A STUDY OF INDIVIDUAL TRAVEL BEHAVIOUR IN EDINBURGH, TO ASSESS THE PROPENSITY TO USE NON-MOTORISED MODES

BY

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A thesis submitted for the degree of Doctor of Philosophy at Napier University

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DECLARATION

I hereby declare that the work presented in this thesis was carried out by myself at Napier University. This thesis has not been submitted in part of whole anywhere for any other degree.

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ABSTRACT

Recent transport policy favours non-motorised modes, yet it remains to be seen, in a car dependent society, whether individuals will increase the amount they walk and cycle. Using Edinburgh as a case study, population segments are identified with the greatest propensity to use non-motorised modes. In addition, discrete choice models, based on random utility theory, are developed to determine propensity.

Population segments are identified from the Scottish Household Survey, largely based upon the life stages of gaining employment, having children and entering retirement. Of the ten segments, those with the greatest propensity to use non-motorised modes are 'students', those 'in-between jobs' and 'part-timers without children'.

A survey of 997 households in West Edinburgh provides further travel behaviour information. It included two stated preference experiments concerning the propensity to walk for motorists making short trips and the propensity to cycle for those travelling to work or study by motor car, bus or on foot. Parking costs are the most influential attribute upon the propensity to walk for motorists; journey time and petrol costs also have a significant effect. Cyclist facilities, primarily at the destination but also on route, affect the propensity to cycle to work or study. Model forecasts indicate that transport policy measures can have a slight impact upon non-motorised mode levels.

Given the reluctance of many motorists within the West Edinburgh survey to change travel behaviour, a package of transport policy measures is to be recommended in order to reduce motor car usage and encourage non-motorised modes. If possible they should be targeted at certain population segments or neighbourhoods. Increasing parking and petrol prices, whilst improving public transport, could reduce motor car usage. Cyclist facility implementation, pedestrian environment improvements and the promotion of exercise benefits could encourage individuals to increase their non-motorised mode usage.

1. INTRODUCTION

1.1 Introduction

The objectives of this research study are presented in Section 1.2. Section 1.3 provides a background to the study, summarising the problems associated with the motor car, motor car dependency, the characteristics of non-motorised modes, transport policy development and wider environmental concerns. Background socio-economic and transport information for Edinburgh, the study area, is summarised in Section 1.4. The scope of the study and the structure of the thesis are outlined in Section 1.5 and Section 1.6 respectively.

1.2 Research objectives

The title of this thesis is "A study of individual travel behaviour in Edinburgh, to assess the propensity to use non-motorised modes". The study is, therefore, concerned with the propensity of individuals to act in particular ways, defined as their 'inclination and tendency to favour certain options'. The options in this study refer to non-motorised modes of transport as alternatives to the motor car.

Problems associated with high levels of motor car ownership and use, such as air pollution and congestion, have highlighted the need for reduced motor car usage and the promotion of alternative modes of transport, including non-motorised modes. To assess the propensity of individuals to use non-motorised modes, two research objectives were formulated:

1. To identify segments of the population with the greatest propensity to use non-motorised modes.
2. To model individual travel behaviour and thus the propensity to use non-motorised modes.

The first objective concerns market segmentation. Segmentation can be defined as "the division of a market into distinct subsets of customers having similar needs and wants" (Mowen and Minor, 1998). Typically, a market is segmented according to demographic variables such as age, gender, family structure, social class and income, race and ethnicity, and geography (Solomon, 1999). These are the type of variables examined in this study, along with transport data and travel behaviour characteristics, to assess and identify which population segments have the greatest propensity to use non-motorised modes.

The second objective is methodological, concerning the development of disaggregate models. The primary methodology used in the study is discrete choice analysis, the modelling of choice from a set of mutually exclusive and collectively exhaustive alternatives. Discrete choice analysis is based on random utility theory. This study is, therefore, based on an established theory, applying it to the modelling application of non-motorised modes. A number of discrete models were developed using stated preference data. The trade-offs individuals make between non-motorised and other transport modes are estimated, including for different population segments. A series of policy measures are tested using the models. A more detailed outline of the methodology is provided in Chapter Two.

The research consists of two stages, using Edinburgh as the study area. The first stage uses an empirical data set, the Scottish Household Survey. The data set contains socio-economic, transport and travel information on 2,910 households in Edinburgh. The components of the Scottish Household Survey analysis include the development of population segments based on current socio-economic characteristics using cluster analysis. Transport availability data and travel behaviour patterns are then examined using these segments. Further information on the Scottish Household Survey data set and the statistical techniques utilised in the analysis are provided in Chapter Five.

The second stage concerns an extensive travel behaviour survey of 997 households along a transport corridor in West Edinburgh. The survey contains more information on non-motorised modes and is on a smaller scale than the Scottish Household Survey. The West Edinburgh survey was designed to include attitudes towards transport problems and solutions of the population and travel behaviour choices made by motorists. The survey also collected stated preference data to be input into the discrete choice models. The stated preference experiments concerned trade-offs between the motor car and walking for general trips, and between cycling and the respondent's current mode for the journey to work. Further information on the West Edinburgh survey data collection and the data set are provided in Chapter Six.

This research aims to provide original and independent outcomes in terms of identifying population segments most likely to use non-motorised modes. The modelling and segmentation of the survey data examine non-motorised mode data in more depth than previous research. Originality also stems from the two stated preference experiments within the West Edinburgh survey and the discrete choice models developed using this data.

1.3 Background

This Section provides a background to the study, using the pollution and congestion resulting from considerable motor car usage as a starting point. The associated aspects of increasing car dependency, the advantages and disadvantages of non-motorised modes, transport policy development and wider environmental concerns are then outlined.

Although there are many undesirable by-products of motor car use, such as noise pollution, the construction of road infrastructure, the manufacture of vehicles, the disposal of vehicles, the usage of valuable fuel resources and the effects of road accidents, it can be argued that the two primary problems associated with the motor car are air pollution and congestion. Although the emphasis changes between these two problems, they represent the main thrust of United Kingdom transport policy documents (Department of the Environment, Transport and the Regions, 1998; Department for Transport, 2004b).

Air pollution has been highlighted as one of the two primary problems associated with the motor car. Pollutants emitted from road transport include nitrogen oxides, carbon monoxide, volatile organic compounds, black smoke and particulates (Ison et al, 2002 – Table 9.5). Transport, in all forms, is a major consumer of energy. In 2002, 35% of all United Kingdom energy consumption was used by transport (Department for Transport, 2003a - Table 2.2, source Department of Trade and Industry). Road transport accounts for more than three quarters of transport energy use. Although local air pollution has been falling due to improved engine technology, carbon dioxide emissions from road traffic will increase in the future, jeopardising the ability of the United Kingdom to meet climate change targets (Begg and Gray, 2004).

Congestion has also been highlighted as a primary problem associated with the motor car. High use of the motor car contributes to severe levels of congestion in many areas of the United Kingdom. Urban areas in the United Kingdom can come to a standstill during peak times, subjecting road users to longer journey times and higher travel costs. It has been estimated that congestion causes 24.8 seconds to be lost per vehicle for every kilometre travelled, in London and other large urban areas (Department of Transport, the Environment and the Regions, 2000d).

Motor car dependency is increasing in the United Kingdom, illustrated by a range of statistics from Transport Statistics Great Britain (Department for Transport, 2003a). Most adults can drive (71% had a licence in 1999/2001 – Table 3.15), most households have access to a motor car (73% in 2001 - Table 3.15) and motor car mileage has increased (car mileage per person per year in 1999/2001 was 5,354, an 11% increase from 1989/1991 – Table 1.2). These are all trends set to continue, reinforced by motor car advertising and peer-group pressure. To many individuals their motor car is a treasured possession, an essential item that gives them freedom and independence. Households are prepared to pay high costs to own and use a motor car; average household spending is £55.10 a week on motoring (Table 1.15).

The United Kingdom trend of increased motor car dependency mirrors the pattern in other developed countries. Individuals are travelling more frequently and over greater distances, with the motor car the dominant mode of transport in developed countries. In contrast, much travel in developing countries is conducted on foot or by bicycle. It is expected that as these countries become more industrialised, motor car ownership and use will increase, with time benefits over non-motorised modes of transport. The motor car is a sign of economic development, a symbol of status and wealth for owners. For a developed country such as the United Kingdom, it is hard to envisage a return to widespread usage of non-motorised modes. However, the argument presented in this thesis is that there is scope for an increase in non-motorised mode usage, particularly amongst certain population segments.

The characteristics of non-motorised modes can be summarised in terms of their advantages and disadvantages. The advantages of non-motorised modes over most other forms of transport are:

- **Convenience** - Cycling and walking enable door to door transport
- **Cost** - Cycling and walking are very cheap
- **Environment** - Neither mode contributes to air or noise pollution
- **Exercise** - Regular cycling and/or walking can help fitness levels
- **Health** - Regular cycling and/or walking can help with heart disease, weight control and stress
- **Social activity and interaction** - Walking and/or cycling as a social activity, be it shopping in town centres or on an organised bicycle ride
- **Socially inclusive -** Most people can use non-motorised modes, and they are not dependent on income

A main disadvantage with non-motorised modes is that they are slower than other modes and usually confined to short trips. In congested conditions cycling and walking can be faster than the motor car, as illustrated by the London-based Journey Times Survey, conducted in 1999 (Department of the Environment Transport and the Regions, 2000e). However, this is the exception rather than the rule. One advantage of non-motorised modes is that they are very cheap, but the costs associated with a motor car are such that most of the adult United Kingdom population can afford to own and run a motor car.

The change in transport policy at both national and local levels, to become more sympathetic to non-motorised modes, was the starting point to this study. Non-motorised modes re-emerged on the United Kingdom transport policy agenda in recent years as part of the Integrated Transport Strategy (Department of the Environment, Transport and the Regions, 1998). At a local level, the Local Transport Strategy for Edinburgh (City of Edinburgh Council, 2004b) recognises that the city cannot accommodate unlimited growth in motor car use. It includes policy measures to encourage non-motorised modes of transport. With uncertainty over the effectiveness of such policies, this study examines individual travel behaviour beneath the policy rhetoric, using Edinburgh as a case study.

The promotion of sustainable transport, of which non-motorised modes are a part, is one strand of a wider global environmental movement. A United Nations Conference on Environment and Development held in 1992, known as the "Rio summit", pushed environmental issues higher up the national policy agenda. Countries present agreed to a series of environmental targets. An international agreement, developed in Kyoto in December 1997, set levels of acceptable greenhouse gas emissions (Ison et al, 2002). The United Kingdom was set a legally binding target to reduce greenhouse gas emissions to 12.5% below 1990 levels by the period 2008 to 2012 (Department of the Environment, Transport and the Regions, 1998). These Kyoto levels were reached in 2002, with greenhouse gas emissions having fallen by 15% between 1990 and 2002 (Department for Environment, Food and Rural Affairs, 2004). Although set to meet the Kyoto targets, partly due to the decline of manufacturing in the United Kingdom, increases in road transport and aircraft emissions need to be curtailed since they contribute to the 'climate change' phenomenon (Sustainable Development Commission, 2004).

The most frequently used definition of sustainability is provided in the Bruntland report (World Commission on Environment and Development, 1987). The sustainability concept is "to provide for the needs of the present without compromising the needs of the future". Black (2000) adapted the Bruntland definition, describing sustainable transport as "satisfying current transport needs without jeopardising the ability of future generations to meet these needs". The attributes of a sustainable transport system defined by Black would be sufficient fuel for the future, minimal pollution from such a fuel, minimal fatalities and injuries from motor vehicle accidents and manageable congestion.

In summary, the promotion of non-motorised modes has gained momentum in transport policy and from heightened environmental public awareness, against a background of motor car dependency. There are many advantages of cycling and walking, but in comparison with the motor car they are outweighed heavily by the speed and convenience of the motor car. It is important to understand the role of individuals and the choice trade-offs they make between non-motorised modes and the motor car. This study concentrates on groups of such individuals, as population segments, and their propensity to use non-motorised modes. It will link back to policy measures that could be targeted at certain population segments to increase the amount they cycle and walk.

