and High Occupancy Vehicle (HOV) lanes. The study quantified the relative 'penalty' of car sharing as opposed to a single occupancy car sharing trip. These improvements were modelled in terms of both an adjustment to the Alternative-Specific Constant (ASC) and an equivalent IVT factor.

5.1.2 The web-based SP survey achieved a high response of 673 respondents. 77.6% of respondents found the survey 'very easy' or 'moderately easy' to complete, and only 4% found the survey 'very difficult'. The sample achieved a representative spread of all the key trip-making, demographic and socio-economic characteristics. It can therefore be considered as representative of the single occupancy car commuting trips in Scotland, and its results may be transferred across the country.

5.1.3 The models presented in this Report all exhibited a good degree-of-fit. All the estimated means of the random parameters are significant, with the majority highly significant, and with the anticipated sign.

5.2 Recommended Valuations

5.2.1 Based upon the preferred model forms, the implied ASC for car share as opposed to a single occupancy car trip is **28.45** minutes using a mixed logit specification with standard deviations estimated on the time, cost and ASC parameters. The corresponding multinomial valuation is 26.68 minutes, and when this is segmented by car ownership, the resulting valuations are **46.51** and **26.42** for one and two plus car owning households respectively.

5.2.2 Recommended segmented values of the ASC for car share using a multinomial structure are:

- in two car plus owning households – (+)21.03 IVT minutes;
- female – (+)7.52 IVT minutes;
- aged between 25 and 44 – (+)14.07 IVT minutes;
- interest in car pooling – (-)35.86 IVT minutes;
- current journey time – (-) IVT minutes; and
- sharing with a stranger – (+)13.66 IVT minutes.

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