1.4 Edinburgh as a case study

This Section summarises Edinburgh, an urban area chosen as a case study. Outcomes from this research on the propensity to use non-motorised modes could be applied to other urban areas with similar characteristics.

Consideration was given to Edinburgh's socio-economic and transport characteristics in undertaking the research. Edinburgh is the capital of Scotland and location of the new Scottish Parliament, set up in 1999. It has an historic centre, designated a World Heritage site by UNESCO in 1995. Edinburgh is succinctly described as a "prosperous city, with a growing economy, rising employment and relatively high wage levels" (Scottish Homes and City of Edinburgh Council, 2000).

Edinburgh has a growing population, measured at 448,624 in the 2001 Census (General Register Office for Scotland, 2003 – Table KS01). Population decentralisation had been substantial from Edinburgh to the surrounding areas during the 1960s and 1970s, slowing significantly during the 1980s (Bailey et al, 1999). Edinburgh is projected to continue growing at a steady rate, to attain an estimated population of 458,911 in 2011 (City of Edinburgh Council, 1998), based on a 1996 projection from the General Register Office for Scotland. It has a higher proportion of young adults (aged 15-34) and a lower proportion of families (aged 5-14 and 45-64) than the Scottish average (City of Edinburgh Council, 1998). Edinburgh areas have been categorised using the geo-demographic classification ACORN ('A Classification of Residential Neighbourhoods') groups (City of Edinburgh Council, 1998). The classification showed that Edinburgh has a higher proportion of housing areas described as 'Affluent urbanites, town and city areas', 'Prosperous professionals, metropolitan areas', 'Better off executives, inner city areas' and 'Council estate residents, high unemployment', than the United Kingdom average. It could, therefore, be considered a city of extremes in housing area types. Conversely, Edinburgh has a lower proportion of 'Comfortable mid-aged, mature home owners', 'Skilled workers, home owning areas', and 'Council estate residents, better off homes' than the United Kingdom average.

Data from a sample of 1,207 households within the Scottish Household Survey (Scottish Executive, 2000b), confirms that, in terms of housing stock, Edinburgh has a majority of flats (60%). The remaining property types in Edinburgh are evenly split between detached house (12%), semi-detached house (13%) and terraced house (14%). Edinburgh faces considerable growth pressures resulting from rising demand for housing. Employment grew in Edinburgh by 5.6% from 1984 to 1993, and employment forecasts from 1991 to 2005 suggest the rise is continuing, with a 5.9% growth rate over this time period (City of Edinburgh Council, 1998). The two largest employment sectors, both of which are set to continue growing, are 'financial and business services' and 'education and health'.

The demands of the motor car upon an expanding city with limited land space make transport a key issue in Edinburgh. It does not have the space to accommodate future car ownership and use. Edinburgh has comparatively low car ownership rates and high-density development rates compared with other United Kingdom cities, which make it more suitable than most for sustainable transport measures. Indeed, it has relatively high walking (25%) and public transport (18%) levels (statistics taken from the Scottish Household Survey of all trips by Edinburgh residents 2001 – from City of Edinburgh Council, 2003). However, like other United Kingdom cities, car ownership and use have been on the increase. It is of interest to understand the factors in urban areas that favour high levels of sustainable transport modes.

Transport comparisons between Edinburgh and other United Kingdom cities can be undertaken using 2001 Census data (City of Edinburgh Council, 2003 - Tables 21 and 22). There are 39.5% of households in Edinburgh without a car available, lower than Glasgow (56.2%) and Dundee (45.5%) but higher than Aberdeen (33.8%). Journey to work figures are provided for a range of Scottish and English cities, although it should be noted that the Scottish figures also include journeys to educational establishments. The percentage of residents cycling to work and study is 3.3% in Edinburgh, higher than Glasgow, Dundee and Aberdeen. Cycling to work in United Kingdom cities is generally low, except for the four English cities of Cambridge (25.9%), Oxford

(14.9%), York (12.0%) and Norwich (8.8%). Edinburgh has very high walking levels for the journey to work or study (20.8%); only Norwich (22.7%) and Dundee (21.4%) have higher levels. Furthermore, Edinburgh has the highest bus use to work or study (26.2%) of any the 42 United Kingdom cities listed, although unlike many other cities does not have an underground or tram system.

In summary, Edinburgh represents an interesting transport case study due to high-density development and favourable sustainable transport modal split, particularly in terms of walking and public transport, relative to other United Kingdom cities. Furthermore, local policy-makers in Edinburgh have strongly promoted a sustainable transport policy, further outlined in Section 4.3. Aside from encouraging non-motorised mode measures, transport policy initiatives such as Greenways, congestion charging plans and the re-introduction of trams have been developed in recent years. The Edinburgh statistics presented in this section will be elaborated upon in the Section 3.2, a review of literature on the relationship between urban form and travel behaviour.

1.5 Scope of the study

Terms employed in the research need to be defined and clarified at the outset. This will ensure consistent terminology throughout the study.

The term "motor car" is used rather than the more generic term "motorised transport", to focus on the personal motorised travel of individuals. Motorised transport includes vans and lorries and thereby freight as well as personal travel, and is thus too broad for the themes covered by this study. Cycling and walking are often aggregated together and referred to as "non-motorised modes" of transport. This is the preferred term for this study, as it implies the opposite of motorised modes of transport.

Other titles for non-motorised modes, not used in this study, include:

- non-polluting modes, because they do not emit pollutants;
- green modes, because they are environmentally-friendly;
- self-propelled modes, because they do not required fuel to power an engine;
- vulnerable road users, because they are more likely to be injured than other road users when involved in a road accident; and
- slow modes, highlighting their main disadvantage, as being generally slower than other transport modes.

These additional definitions illustrate some of the reasons why cycling and walking are often aggregated together, such as their speed and safety record. This is why they are considered jointly in this study. Despite more similarities than differences, there is a key difference between the two non-motorised modes. The bicycle is a form of transport, with provision for cyclists tending to be on the carriageway. Walking is a natural act that does not need any equipment, and provision for pedestrians tends to be on the footway.

The study is restricted to cycling and walking, and does not directly include other sustainable modes such as public transport and the motorcycle (including scooters and mopeds). Public transport is sustainable as it emits less pollution and causes less congestion per occupant than the motor car. Motorcycles are more environmentally friendly than other motor vehicles since they are require less road and parking space. However, since they are a motorised mode of transport they contribute to air pollution in the same way as a motor car. Therefore, if measuring in terms of contributions to air pollution and congestion, non-motorised modes are the most sustainable forms of transport.

The study is concerned with individuals, and groups of individuals as population segments, rather than on the nature of the trips made. The focus is on an individual's demand for transport, the choices they make and how this can be translated into behavioural change towards non-motorised modes. Individuals are seen as consumers of transport, who can be targeted through a variety of policy measures. The study does not have the scope to directly concern outside influences upon an individual's demand for transport, such as businesses or developers.

1.6 Structure of the thesis

This section summarises the Chapters of this thesis.

Chapters One and Two introduce the study and methodology. Chapter Two develops upon the introduction in Chapter One, providing an overview and justification of the methodology utilised to achieve the research objectives described in Section 1.2.

Chapters Three and Four provide a review of literature and policy. Chapter Three reviews other research, as documented in academic literature, to show how this study represents a new and original contribution to knowledge. Chapter Four presents the transport policy response to problems associated with the motor car and the type of policy measures that can be introduced to encourage non-motorised modes.

Chapters Five and Six outline the data sets and survey design. Chapter Five explains the relevance and validity of the data source used in stage one of the research, the Scottish Household Survey. Chapter Six explains the relevance and validity of the data source used in stage two, the West Edinburgh survey.

Chapters Seven and Eight provide results of the data analysis that relate to the first research objective, identifying population segments with the greatest propensity to use non-motorised modes. Chapter Seven presents analysis of the Scottish Household Survey data. Chapter Eight presents results from analysis of data from the West Edinburgh survey.

Chapters Nine and Ten relate to the second research objective, modelling individual travel behaviour. A series of discrete choice models were developed using stated preference data from the West Edinburgh survey. Forecasts have been provided on the propensity to walk and the propensity to cycle amongst respondents.

Chapter Eleven discusses the findings and provides conclusions to the study.

1.7 Summary

This Chapter provides an introduction to the research. The following two research objectives were formulated and described in Section 1.2:

1. To identify segments of the population with the greatest propensity to use non-motorised modes
2. To model individual travel behaviour and thus the propensity to use non-motorised modes

From these research objectives, it is intended to provide original and independent research outcomes. To achieve this, two data sets were utilised, analysed in two separate stages. The first stage concerns Scottish Household Survey data, the second stage concerns a travel behaviour survey along a transport corridor in West Edinburgh.

A background to the study is provided in Section 1.3. The promotion of non-motorised modes has gained momentum in recent years from the direction of transport policy and heightened public awareness of environmental issues, against a background of ever-increasing motor car dependency. There are many advantages of cycling and walking, but in comparison with the motor car they are outweighed heavily by the speed and convenience of the motor car. It is, therefore, important to understand the role of individuals and the choice trade-offs they make between non-motorised modes and the motor car. This study concentrates on groups of such individuals as population segments and their propensity to use non-motorised modes. It will suggest policy measures that target certain population segments to increase their non-motorised mode usage.

Edinburgh is introduced in Section 1.4, the urban area chosen as the case study. Edinburgh can be summarised as a compact and prosperous city with a historic core. It represents a particularly interesting transport case study due to its' favourable transport policy, high density development and sustainable modal split, in terms of walking and public transport, relative to other United Kingdom cities.

The remainder of this introductory Chapter defines and justifies the scope of the study. Section 1.5 emphasises that the focus of the research is on non-motorised modes competing with the motor car. The structure of the thesis is outlined in Section 1.6.

This Chapter introduces the topic area, outlining the research objectives and case study for the research. The next Chapter develops upon this introduction, providing an overview and justification of the methodology used to achieve the research objectives.

2. METHODOLOGICAL OVERVIEW

2.1 Introduction

Chapter Two provides an overview and justification of the methodology utilised to achieve the research objectives. Section 2.2 explores the data issues that have determined the nature of the methodology used.

The first research objective is "to identify segments of the population with the greatest propensity to use non-motorised modes". The methodology to identify population segments, market segmentation, is considered in Section 2.3. The market segmentation technique of cluster analysis is applied to the Scottish Household Survey data.

The second research objective is "to model individual travel behaviour and thus the propensity to use non-motorised modes". Section 2.4 presents concepts used in the analysis of travel behaviour, specifically the mechanisms of travel behaviour change and the measures to achieve travel behaviour change. The models developed in the research are considered in Sections 2.5 to 2.7. Section 2.5 outlines general developments in transport modelling. Section 2.6 provides a theoretical background to the discrete choice models developed in this study, based on random utility theory. The development of discrete choice models from the theory is presented in Section 2.7.

The Geographical Information System (GIS) spatial framework for the study is considered in Section 2.8 and the nine hypotheses to be tested are outlined in Section 2.9.

2.2 Data issues

There are a number of data issues explored in this section, that determine the methodology used in the research. The distinctions between quantitative and qualitative data, and between revealed and stated preferences are outlined. The focus is then on non-motorised modes, with a particular focus on available data regarding the types of cycling and walking journeys that individuals undertake. Finally, a justification for the two stages of obtaining and analysing the data sets is provided.

2.2.1 Quantitative and qualitative data

This study is primarily quantitative, due to the statistical and modelling requirements. However, this was complemented by some qualitative data in the form of open-ended questions within the West Edinburgh survey questionnaire.

2.2.2 Revealed and stated preference data

Data can be divided into two types based on revealed and stated preferences. Revealed preferences consist of disaggregate information on past behaviour, assuming that human preferences and aims can be inferred from decisions made. Up to the mid-1980s, transportation models exclusively used revealed data, based on observed choices and decisions. Interest arose in theories and methods from behavioural sciences, and stated preference data has since been incorporated into transportation applications to complement revealed preference data (Kroes and Sheldon, 1988; Institute of Highways and Transportation, 1997; Polak and Jones, 1997).

A revealed preference approach can be limited in that it does not explicitly consider the decision making process of consumers. This highlights the advantage of a stated preference approach, allowing the analysis of choice processes and thus giving a more integrated economic-psychological approach. Stated preference models provide hypothetical choices presented to an individual, and measure how a respondent's choices would change if circumstances changed. Models can be estimated for an individual, which make stated preference techniques appropriate for this study. The main advantage of stated preference based techniques is that they allow testing under experimental conditions. Proposed sustainable transport policies can be tested. This study tests non-motorised mode policy measures in two stated preference experiments within the West Edinburgh survey.

However, there are also disadvantages of stated preference techniques. These include the difficulties to predict efficiently and to validate the results. Reviewing other studies, Polak and Jones (1997) show that stated preference studies typically over-estimate forecasts and emphasise the need for validation. Crucially, it is unclear as to whether respondents would actually make the decision to change mode. They may state something in the experiment but act differently in practice.

Revealed and stated preference data are both incorporated in this study, to allow actual and hypothetical choices to be analysed and to compensate for the deficiencies exhibited by each type of data. Revealed preference data is analysed from both data sets, whereas stated preference data is analysed and modelled in the second stage of the methodology, the West Edinburgh survey. The transport mode element in a stated preference experiment tends to concern a comparison of motor car versus bus, using cost (parking cost versus fare), journey time and bus frequency. Two stated preference experiments are included in the West Edinburgh survey to enable the modelling of trade-offs between the motor car and walking for general trips and between the current mode and cycling for the journey to work.

2.2.3 Non-motorised mode data

Analysis of United Kingdom transport statistics, using the primary United Kingdom transport statistics source, Transport Statistics Great Britain (Department for Transport, 2003a), shows several gaps and a lack of available non-motorised mode data. The following transport statistics from Transport Statistics Great Britain relate to non-motorised modes:

- A person will travel on average 6,843 miles per year. Of these, 5,355 (78.2%) are by motor car, 186 (3.7%) are on foot (including short walks) and 38 (0.6%) are by bicycle.
- Non-motorised mode mileage has fallen by 25% for walking and 22% for cycling between 1975/1976 and 1998/2000. Over the same time period motor car use rose by 67%.
- In the year 2000, a higher proportion of non-motorised mode users (19.9%) were killed or seriously injured than motor car drivers or passengers (9.5%).
- Commuting is the main journey suited to cycling. It is the only cycling trip purpose an average greater than two trips per person per year.

- The three most popular walking trip purposes (trips per person per year) are shopping (63), "other" which includes going for a walk (44), and education (31). Education is the only journey purpose that motor car use does not dominate (i.e. has the greatest number of trips per person per year).

Aggregate data and the statistics produced from sources such as Transport Statistics Great Britain pose several problems for the analysis of non-motorised modes. Firstly, many of the statistics are presented as averages, crude indicators that can hide more subtle trends. Means are particularly difficult to calculate for cycling statistics, as most of the population do not cycle. It could also be argued that these statistics are not detailed enough for this study, concerned with more disaggregate population segments. Secondly, there is not enough emphasis on walking, a mode often ignored in travel data. Walking journeys are difficult to measure because they are often undertaken in combination with other modes, say as the access and egress parts of a public transport trip. In many data sets, trips under a certain threshold level are omitted, thereby reducing the number of recorded walking journeys. For example, the threshold level in the National Travel Survey is 50 yards and in the Scottish Household Survey a quarter of a mile or five minutes.

Certain non-motorised mode statistics can be gleaned from other sources. There are more bicycles owned by the United Kingdom population than at any time and annual bicycle sales are outstripping the number of new cars sold (Department of the Environment, Transport and the Regions, 1998). However, each bicycle is being used less in contrast to an increased reliance on the motor car. Therefore, a distinct difference is evident between ownership and use of transport modes.

Further statistical information on non-motorised modes can be obtained from Personal Travel fact-sheets, collated by the United Kingdom Department for Transport. By trip purpose, cycling is dominated by male users (particularly 16-20 year olds) and Summer trips (Department for Transport, 2003b). Adults living in households with a car make fewer journeys by bicycle on average than those in households without a car. Walking statistics show that in addition to 263 journeys a year mainly on foot, the average person walks 78 part journeys completed mainly by other modes of transport, almost half of which are by bus (Department for Transport, 2003c). Akin to the cycling relationship, adults (aged 17 and over) living in households without a motor car walk much further on average, 265 miles, than those living in households with a car, 163 miles. In terms of the ease with which individuals can walk, 11% of males and 13% of females have some sort of difficulty walking, but the majority of these are still able to go out on their own for a walk.

This study will elaborate further on the non-motorised mode statistical relationships presented in the Personal Travel fact-sheets for cycling and walking, including a more detailed examination of socio-economic variables such as gender and age.

Ultimately, detailed statistical information on non-motorised modes is difficult to attain because such modes, particularly cycling, compose a small share of the modal split. If they are included, non-motorised modes tend to be grouped as "other" modes. Neither national nor Edinburgh statistics are detailed enough for the purposes of this research, since the spatial scale of this study is very small, at a sub-Edinburgh level.

2.2.4 Non-motorised mode journeys

The first of the two research objectives concerns the segmentation of the population into groups. In order to gain an understanding of the breakdown by types of individual, it is of interest to appreciate the breakdown by types of journey that individuals make using non-motorised modes. In traditional four-stage transport models (Ortuzar & Willumsen, 2001), journeys are split into home-based and non-home based trips. Home-based trips are then further sub-divided into five distinct types of journeys to work, journeys to school or college, shopping trips, social or recreation trips and other journeys.

Trip chaining is an added complication to the analysis of journeys. A simple chain, the basic journey from origin to destination and return, makes up most journeys. An example in Swindon showed this to be the case in 70% of trips (MacIver, 1999). However, the same study showed that for some sample segments the percentage is much lower. For instance, only 50% of male shopping trips were simple chains. The previous sub-section showed that walking is important as part of a trip chain with public transport. There has also been an increasing interest in the use of the bicycle as a feeder mode to public transport (Martens, 2004).

As shown in Section 2.2.3, the primary non-motorised mode journey types are the journey to work and the journey to school. The commuter trip is the easiest to examine because it is regular and the most frequent trip type of the overall population. An important distinction is between those making utility trips, using their bicycle or walk journey as a mode of transport, and those who make leisure trips, using their bicycle or walk journey for a leisure or sporting activity. In the Scottish Household Survey, non-motorised mode journeys are classified as either utility or leisure trips.

This utility versus leisure trip dichotomy has been particularly researched in cycling. One study examines how leisure cyclists can be encouraged to make more utility cycling trips (Gardner, 1998), from interviews with over 500 cyclists. The main barrier for leisure cyclists making utility trips is their fear or traffic, and they would like to see more segregation of cycle routes. The study recommends increased provision of green routes through urban parks and marketing occasional cycling to work 'when conditions are right'.

The West Edinburgh survey focuses on utility trips since the journey to work is the most appropriate to study the propensity to cycle. Like many studies, Wardman et al (1997) consider the cycling commuter journey but recommend that the leisure market should also be considered. This leisure market encompasses cycle tourism, cycling holidays and cycling as sport.

Department of the Environment and Department of Transport (1995) presents proximity and thresholds for different transport modes, based on National Travel Survey data. A distance of 8km (5 miles) is the upper threshold for a cycling trip, beyond which only a small proportion of trips will be cycled in the United Kingdom. At one distance, journeys of around 2km in length, more people cycle than use any other mode of transport. The upper threshold for walking in one trip is 2km, showing that most people walk journeys that are less than 2km in length (very short journeys, of less than 1km, are excluded from National Travel Survey data).

Several studies that examine short trips for cycling and walking journeys use five miles as the upper threshold (Royles, 1995; Mackett and Robertson, 2000). Mackett and Robertson (2000), examining National Travel Survey data, estimated that half of short trips are undertaken by motor car (over 70% of journeys were short trips). The number of short trips by all modes has been decreasing. The shortest trips tended to be undertaken by the very young and the very old, typically for education, escort to education, shopping and personal business. Females make proportionately more short trips than males.

The diverse and complex nature of journey types makes it important to be able to classify users into easily manageable groups, justifying the use of market segmentation to sub-divide the survey population in this study.

2.2.5 Links between the two data sets

The two stages of obtaining and analysing the data sets have been outlined in Section 1.2. This section will justify the methodologies utilised. Detailed outlines of the data sets, including survey design of the West Edinburgh survey, are provided in Chapters 5 and 6.

The first stage uses a data set obtained from the Scottish Executive, the Scottish Household Survey. The Scottish Household Survey is a large, empirical data set with useful background transport and travel diary information. The analytical approach within the first stage is inductive, to identify segments and to test travel behaviour relationships. The Scottish Household Survey data set contains information on 2,910 households in Edinburgh, and is used here to provide an insight into the population segments that might be encouraged to use non-motorised modes.

The second stage is more deductive, using primary data. Data collection concerns the West Edinburgh survey: an extensive travel behaviour survey of 997 households conducted in July 2003. This survey contains more non-motorised mode information than the Scottish Household Survey, and is on a smaller scale. The extensive empirical travel behaviour data set collected in stage two, with innovative stated preference experiments, enables statistical relationships and discrete choice models to be developed on the propensity to use non-motorised modes. A variety of behavioural hypotheses are tested using the West Edinburgh survey data, applying the population segments defined in stage one.

The population segments developed from the Scottish Household Survey data are applied to the West Edinburgh Survey data, in both the statistical analysis and the discrete choice modelling. The West Edinburgh survey is used to confirm and develop upon the transport availability and travel behaviour relationships established using Scottish Household Survey data. A further link between the two data sets concerns the aggregation of the discrete choice model forecasts. The model forecasts using the West Edinburgh survey data are factored up to apply to the Edinburgh population.

An alternative method to assess travel behaviour change would have been 'before and after' studies of a particular measure, or longitudinal studies (Oppenheim, 1992). 'Before and after' studies are used to measure the effect of an experimental variable by repeating a set of measurements pre-test and post-test. Examples of such designs for cycling schemes include Ryley (1996) and Transport Research Laboratory et al (1999). With these methodologies it is difficult to ascertain whether it is the scheme or other factors that make individuals change travel behaviour. Furthermore, a 'before and after' study only tends to include those using the new facility, and not those unaffected by the change. Longitudinal studies involve repeated measures of the same respondents, such as panel study interviews, but are beyond the timeframe of this study. However, this study does consider changes over time from the discrete choice model forecasts.

Modal shift tends to be measured as a percentage change from one year to another. In the United Kingdom, due to declining cycling levels, reference is made to instances of a modal shift to cycling in other European countries. For example, cycle use rose from 6% of all trips in 1976 to 15% in 1992 in Munich, and from 9% in 1976 to 16% in 1990 in Hanover (Department of the Environment, Transport and the Regions, 1998). The problem with percentage change is the difficulty to link it to a particular policy measure. For instance, if cycling rose from 2% to 5% of all trips, there may be 4% increase in some cycle trips and a 1% decrease in other cycle trips, but it is impossible to deduce this from the general percentage figures. It is preferable, as in this study, to examine probability change forecasts in response to specific transport policy measures. The transport policy measures are represented by attributes within the West Edinburgh survey stated preference experiments.

2.3 Market segmentation

The first research objective is "to identify segments of the population with the greatest propensity to change travel behaviour". The method employed in this study to achieve this is market segmentation, "the division of a market into distinct subsets of customers having similar needs and wants" (Mowen and Minor, 1998). Typically a market is segmented according to demographic variables such as age, gender, family structure, social class and income, race and ethnicity, and geography (Solomon, 1999). These are the type of variables examined in this study, to aid the understanding of the market segments who might be encouraged to use non-motorised modes. A market as a whole does not consist of homogeneous individuals. Instead it is assumed that there are a number of market segments or groups, each with their own needs and views. The survey samples in this study were divided into a number of groups or segments all assumed to share the same characteristics.

Market segmentation is a technique used by public transport operators to optimise revenue (Cole, 1998). Population segments respond differently to changes in fare levels and other journey attributes. Variables included tend to be comfort, flexibility, price, ease of changing reservation and level of advanced booking required. Operators respond by setting charges for different segments based on the degree of competition, the degree of necessity in the journey and the customers' ability or desire to pay a particular price.

The geodemographics industry use spatial databases in the field of market research. More precisely, geodemographics is "the development of area typologies that have proven to be powerful discriminators of consumer behaviour and aids to market analysis" (Brown, 1991, p221). Two of the main geodemographic classifications used in the United Kingdom are MOSAIC and ACORN ('A Classification of Residential Neighbourhoods' – examples of ACORN groups for Edinburgh are shown in Section 1.4), and have been adapted for use in transport applications (Enoch et al, 2002). They use area typologies based on two sources, the Census and postcode information. Market segmentation techniques are used to develop the geodemographic classifications. Each neighbourhood within the Scottish Household Survey is classified according to a MOSAIC category, but these could not be supplied with the study sample because of confidentiality issues.

Market segmentation relates to lifestyle and an individual's consumption, attitudes and behaviours associated with that lifestyle. Individuals are often classified according to their life cycle and life stage. A life cycle event affects an individual as he or she gets older, progressing from a child to an adult and then to a senior citizen. An individual's attitude to travel will change at different ages. A life stage can be defined as a specific, optional event such as learning to drive, moving home, moving job and choosing to have children. Travel behaviour will change in response to these choices. The following is an example of a classification based on household composition and life stage (Transport Visions Network, 2001 - Paragraph 67):

- Young single adult living alone. Prime activities for young single adults are work or education and leisure. Nightlife and meeting other young people would tend to be seen as a priority and travel would predominantly be by bus and taxi.
- Young adult living with partner. The effect of two individuals living together would be an increase in household income, a change of leisure activities, and spending time with each other and other couples would tend to be seen as a priority. Car ownership and use would be more affordable, and although not essential, would probably increase.
- Living with partner and young family. With a family, time would become a premium and the patterns of activities would tend to be centred on the children. Motor car use would be seen as essential.
- Living with partner and teenage family. A divergent pattern of activities for parents and children would have increased demands on motor car use, and may lead to an increase in household car ownership.
- Middle aged living with partner. Once children have left home there would tend to be an increase in affluence and further changes in activities. House size and motor car ownership could be in excess of that required.

- Retired couple. The daily commute(s) would disappear and the absence of the work activity would lead to routines and patterns of activity being redefined with a greater flexibility. Time would tend to be less of a premium, and the activity pattern could be shaped by a role as grandparents.

Such a classification can be adapted for non-motorised mode use. Using cycling as an example, an individual may change their level of cycling at different life stages (Davies et al, 1997). For children, cycling can be a popular pastime, giving them their first chance of independent mobility. However, as they reach adulthood, peer and media pressure make car ownership more attractive than cycling. Individuals may return to cycling later in life, perhaps for health reasons or if they have children of their own.

Population segments at certain life stages can be targeted by specific policy initiatives. Retirees could be targeted because they will represent a larger market segment in the future, since the United Kingdom has an ageing population and the elderly segments of the population have particular transport needs (Banister and Bowling, 2004). Alternatively, children could be targeted before they reach seventeen, the age at which they can learn to drive. Another possibility is to target those socially excluded from society, tying in with social inclusion policy (Social Exclusion Unit, 2003), outlined further in Chapter 4.

The methodology utilised to identify the population segments from the Scottish Household Survey data is cluster analysis. Cluster analysis is an exploratory, statistical technique for developing meaningful subgroups of individuals or objects (Hair et al, 1998). It classifies a sample of entities into a small number of mutually exclusive groups based on the similarities among the entities, to reduce the data into manageable parts. The cluster analysis procedures are outlined more fully in Section 5.5.

2.4 Analysing travel behaviour

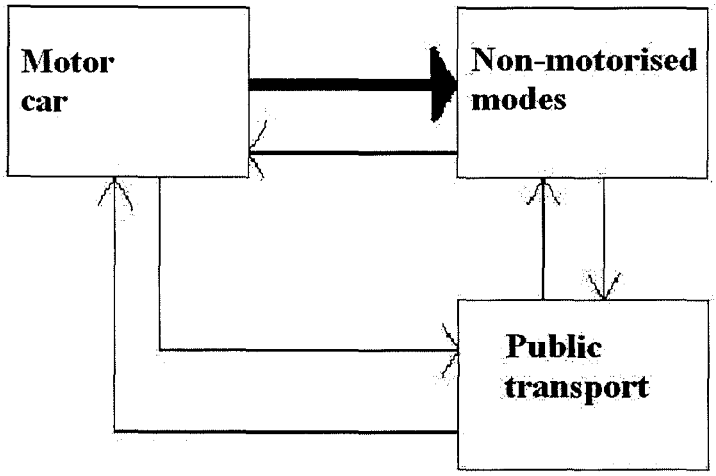
This Section considers the travel behaviour analysis approach of this study. The mechanisms of travel behaviour change and the measures to achieve such a change are outlined.

2.4.1 Mechanisms of a change in travel behaviour

A change in travel behaviour is a complex process and needs to be put into context. Modal shift represents a prominent and visible change in travel behaviour. Modal shift, often also referred to as modal transfer, implies a change in transport mode chosen. This could be for a specific journey or part-journey, say if linked with public transport. Public transport is usually the first mode put forward as an alternative to the motor car, ahead of non-motorised modes, because travel by public transport involves a similar speed and distance as travel by motor car.

This study is concerned with the mode choice decision-making between the motor car and non-motorised modes. Figure 2.1 shows the various options as a flow chart, with arrows for the changes in mode between the motor car, non-motorised modes and public transport. The modal choices in this study relate to the change away from the motor car and towards non-motorised modes, particularly focused on the propensity towards walking and cycling, as shown by the bold arrow in Figure 2.1. The consideration in this study, for a change in travel behaviour towards non-motorised modes, needs to be placed in a wider context. There could alternatively be no change in travel behaviour or a change in the opposite direction from non-motorised modes to the motor car. As shown from the background to the study, in Section 1.3, a change away from non-motorised modes and towards the motor car is currently more common. The situation is further complicated by other transport modes, such as public transport. The modes can be seen as competing with each other for consumers.

Figure 2.1. A flow chart of the various modal shift options between the motor car, non-motorised modes and public transport



Across all transport modes, three types of factors affect mode choice (Ortuzar & Willumsen, 2001):

1. Characteristics of the trip maker. This includes car availability and ownership; possession of a driving licence; household structure (young couple, couple with children, retired, singles); income; decisions made elsewhere (e.g. need to use car at work, take children to school); and residential density.

2. Characteristics of the transport facility. This includes quantitative factors such as relative travel time – in-vehicle, waiting and walking times; relative monetary costs (fares, fuels, direct costs); and availability and cost of parking. It also includes qualitative factors such as comfort and convenience; reliability and regularity; and protection and security.

3. Characteristics of the journey. This includes trip purpose and time of the day.

Variables within the Scottish Household Survey and West Edinburgh survey data sets are categorised according to these three types of factors. The categories are socio-economic characteristics (characteristics of the trip maker), transport information (characteristics of the transport facility, including motor car and bicycle availability) and travel behaviour (characteristic of the journey).

There are broader behaviour choices towards more sustainable travel aside from a modal shift. Alternatively, a trip-maker might change their route, the time of the journey, the destination and the frequency of journeys. Motor vehicles could be made more energy efficient, for example through catalytic converters or better fuel consumption. Journey patterns could be altered, rationalising rather than restricting car ownership and use, such as changing the route, the time or a combination of route and time. For instance, a person could decide not to make a journey and therefore travel less or they might retime a number of journeys to make more efficient use of their motor car. Another way of reducing reliance on the motor car is to increase the number of individuals travelling in a motor car, through informal ride sharing or an organised car sharing scheme. There are also long-term changes, such as in job and residential location, that impact upon travel behaviour. Loukopoulos et al (2004) classify car user responses into three categories. They are to have more efficient motor car usage, to suppress trips and to switch travel mode. As stated at the outset of this Section, switching travel mode is the focus of this research.

The positive images associated with a car culture are often contrasted with negative images of non-motorised modes, particularly cycling. It would be interesting to know the extent to which this is the case, and how it could be changed. These images depend largely on the underlying perceptions people have towards different modes and how these perceptions influence modal choice. Cycling may be seen as low status because it is cheap or because it is chosen by so few. The mental image a person has of a particular mode will affect their decision to change mode. Higgitt (1999), considering walking, mentions the concept of a vicious circle of a low status mode such as walking against the habits of car use, which make it unrealistic for people to change mode. If someone was to consider changing mode, the decision to get rid of a motor car is one not taken lightly, and would take a lot of careful consideration.

This Section shows that travel behaviour decisions are complex to analyse. The approach of this study is therefore to focus on the mode choice aspect of travel behaviour change. Within the mode choice aspect, propensity towards travel by non-motorised modes is examined. For the propensity to walk, this is for a 10 minute journey by motor car, whereas for the propensity to cycle, this is for the journey to work, if currently undertaken by motor car, bus or on foot.

2.4.2 Measures to achieve a change in individual travel behaviour

Outside measures affect an individual's travel behaviour. Examples in this Section relate to a change away from the motor car and towards non-motorised modes.

Banister (2000) provides a detailed classification of measures with the specific purpose of reducing travel, shown in Table 2.1. Of the five categories listed in Table 2.1, the infrastructure and financial travel reduction particularly relate to non-motorised mode travel, against a background of organisation and operational, land use, and technological changes.

Table 2.1. A classification of travel reduction measures

Classification	Measures
Organisational and operational	Car pooling, car sharing, commuted payments, company working hours, demand responsive transport, media campaigns, peak congestion avoidance, and transport optimisation
Infrastructure	Cycle priority and road space, High Occupancy Vehicle and road space, Park and Ride, parking capacity, public transport priority and road space, road capacity restraint and reduction, traffic calming, and area access control
Financial	Cycle subsidy, parking charges, public transport investment, public transport subsidy, and road pricing
Land use	Location of new development, location of firms, mixed use development, design of locations, and car free developments
Technology	Home delivery of goods and services, information, teleactivities, and teleworking

Many of these measures relate to travel demand management as a method to reduce motor car usage. The concept of travel demand management was introduced in the 1990s with a realisation that demand for the motor car outstrips road supply, irrespective of the amount of road building undertaken. Measures to manage travel demand became preferable to building more roads; research into such measures is reviewed in Section 3.5.

Stradling (2002) classifies measures to achieve travel behaviour change into two types. There are "sticks" which constrain individuals in their transport choices, forcing them away from a mode, and "carrots" which encourage individuals in their transport choices, enticing them towards a mode. Sticks tend to be concerned with increasing cost and decreasing availability. Examples include introducing congestion charges, increasing parking costs and banning motor cars from certain streets. Carrots tend to be concerned with the provision of facilities for certain transport modes.

It is beneficial to emphasise and promote carrot measures ahead of stick measures, so individuals feel they are being encouraged rather than forced (Pearce, 1999; Stradling et al, 2000). However, sticks are known to be more effective than carrots to get people to change and are needed to restrain car use. A balanced approach is therefore required. For example, money from the stick of congestion charges could be ring-fenced towards the carrot of other transport improvements. The ring-fence process should be transparent to the general public, to maintain a positive perception of the scheme.

Various carrot and stick measures are considered in turn in this Section. Cost measures are typically considered as sticks against the motor car, such as congestion charges, workplace charges and increasing parking charges. Cost measures can also act as a carrot towards sustainable transport. Examples for employees include employers reimbursing travel expenses for public transport, providing a competitive business cycling mileage rate and subsiding the purchase of a bicycle.

Individuals tend to spend a lot of money purchasing a motor car, and once owned, will use it for most journeys at a low marginal cost. This is despite the high proportion of a typical household budget that motorised travel constitutes. On average, for households, travel by motor car costs £53.60 a week (14.9%), from a weekly expenditure of £359.40

in 1999/2000 (Department for Transport, 2003a). As households become wealthier, they spend more of disposable income on transport and travel. This makes it very difficult to get motorists to change travel behaviour using cost.

Encouraging non-motorised modes, as a carrot measure, typically concerns the provision of facilities. The non-motorised mode infrastructure facilities are often grouped together as routes and networks. The development of routes and networks is more relevant for cycling than walking, since footways are provided alongside most roads, making upkeep and better quality more important than the quantity of footways. For cyclists, safe cycle-friendly facilities are desirable at locations where road and traffic conditions are particularly dangerous for cyclists, such as road junctions and crossing-points of busy roads. A number of road based innovative cycle schemes, such as advanced stop lines, Toucan crossings and contra-flow cycle schemes, have been introduced in the United Kingdom to overcome some of these problems. In addition, non-road based innovative schemes, a more recent concept in the United Kingdom, can provide a focal point for cycling in a city. Examples include cycle centres (complete security, changing and maintenance facilities for cyclists in a town or city) and city bike schemes (hire bikes and special parking racks across a city). Ideally, a range of measures is implemented to complement cyclist facility provision, such as promotional events, advertising, secure cycle parking facilities, employer initiatives, school initiatives and integrated transport initiatives.

Marketing can be used as a carrot measure to promote sustainable transport such as non-motorised modes to counter the mass marketing of the motor car. A marketing example is the £700,000 "Learn to let go" (from using the motor car) advertising campaign from the Scottish Executive in 2001and 2002. Mass advertising campaigns that have successfully altered image and thus behaviour amongst the general public, such as drink driving and smoking, take a decade or so to change public opinion. The anti-social elements of drink driving and smoking are evident to individuals. The problems associated with the motor car are not so visible. Individuals consider it their natural right to drive where they like, when they like, particularly their personal expenditure on a motor car. Wright and Egan (2000) suggest it may be possible to de-market the motor car at a relatively low cost, targeting different market segments. They propose that alternatives to the motor car be marketed in a more imaginative way. Pearce (1999), using general observations from the promotion of Green Commuter Plans, echoes the need to identify a clear target group and clear target message, in that case to change mode for the journey to work. Ogilvie et al (2004) recommend targeted behaviour change programmes to encourage a modal shift towards non-motorised modes.

Travel blending is a technique whereby the marketing is aimed specifically at an individual, by giving them facts about the travel options available to them, often in repeated stages. Individuals are provided with travel information to encourage use of alternatives to the motor car, including non-motorised modes. An Adelaide-based study (Rose and Ampt, 2001) supplied 100 households with individualised marketing material over a nine-week period in order to reduce travel by motor car. The study reported a 10% reduction in car driver kilometres, although acknowledged caution in the findings. However, when Tertoolen et al (1998) provided information to 350 households in the Netherlands on the effect of their motor car usage on the environment and their finances over a two week period, there was no change in travel behaviour. These travel blending results imply that individualised marketing can affect travel behaviour, but if they do, such impacts tend to be minimal.

There are a number of interesting developments, encouraged by technological advancement, which could affect motor car ownership, motor car use and the use of alternative modes. Examples include home delivery shopping and tele-working. For cycling, developments such as electronic bicycles and bicycle trailers may encourage more individuals to cycle due to faster speeds and the ability to carry heavier loads.

Recent evidence (Cairns et al, 2004) suggests that there could be a reduction in traffic as a result of 'soft' transport policy measures (another name for 'carrot'). Such measures, including travel plans, marketing, car sharing schemes and non-motorised mode facilities, help individuals to choose alternatives to the motor car. The study suggests that, if current soft transport policy measures are significantly expanded, traffic could be reduced by 21% at peak times in urban areas.

Promotion of these measures through transport policy is examined in Chapter Four. Many of the measures, particularly sticks relating to transport costs and carrots relating to non-motorised mode facilities, are included in the West Edinburgh survey questionnaire. The design of the West Edinburgh survey is outlined in Chapter Six.

2.5 Transport modelling

The second research objective concerns the modelling of individual travel behaviour. A model is an "idealised and structured representation of the real" (Johnston, 1986), a tool used in many academic disciplines including transport (Hensher and Button, 2000; Ortuzar & Willumsen, 2001), to help the understanding of complex issues. Model development can encounter problems if the models chosen are too ambitious and abstract, or at the other extreme, too simplified to deepen knowledge in a particular field. Also, models can become too case specific to be applicable elsewhere. The user must be aware of the existence or the introduction of errors within models developed. Errors can occur in the measurement, sampling, computation, specification, transfer and aggregation of data.

Modelling in transport has tended to concern the traditional four-stage transportation model, covering trip generation (whether to make a trip), distribution (where to go), modal choice (which mode of transport to use) and assignment (which route to use). The third of these stages, regarding modal choice, is of relevance to this study. The mode choice element of the four stage model incorporates disaggregate models, typically the nested logit model. The four-stage models have tended to focus on the competition between motor vehicles and public transport, affected primarily by time and cost for each trip, and motor car availability. Non-motorised modes are usually not incorporated because they make up too small a share of the modal split, as shown in Section 2.2. Attempts to incorporate non-motorised modes into transport models are reviewed in Section 3.7.

The aggregate four-stage models require large amounts of data, the scale of which is beyond the scope of this research. They tend to lack spatial detail to model non-motorised modes, being concerned with the movement of groups of individuals in a traffic zone. Therefore, the focus of this study is on smaller-scale, disaggregate, second-generation models concerning the behaviour of individuals, rather than the use of aggregate, first-generation transport models.

2.6 Discrete choice theory

This Section provides a theoretical background to the primary methodology used in this study, discrete choice modelling (Ben-Akiva and Lerman, 1985; Louviere et al, 2000; Ortuzar and Willumsen, 2001). Discrete choice modelling concerns the choices individuals make from a set of mutually exclusive and collectively exhaustive alternatives. It is a widely accepted methodological modelling technique, used in transport research since the early 1970s. The theoretical background to discrete choice modelling is random utility theory. The concept of random utility first appeared in psychology in 1927. Utility is defined as the attractiveness of the alternatives, a measure that the decision maker tries to maximise through their choice. The probability of an alternative being chosen implies that it has the greatest utility of the available alternatives. The true utilities of the alternatives are considered random variables.

The origins of discrete choice theory lie in economic consumer theory. Economic consumer theory transforms the consumer desire assumptions into a demand function, expressing the action of a consumer under certain circumstances. There were two main extensions of consumer theory in the 1960s (Ben-Akiva and Lerman, 1985). Firstly, Lancaster defined utility in terms of the attributes of the commodities, and stated that utility was derived from the characteristics of the alternatives rather than the alternatives themselves. Secondly, Becker added a time constraint. A further extension was discrete choice theory, an application of the same concepts as consumer theory, but with discrete representation of the set of alternatives.

Probabilistic choice theory began in psychology, developing from the need to explain experimental observations of inconsistent and non-transitive preferences. Probabilistic choice theory is particularly appropriate for this research because it provides a powerful framework for analysing discrete choice solutions. The probability of an individual selecting between feasible alternatives is specified. There are two approaches. Firstly there is constant utility, whereby the utilities of the alternatives are fixed. Secondly there is random utility, whereby the utility of the alternatives are random because the analyst cannot be certain about their values. Random utility is more consistent with consumer theory, due to observational deficiencies on the part of the analyst. Such deficiencies are the result of unobserved attributes, unobserved taste variations, measurement errors and the use of instrumental, or proxy, variables.

This study does not aim to improve the theoretical constructs behind established discrete choice models, but rather to apply them to non-motorised mode transport choices. Practical transport planning and policy measures can be incorporated into discrete choice models.

2.7 Discrete choice models

This Section outlines the development of discrete choice models from random utility theory presented in Section 2.6. A general framework for the choices that individuals make is provided by Ben-Akiva and Lerman, 1985), and is composed of four elements:

1. Decision maker - this could be an individual or a group of individuals.
2. Alternatives - there are a universal set of alternatives, including a sub-set feasibly available to the decision maker known as the choice set.
3. Attributes of alternatives.
4. Decision rule – this is based upon utility.

In this study, the individual respondents in the West Edinburgh survey are the decision makers. The modes of travelling by motor car, bus, bicycle and on foot are the alternatives provided within the choice set. The attributes of the alternatives within the propensity to walk stated preference experiment are journey time, petrol cost and parking cost. The attributes of the alternatives within the propensity to cycle to work stated preference experiment are journey time, daily payment, cyclist facilities at the workplace and cyclist facilities on route. The decision rule used an approach based on the process of utility maximisation, whereby an individual chooses the alternative with the greatest utility from those available. The decision-making process assumes that individuals act rationally: they would repeat the same mode choice under similar circumstances and have a specified order of mode choice.

Random utility theory was originally developed in the field of transport using operational binary choice models. The value of time against cost was estimated. These models were expanded in the 1970s to other travel related choices such as trip destination, trip frequency, car ownership and residential location. A choice set of more than two alternatives and multinomial choice models were developed. Thus, non-motorised modes could be incorporated alongside the typically used modes of the motor car and bus. Multinomial choice models, by providing more than two choices to an individual, enable constraints such as car availability to be incorporated. Not all alternatives would be available to all of the participants. The most common multinomial choice model is the multinomial logit model (MNL). MNL models were estimated in this study using the ALOGIT package (Hague Consulting Group, 1995). Other multinomial choice models are the random coefficients logit model, the ordered logit model, the generalized extreme value model and the multinomial probit model.

The MNL model is based on three assumptions about the disturbance terms of the utilities. These assumptions are that the disturbance terms are independent, identically distributed and Gumbel (or type I extreme value) distributed. There are three important properties of logit:

1. Independence from Irrelevant Alternatives Property (IIA), applies to each homogeneous group but not to the population as a whole.
2. Elasticities of logit can be calculated.
3. The incremental MNL model can be utilised. Using elasticities, changes due to modifications in the independent variables can be predicted – thus the incremental MNL model.

MNL modes can therefore be utilised to predict consumer behaviour, forecasting what travellers do under changed circumstances. The following logit formula is used (Hague Consulting Group, 1995):

$$P_1 = \exp(U_1) / \{ \exp(U_1) + \exp(U_2) + \ldots + \exp(U_k) \}$$

The logit formula predicts the probability of each alternative and has the exponential functions of U (utility of each of the alternatives from 1 to k). It is a mathematical transformation typically characterised as having an S-shaped plot. Utility functions (U) are generally of the following simple, linear form and have the estimation of weights (β, beta coefficients) multiplied by the measured data items (D):

$$U_1 = \beta_1.D_{11} + \beta_2.D_{21} + \ldots + \beta_n.D_{n1}$$

The design of the stated preference experiments within this study, that determine the propensity to use non-motorised modes, is shown in Section 6.5. The aim of the second research objective is to develop robust models, and from these discrete choice models produce practical outputs.

The sample of the West Edinburgh survey, with 997 respondents, was large enough to allow the modelling of population segments. Discrete choice model results were successfully segmented in a previous stated preference experiment by a team including the author. The models concern the choices made by individuals in the Belfast Metropolitan Area when buying property (Cooper et al, 2001).

The value of travel time is a useful statistic produced from discrete choice models. The value of travel time savings is often used in proposed transport infrastructure and related projects. A comprehensive review of United Kingdom value of time studies (Wardman, 1998) considers hundreds of case studies, but they tend not to concern non-motorised modes. Some cyclist route choice models produce values for travel time (Hopkinson and Wardman, 1996; Wardman et al, 1997; Abraham et al, 2002).

The elasticity of demand is the response of demand for a product to the change in one of its determinant factors. Many studies, such as Noland and Kunreuther (1995), use the elasticity outputs from discrete choice models. Direct and cross elasticities are produced. Direct elasticity relates to factors associated with the product in question, whereas cross elasticity relates to factors associated with another related product. Elasticities are used in the model forecasting process. Ideally forecasting is incorporated into discrete choice modelling, to show future propensity to change. The coefficients produced in the model estimation process can be used to generate probabilities. Most studies consider sample enumeration forecasting (Noland & Kunreuther, 1995; Wardman et al, 1997; Ortuzar et al, 2000). Scenarios depicting how the transport situation may change in the future are input into the model.

2.8 Spatial framework development

A Geographical Information System (GIS) was incorporated into the study, a valuable tool in the spatial analysis and presentation of data. GIS has been recommended as a tool to be incorporated into bicycle demand models (Katz, 1995; McDonald & Burns, 2001). The GIS package Arcview was used, incorporating 1:50,000 Ordnance Survey Landranger® maps. These maps were downloaded from DIGIMAP, an EDINA (University of Edinburgh Data Library) service delivering Ordnance Survey map data to United Kingdom Higher Education institutions.

Postcode sector information was provided within the Scottish Household Survey data set for household location, work location, school location and travel diary information (both origin and destination). Postcode sector zones were drawn on GIS for 74 postcode sectors within the case study area. Using a macro within the GIS package, a centroid was designated for each of the 74 zones, and the distance was subsequently calculated between each zone within a matrix. The average distance was 6.41km. The minimum was 0.27km (postcode sector EH2 1 to EH2 3) and the maximum distance was 19.65km (postcode sector EH21 8 to EH29 9). The GIS has enabled survey data map outputs to be generated (Figure 6.1; Figure 7.1); Scottish Household Survey analysis (of journey to work data) to incorporate distance information (Section 7.5.2); and background information on the four West Edinburgh survey areas to include postcode sector size and distance from the city centre (Section 8.2).

2.9 Hypotheses development

A series of hypotheses were developed to enable a number of inferences to be made concerning the overall population from the data set samples. There were nine hypotheses tested in total. The data and methods used to test the hypotheses, with links to objectives and propensity to use non-motorised modes, are shown in Table 2.2.

Table 2.2. The data and methods used to test the hypotheses, with links to objectives and propensity to use non-motorised modes

Hypothesis	Data	Method	Segmentation objective	Modelling objective	Reducing car use	Propensity to walk	Propensity to cycle
1 - The population is split into segments according to socio-economic characteristics	Scottish Household Survey	Cluster analysis	✓				
2 - Motor car and bicycle availability affects the propensity to use non-motorised modes	Scottish Household Survey	Multi-variate analysis	✓		✓	✓	✓
3 - Socio-economic and transport availability characteristics affect travel behaviour	Scottish Household Survey	Multi-variate analysis	✓		✓	✓	✓
4 - Car drivers acknowledge the problems associated with the motor car but are unwilling to change travel behaviour	West Edinburgh survey	Multi-variate analysis	✓		✓		
5 - Attitudes towards non-motorised modes vary greatly amongst the population segments	West Edinburgh survey	Multi-variate analysis	✓			✓	✓
6 - The most influential attribute affecting mode choice between the motor car and walking for short trips varies amongst population segments	West Edinburgh survey	Discrete choice models	✓	✓	✓	✓	
7 - Increases in petrol prices and parking costs could induce a modal shift from the motor car to walking for short trips	West Edinburgh survey	Discrete choice models	✓	✓	✓	✓	
8 - The most influential attribute affecting mode choice between the motor car and cycling for the journey to work varies amongst population segments	West Edinburgh survey	Discrete choice models	✓	✓	✓		✓
9 - An improvement in cyclist facilities could induce a modal shift from the motor car to cycling for the journey to work or study	West Edinburgh survey	Discrete choice models	✓	✓	✓		✓

The first three hypotheses concern the first research objective, "to identify segments of the population with the greatest propensity to use non-motorised modes". They use the three types of data within the Scottish Household Survey, namely socio-economic, transport availability and travel behaviour variables. The three hypotheses tested (in Chapter Seven) are:

- Hypothesis one: "The population is split into segments according to socio-economic characteristics"
- Hypothesis two: "Motor car and bicycle availability affects the propensity to use non-motorised modes"
- Hypothesis three: "Socio-economic and transport availability characteristics affect travel behaviour"

To test the first hypothesis, cluster analysis is used to identify distinct household segments based on the socio-economic variables. This hypothesis has been chosen to enable market segmentation using non-transport characteristics, before transport relationships upon the population segments are tested. This tends not to be the case in transport research. The second and third hypotheses analyse Scottish Household Survey transport availability and travel behaviour variables split by the population segments identified from the testing of hypotheses one. Transport availability data, namely motor car and bicycle availability, is used to test the second hypothesis. Three travel behaviour trips are examined in the testing of the third hypothesis: non-motorised journeys made the previous week, the journey to work, and journeys made the previous day.

The next two hypotheses also concern the first research objective, using data from the survey of travel behaviour in West Edinburgh. The two hypotheses tested (in Chapter Eight) are:

- Hypothesis four: "Car drivers acknowledge the problems associated with the motor car but are unwilling to change travel behaviour"
- Hypothesis five: "Attitudes towards non-motorised modes vary greatly amongst the population segments"

Hypothesis four is developed from the literature review, concerning the statement that car drivers are unwilling to act altruistically. The focus is on the propensity for car drivers to reduce car use, which can be linked at the end to the propensity for individuals to use non-motorised modes. Hypothesis five uses West Edinburgh survey attitudinal data to examine how the attitudes towards non-motorised modes vary amongst the population segments. Since responses towards transport policy measures are included in the West Edinburgh survey, findings from these two hypotheses are linked to policy implications.

The remaining four hypotheses relate directly to the second research objective "to model individual travel behaviour and thus the propensity to use non-motorised modes" and involved the development of the discrete choice models. The four hypotheses tested (in Chapters Nine and Ten) are:

- Hypothesis six: "The most influential attribute affecting mode choice between the motor car and walking for short trips varies amongst population segments"
- Hypothesis seven: "Increases in petrol prices and parking costs could induce a modal shift from the motor car to walking for short trips"
- Hypothesis eight: "The most influential attribute affecting mode choice between the motor car and cycling for the journey to work varies amongst population segments"
- Hypothesis nine: "An improvement in cyclist facilities could induce a modal shift from the motor car to cycling for the journey to work or study"

Robust model estimation and forecasting of the West Edinburgh survey stated preference data is required for the hypotheses to be successfully tested. Model estimation enables population segments to be identified with the greatest propensity to use non-motorised modes (hypotheses six and eight). This enables the findings to be linked to the first research objective, identifying the population segments with the greatest propensity to walk and cycle. The discrete choice model forecasting (hypotheses seven and nine) enables transport policy measures to be directly tested and provides an indication of modal shift. The policy measures are petrol and parking cost changes for the propensity to walk for short trips, and cyclist facilities (at the destination and on route) for the propensity to cycle for the journey to work or study.

2.10 Summary

This Chapter provides an overview and justification of the methodology utilised to achieve the research objectives.

Section 2.2 explores the data issues that determine the nature of the research methodology, including an outline of the two data sets. These are the Scottish Household Survey and an extensive survey along a transport corridor in West Edinburgh. The depth and breadth of the empirical data is a key strength of this study. Links between the two surveys include the application of Scottish Household Survey population segments to the West Edinburgh survey travel behaviour relationships, and the aggregation of the West Edinburgh survey discrete choice model forecasts using Scottish Household Survey data. Detailed non-motorised mode information within both data sets, particularly on walking, has contributed to the originality of the research.

The methodology of market segmentation, used to achieve the first research objective, "to identify segments of the population with the greatest propensity to use non-motorised modes", is considered in Section 2.3. Examples of market segmentation and cluster analysis, the segmentation methodology in this study, are presented. Section 2.4 presents concepts used in travel behaviour analysis, specifically the mechanisms of travel behaviour change and the measures to achieve travel behaviour change. The intention is to provide a greater understanding of complicated travel behavioural patterns than previous research.

Sections 2.5 to 2.7 concern the second research objective, "modelling individual travel behaviour and thus the propensity to use non-motorised modes". Section 2.5 outlines general developments in transport modelling. Disaggregate second-generation discrete choice models are used in this study. The theoretical background to discrete choice analysis, the methodology used in the study, is presented and justified in Section 2.6. Random utility theory is the basis upon which discrete choice models are developed. The development of discrete choice models from the theory is presented in Section 2.7. The methodology of discrete choice analysis is a tried and tested method, but application into the area of non-motorised modes is relatively new. This study applies a model rather than being a theoretical modelling study per se. It is hoped to produce some new non-motorised mode outputs, predicting travel demand and testing policy measures.

The development of a spatial framework is outlined in Section 2.8, a novel strand to the study. A Geographical Information System spatial framework of postcode sectors for Edinburgh has been developed to assist the methodology.

Finally, nine hypotheses are outlined in Section 2.9. The first three concern analysis of the Scottish Household Survey in order to meet the first research objective, market segmentation. A further two hypotheses test this objective using data from the West Edinburgh survey. The final four hypotheses concern the development of discrete choice models to achieve the second research objective. Model development includes estimation split by population segments and forecasting transport policy measures.

To summarise, the methodological approach concerns the application of tried and tested discrete choice modelling to non-motorised mode choices, using stated preference data. The stated preference data was from two innovative experiments within the West Edinburgh survey. One concerns the propensity to walk for a 10 minute journey by motor car, the other the propensity to cycle for the journey to work if currently undertaken by motor car, bus or on foot. Response to transport policy measures can be examined from policy-related attributes within the two experiments.

An introduction to the study has been provided in Chapters One and Two. The next two Chapters, Three and Four, review literature and policy respectively.

3. LITERATURE REVIEW

3.1 Introduction

Chapter Three is a review of the academic literature concerned with the propensity to use non-motorised modes, showing how this study develops upon previous research.

The study focuses on the urban area of Edinburgh. As a starting point for the literature review, the relationship between urban form and travel behaviour is explored in Section 3.2. The remainder of the Chapter follows the same structure as the Background section (Section 1.3). Research on motor car dependency is presented in Section 3.3. Literature examining how individuals respond to the problems associated with the motor car is reviewed in Section 3.4, and in Section 3.5 possible solutions are put forward to counter the issues raised in Section 3.4. The remainder of the Chapter concentrates on the role of non-motorised modes as one solution to counter the problems associated with the motor car. The factors affecting non-motorised modes are presented in Section 3.6. Section 3.7 examines the modelling of non-motorised modes. The concluding section, Section 3.8, summarises the current state of research as discussed in the literature review.

3.2 The relationship between urban form and travel behaviour

In Section 1.4, the Edinburgh urban area is summarised as a compact, growing and prosperous city with an historic core. Developing upon this definition, Section 3.2 examines the relationship between urban form and travel behaviour in more depth.

3.2.1 Transport problems in urban areas

The characteristics of transport in urban areas are widely documented in the literature (Hoyle and Knowles, 1992; Tolley and Turton, 1995). Transport problems are particularly acute in urban areas because they are locations of the greatest concentrations of people. Thomson (1978) lists the seven facets of the urban transport problem to be traffic movement, parking difficulties, environmental impact, pedestrian difficulties, accidents, peak-hour crowding of public transport, and the off-peak inadequacy of public transport.

Much space within the urban environment has been used to facilitate travel by motor car, including the road network, petrol stations and car parks. The increasing emphasis on motor car usage in urban areas led to the construction of motorways and inner ring roads, often preventing cycling and walking trips to the centre. Tensions between the city structure and the motor car are not a recent phenomenon, but one that dates to the 1970s and before (Owen, 1972; Hass-Klau, 1990). The motor car has the advantage of the freedom to travel in any direction over any distance within an urban area, unlike most other modes. Public transport tends to be confined to fixed routes whilst non-motorised modes tend to be confined to short trips.

Transport problems in urban areas are linked to a lack of space. Table 3.1 shows the relationship between the space required per person and the speed of travel for the three modes of interest to this study (from Tolley and Turton, 1995). It illustrates not only how much less space non-motorised modes take up in urban areas, but also how space required per person can vary according to the number of individuals travelling and vehicular speed.

Table 3.1. The relationship between the speed of travel and the space required per person for the transport modes of walking, cycling and travel by motor car

Transport mode	**Speed**	**Space required per person**
Walking	5 km/hour	0.8 m^2 per person
Cycling	10 km/hour	3 m^2 per person
Fully occupied motor car	10 km/hour	6.2 m^2 per person
Fully occupied motor car	40 km/hour	18.7 m^2 per person
Motor car with one person	10 km/hour	20 m^2 per person
Motor car with one person	40 km/hour	60 m^2 per person

Note: from Figure 7.4 in Tolley and Turton (1995), who reproduced the data from a study based in Switzerland

Transport problems associated with the motor car extend beyond the urban area. As shown in Section 1.4, there has been substantial population decentralisation from Edinburgh to surrounding areas, a trend common to United Kingdom urban areas. Evidence of a higher reliance on the motor car in a surrounding area than a city is shown using data for Belfast Metropolitan Area (Cooper et al, 2001). The trend for increased urban sprawl has been exacerbated by associated land use developments; examples include the increase in out-of-town shopping centres and lower density housing. In addition, many travel destinations such as local government offices, schools and leisure facilities have been amalgamated, producing a wider hinterland. Individuals wishing to access these facilities often have to use motorised transport. The effect of suburbanisation is evident from Goudie (2002), whereby outer urban dwellers use approximately three times the amount of fuel than their more centrally located counterparts.

3.2.2 Debate on the relationship between urban form and travel behaviour

Academic debate has concerned the nature of the effect of urban form upon travel behaviour, often using aggregate, comparative city studies. The influential work on energy use and urban form by Newman and Kenworthy (1989) ranked 32 cities in terms of motor car dependence. The highest ranking and most motor car dependent tend to be the United States and Australian cities. Conversely, the lowest tend to be European and Asian cities (note Edinburgh was not included, London was the only United Kingdom city). Studies have continued to rank and compare cities according to sustainable transport planning and practice criteria (Schiller and Kenworthy, 1999; Giuliano and Narayan, 2003).

It is of interest to compare Edinburgh with other cities in order to ascertain the applicability of the study findings. A comparative study between Belfast and Edinburgh shows that Belfast has a higher level of car dependency, but that Edinburgh is still car dependent (Donegan et al, 2003). The extent of car dependency in Edinburgh has been limited by land use characteristics. United Kingdom cities tend to be more motor car dependent than other European urban areas, some of which are regarded as examples of productive sustainable transport planning and policy.

Stead (2001) contests the traditional relationship that land-use characteristics affect travel patterns, to show that there is in fact a three-way inter-relationship of land use, travel behaviour and socio-economic characteristics such as car ownership, socio-economic group and employment levels. The debate has progressed to confirm that land use and urban form affect travel behaviour (van Wee, 2002; Cameron et al, 2003). A relationship between building density and travel behaviour has been suggested. A higher density has been linked to less travel in studies such as ECOTEC (1993), but others such as Schimek (1996) found the effect to be small. This study examines data on urban form and travel behaviour, albeit with a narrower focus on non-motorised modes. Yet, as Handy (1996a) states, researchers have done a better job of revealing the strength of relationship between urban form and travel behaviour than of understanding the how and why of the relationship. This study will endeavour to deepen the understanding of the relationship between urban form and travel behaviour.

To counter urban sprawl, cities should be designed in a compact form with associated promotion of the city centre, high-density buildings and greenbelt land. Cities would then be more supportive of public transport and non-motorised modes, and less dependent on the motor car. Taking the sustainable city design to its conclusion has led to the concept of a "car-free" city (McKenzie, 1999). Initiatives to make housing more encouraging towards non-motorised mode usage include the discouragement of the motor car, say through restricted access and parking. Edinburgh has been at the forefront of such initiatives with the first car-free housing complex in the United Kingdom, at Slateford Green. Ultimately, it is important to design and build urban systems that make the city both accessible and pleasant to live in. The links between residential choice and travel behaviour have been examined (Headicar and Curtis, 1994; Cooper et al, 2001). Although usually not a primary reason for moving home, reasons associated with the motor car, such as parking and access to the network, are influential for many in choosing where to live.

3.2.3 The role of non-motorised modes in urban areas

The focus of this study is non-motorised modes of transport. This Section considers their role within the broader travel behaviour debate that tends to considers the motor car and public transport as viable urban modes. Nonetheless, the role of non-motorised modes is often acknowledged in the literature. For example, Newman and Kenworthy

(1989) show that where land use is sufficiently concentrated, opportunities for non-motorised modes can be greatly encouraged by improved facilities. High automobile dependence city groups, typically in the United States, have low non-motorised mode percentages (6% or less), whereas moderate to very low automobile dependence city groups, typically in Europe, have higher non-motorised mode percentages (16% or more). As shown in Section 1.4, Edinburgh has a modal split of 24% non-motorised modes (21% walking, 3% cycling) from the 2001 Census, although this is purely a measure of the journey to work or study, not all trips.

Non-motorised modes are particularly suited to urban areas because people tend to be closer to where they want to travel, making journeys shorter than in non-urban areas. There is therefore an important link between non-motorised modes and high-density living. A review of research into this link has shown that residents are more likely to travel using non-motorised modes in traditional neighbourhoods characterised by higher densities, better accessibility and pedestrian-orientated design than those in less conventional neighbourhoods (Handy, 1996a). A case study in Austin, Texas shows that at a neighbourhood level urban form can influence pedestrian choices (Handy, 1996b).

City design varies in the amount it encourages non-motorised modes. Cities such as Phoenix, Arizona are at one extreme, having a structure that almost eliminates walking, whereas cities such as Venice are at the other extreme, arranged to maximise walking (Department of Transport, 1996b). The urban form of Dutch cities is often promoted as an example of best practice in terms of sustainable transport, and therefore non-motorised modes. The Netherlands has the highest level of cycling in the developed world, with over a quarter of all trips made by bicycle (Martens, 2004). National spatial planning, such as through the strict compact-city and 'A-B-C' location of firm policies has been effective in retaining high shares of cycling and walking in the large and medium-sized cities (Schwanen et al, 2004). 'A-B-C' location policy encourages firms to locate in the Central Business District (type A areas), in development nodes outside the Central Business District or in the centre of smaller urban settlements (both type B areas), rather than in locations with very good motorway access (type C areas). The policy has been developed to explicitly encourage public transport, cycling and walking at the expense of the motor car.

As shown from 2001 Census data in Section 1.4, the United Kingdom locations with the highest proportion of cycling to work are the large towns of Cambridge, Oxford and York. A study of United States Census data by Nelson and Allen (1997) shows the highest proportion of commuter cycling to be in the college towns of Boulder (32%), Gainesville (25%), Madison (22%) and Eugene (16%). There appears to be a link with cycling and student numbers in large towns and cities both in the United Kingdom and the United States. Although Edinburgh has many students, with four universities and many further educational colleges, it would be of interest to assess why it does not have the cycling numbers of these large towns and cities. It may be due to a larger than expected modal share of walking and public transport journeys in comparison with other urban areas.

3.2.4 Implications for this study

In summary, there has been much debate on the effect of the motor car upon urban form, the rate of urban sprawl and suburbanisation, the impacts of residential density, the sustainability categorisation of cities and urban design solutions. When considering the relationship between urban form and travel behaviour, the focus tends to be on variables relating to the motor car and public transport. A greater role for non-motorised modes can be argued in United Kingdom urban areas, in comparison with European compact cities, which illustrate that urban form can affect non-motorised mode usage. This would be particularly the case for cycling in Edinburgh, which has considerably lower levels than many other United Kingdom cities. Many of the studies relating to urban form and travel behaviour are aggregate and comparative between different cities. Handy (1996a) recommends choice models as a methodology to aid greater understanding of the link between urban form and travel behaviour, and that is the direction which this study takes. It focuses on one urban area, Edinburgh, a high-density compact city with many students, at the more sustainable end of United Kingdom cities. Of interest are relationships at the city-wide level from the Scottish Household Survey data and at the neighbourhood level from the West Edinburgh survey data.

The debate on urban form and travel behaviour provides two useful variables to be collected as part of the West Edinburgh survey. The first is a surrogate for density, an important variable in the literature, namely the accommodation type (flat or detached) of the household interviewed. The second is distance from the city centre, providing insights into travel behaviour of those living near to the centre of the city (that would suit a compact city design), as opposed to those in the suburbs and city fringe. A similar approach to that of Goudie (2002) is used, who examined households at different distances from the centre of two cities in North Queensland, Australia.

3.3 Motor car dependency

This Section explores the concept of motor car dependency within the literature, and then examines attitudinal and segmentation studies of motor car ownership and usage.

3.3.1 The concept of motor car dependency

The literature increasingly refers to motor car dependency, whether in the United States as "automobile dependency" (Newman and Kenworthy, 1989) or in the United Kingdom as "car dependence" (Goodwin, 1997). Motor car dependency implies that people are reliant on their motor car, without any alternative modes available. Davies et al (1997) consider that the population is completely encased in a car culture. Stradling (2002) takes the debate further, sub-dividing motor car dependency into car dependent people, car dependent trips and car dependent places. The focus in this study is on people, in the sense that those individuals who are not car dependent will have a greater propensity to use non-motorised modes.

The case for increased motor car dependency has been outlined in the background to the study (Section 1.3). Further evidence can be derived from Cooper et al (2001), showing the extent of car dependency in one United Kingdom city region, the Belfast Metropolitan Area, from a household survey of 812 home owners. Almost all households in the sample owned at least one car (92%) and contained at least one person with a driving licence (96%). Travel profiles reveal that most trip-makers would use a motor car for their journey to work (84%), their journey to main food shopping centre (90%) and their journey to educational establishment (63%). When asked about the factors that influenced their choice of residential property, less emphasis was put on public transport than motor car based travel. Parking facilities and access to the road network are rated more highly than links to public transport.

The main advantages of the motor car compared to other modes of transport are the speed of travel and the convenience of door-to-door transport. The costs of travel by motor car reinforce car use, as explored in the paper by James (1998), with perceived costs of ownership and use of the motor car much lower than actual costs incurred. There may be a high ownership cost associated with a motor car, but once owned it offers a low marginal cost of travelling.

The situation of car dependency can be illustrated as a vicious circle of continuing car ownership and use which is very difficult to break (Ortuzar and Willumsen, 2001, p9), as opposed to a self-reinforcing "virtuous" circle of non-motorised mode use. For many, a motor car will be the most expensive item they own after their home. This can make the motor car one of the most treasured possessions. Many people in the United Kingdom consider a motor car an essential item to own, giving them freedom and independence. This is further reinforced by motor car advertising and peer-group pressure to make the car a symbol of individual liberty and self-expression. Manufacturers are making motor car travel a more pleasant experience by designing them to be comfortable and with in-car entertainment systems.

3.3.2 Attitudinal studies on car ownership and usage

Studies have examined attitudes to car ownership and use, sampling households (Cooper et al, 2001; Cullinane, 1992), journey segments such as short trips (Mackett and Ahern, 2000) and population segments such as motorists (Liebling, 1998; Lawson and Morris, 1999). Liebling (1998) provides an insight into the current behaviour, attitudes and lifestyles of motorists. In a survey of 1,500 motorists, about 80% of the sample agreed with the statement "I would find it very difficult to adjust my lifestyle to being without a car". Since most motorists would find it difficult to live without access to a motor car, a difficulty exists in encouraging any form of change in travel behaviour away from the motor car.

3.3.3 Segmentation studies on car ownership and usage

Segmentation research into motor car ownership and use has been documented in the literature. One example (Cullinane, 1992) established that car ownership tends to be higher in areas with a high social class, in rural locations, in the south of the United

Kingdom, and in areas with high proportions of households with older children. Huby and Burkitt (2000), using British Social Attitudes Survey data, suggest that car dependency is particularly strong among men, people with higher incomes, those aged between 25 and 59, individuals with children, the non-manual social classes, and those living in rural areas. Anderson and Stradling (2004) confirm these results using Scottish Social Attitudes Survey data. The Swedish study by Polk (2004) shows that gender affects daily car use (greatest for men) and willingness to reduce car use (greater for women), even when other factors such as age and income were controlled.

There is a wide variation in motor car usage amongst the population. James (1998), using secondary data, stated that if motorists are ranked according to mileage, 60% of motor car mileage would be undertaken by the top 24% of motorists, whilst only 16% of motor car mileage would be undertaken by the bottom 50% of users. Access to a motor car is also an important variable to predict usage. For instance, an individual in a two-person household with one motor car may not have access to a car at certain times of the day.

It is noticeable from reviewing market segmentation of motor car ownership and usage, that the methods employed are not statistically rigorous. Apart from Huby and Burkit (2000), who used multiple regression, the studies (Cullinane, 1992; Anderson and Stradling, 2004; Polk, 2004) do not use statistical tests, but rather an examination of percentage differences between groups. It is hoped that this study can be more statistically rigorous, using cluster analysis, in the market segmentation process.

3.3.4 Implications for this study

Motor car dependency is a concept widely recognised that has been difficult to break. Attitudinal studies show that motorists find it difficult to adjust to a lifestyle without a car. However, it can be argued that there are degrees of car dependency and individuals with a lesser dependence on the motor car could be targeted with measures to encourage them to use non-motorised modes. Segmentation research shows that many socio-economic factors affect motor car ownership and use. The socio-economic factors of relevance to this urban Edinburgh-based study include age, gender, income and whether children are present in the household. Individuals with the greatest propensity to own and use a motor car include those of working age, male, on higher incomes and who have children.

3.4 Individual responses to the problems associated with the motor car

It has been established from the background to this study (Section 1.3) that although there are many, the two principal problems posed by increasing use of the motor car are traffic congestion and air pollution. It is of particular interest in a car dependent society how individual members of the public respond to such problems. This gives an indication of likelihood for the non-motorised mode demand. A number of the attitudinal studies, outlined in Section 3.3, examine how motorists perceive problems associated with the motor car.

Liebling (1998) examines how motorists would respond to the two problems of pollution and congestion. For pollution, individuals would like production of more fuel-efficient vehicles and more use of public transport to be encouraged; for congestion, they would like road networks to be managed more efficiently to increase capacity, as well as more use of public transport to be encouraged. Therefore, motorists are willing to put forward suggestions to overcome pollution and congestion, but are not so keen on measures that restrict their own car ownership and use. Most individuals recognise the problems associated with the motor car, but would not be prepared to act altruistically. They would rather that other individuals change travel behaviour. Individuals may want to change travel behaviour, but not at the expense of detrimentally affecting their lifestyle. There needs to be an obvious benefit to the individual, say in terms of cost or time, for an individual to change.

A similar survey by Lawson and Morris (1999), asked 1,000 motorists whether they believed motor cars seriously damaged the environment and whether they should be forced to reduce use of the car. Approximately a quarter of the sample reject the notion of an environmental problem. Slightly more than a half of motorists accept the notion, but if possible, would not allow themselves to be forced to change travel behaviour. The remainder, slightly more than a fifth, accepted the notion, and stated that they may accept measures of change away from the motor car. Those living in London and the South East, AB social groups, low mileage drivers and active environmentalists are identified as segments that would support any alternative to the motor car. A caveat to this survey is that the sample consists of Automobile Association members and therefore motorists who can afford the monthly subscriptions and want roadside assistance.

Metz (2002) comments that the segments who would voluntarily forgo a motor car are students, older people, idealists, and those living in convenient and attractive urban areas (preferably with pedestrian zones). There should be a clear distinction between those who have to and those who want to reduce their car use or even go without a car altogether. There remains a nagging doubt though, as illustrated by the survey of cycling motorists by the Automobile Association (1993), and previously shown in Section 2.2, that individuals (in this case motorists) will state that they are prepared to make a change in a survey but may not in fact make the change. Half of all cyclists state in the Automobile Association survey that they would use a bicycle instead of a car more frequently if there is an increase in the number of cycle lanes. However, in areas where cycle lanes have been introduced, such as Milton Keynes and Stevenage in the 1980s, there has been little modal shift from the motor car to cycling (Davies et al, 1998).

In summary, the two main problems associated with the motor car are air pollution and congestion. Most motorists would acknowledge the problems but would unwilling to change their own behaviour. There may be agreement that there are problems and further, that something needs to be done, but popular solutions amongst survey respondents tend to concern other road users changing behaviour. Very few people would change behaviour unless there is an obvious benefit to them, in terms of cost and time. There are also those who cannot change travel behaviour because certain journeys are dependent on the use of a motor car. For example, it could be that where they live or work means that they have to use a motor car or that their job necessitates use of a motor car. It has been shown that motorists can be segmented into smaller sub-groups, with a minority willing to change mode away from the motor car. Such segments could be targeted with sustainable transport measures. The surveys in the literature have shown that there are segments of the population at the extremes of the population, at one end very willing to change travel behaviour away from the motor car whilst at the other end very reluctant to change travel behaviour. In terms of the methodology used, many of the studies examining individual responses have been attitudinal, concentrating on percentage opinions, rather than giving an in-depth statistical or model-based analysis.

3.5 Solutions to the problems associated with the motor car

This Section presents the possible solutions to the problems associated with the motor car offered by commentators. It develops upon the measures to achieve a change in travel behaviour outlined in Section 2.4. It is interesting to trace amongst these comments where non-motorised modes are ranked amongst solutions to the problems associated with the motor car. It is contended that non-motorised modes are high enough amongst solutions to warrant encouragement in policy formation.

Section 2.4 outlines the concept of travel demand management measures. Thorpe et al (2000) examine responses to four travel demand management measures from attitudinal surveys in Cambridge and Newcastle upon Tyne. Not surprisingly, the carrot of improving public transport is more popular than the three stick measures. The stick travel demand management measures in order of acceptability (the most acceptable first) are road-user charging, zone access controls and increased parking charges. Loukopoulos et al (2004) consider three travel demand management scenarios based on existing schemes. They are prohibiting car traffic from the city centre in Cambridge; road pricing in Singapore; and individualised marketing in Perth, Australia. These studies show that travel demand management measures tend to be on a larger scale than non-motorised mode measures.

It is arguable whether cost alone, making cars more expensive and public transport cheaper, will bring about more than a slight or temporary change in travel behaviour. Attitudinal studies have shown that cost changes will not drastically affect car use, because people are so dependent on their motor car. One example examined rising petrol prices in the 1970s (Bendixson, 1977). These findings, of limited impact of rising petrol prices, have been reiterated by the fuel price increase in the year 2000, which culminated in the September fuel crisis (Lyons and Chatterjee, 2002). Continued fuel price escalation or rationing petrol, as implemented in the 1970s, could be implemented but would be an extremely unpopular policy measure. There would also be a social dimension to such a policy, as lower income groups may be hardest hit, since wealthier segments can afford to absorb the extra costs imposed (Black, 2000).

Wootton (1999) presents a number of long-term measures to alleviate the problems associated with increased use of the motor car. The long-term measures are developing education to encourage changes in behaviour; reshaping towns and cities to reduce the need for personal mobility by mechanised transport; improving public transport; building more roads; rapidly introducing new technology, producing more fuel-effective vehicles; introducing pricing mechanisms to give the right incentives; and developing new sources of funds to finance the solutions. Non-motorised modes are not considered because they are not thought to make an impact and do not represent a new technology. Although cycling is perceived to be a popular solution, it appears "unlikely to have a significant impact on reducing the amount of traffic on our roads" (Wootton, 1999). Even if the original target to quadruple cycling levels by the year 2012 is attained, it only represents 1% of the amount of travel by the car. Walking is also not suggested as a solution in the paper.

Mackett and Ahern (2000) share the viewpoint of non-motorised mode measures having a limited impact upon motor car levels, from their motorist survey. Less than half of the motorists surveyed (37%) consider walking to be an alternative to the motor car for short trips. Only 10% consider cycling as an option for short trips. Scaling up the results from their survey, Mackett and Ahern estimate that actions increasing the level of walking and cycling could reduce the number of car trips by about 3% and 1.5% respectively, and the distance travelled by car by about 0.3% to 0.4% each.

As stated in Section 3.4, some new cycle schemes and networks, such as those in Milton Keynes and Stevenage in the 1980s, did not yield the desired large increase in cycling numbers (Davies et al, 1998). However, they still send a signal from policy makers to everyone that cycling is a viable option. A United States study (Dill and Carr, 2003) correlated bicycle infrastructure levels with bicycle commuting rates from the United States Census, suggesting that if facilities are built commuters will use them.

With fears of induced demand for car travel, as realised in the Standing Advisory Committee on Trunk Road Assessment (SACTRA) report (1994), road space created from these savings would be replaced by more motorised transport. It is accepted that non-motorised modes might not seem a long-term option. For many though, as shown in this section, non-motorised modes have a role, albeit small, in enticing people out of the motor car. One viewpoint is that non-motorised modes have been relegated to leisure modes (Lyons, 2003). However, this study contends that non-motorised modes should continue to be promoted, particularly for certain population segments and certainly in urban areas such as Edinburgh.

There are some who consider non-motorised modes to be a viable policy option. Cullinane (1992) outlines six options reflecting the most popular policy responses to the problems associated with the motor car (in the early 1990s). The six policy options are:

- Encouraging people to walk and cycle instead of driving by providing more pedestrian and cycle routes.
- Banning cars from central areas except drivers with special permits (for residents, disabled people etc.).
- Improving bus and rail services to provide an attractive alternative to the car.
- Reducing congestion by charging drivers to enter busy city areas.
- Building new roads to increase traffic capacity.
- Ensuring much stronger enforcement of parking controls.

Indeed, encouraging individuals to use non-motorised modes is the second most popular response by those interviewed (77% support) after improving public transport services. However, it is of note that the most popular responses are those not restricting the respondent's driving.

In summary, viable alternatives to the motor car have been suggested, often on a large-scale and using new technology. Non-motorised modes although not always mentioned in the literature, still have a role as a viable alternative in some instances. The role will be more prominent if new technology can be embraced to make non-motorised modes more competitive with the motor car. Although there may not be widespread change, Hopkinson and Wardman (1996) have shown that there is a suppressed demand for cycling and that cycling has untapped potential. Whilst many do not see much of a role for non-motorised modes, it can be argued that in some urban areas of the United Kingdom cycling and walking could impact upon traffic levels. If such a shift could occur anywhere in the United Kingdom then Edinburgh would be a prime target, as shown in Section 1.4, with favourable land use patterns and sustainable transport policies.

3.6 Non-motorised mode research

Section 3.6 examines the prominent issues relating to non-motorised mode research, aside from non-motorised mode modelling (considered separately in Section 3.7).

Research into non-motorised modes has increased over the last twenty years or so, to be considered a research topic in its own right (Hass-Klau, 1990; McClintock, 1992; Tolley, 1997). It is typical of non-motorised mode research to have more of a focus on cycling than walking. The type of academic research undertaken on non-motorised modes can be illustrated from the content of the latest Transportation Research Record dedicated to non-motorised modes (Number 1828, published in 2003). Many of the articles are not relevant to this study, based on level of service of facility provision, the safety of pedestrians (particularly the vulnerable i.e. children, elderly), pedestrian flow models and engineering measures. Within the Transportation Research Record Number 1828 there are two articles of particular relevance to this study: bicycle commuting and facilities in major United States cities (Dill and Carr, 2003) and a stated preference bicycle route choice survey (Stinson and Bhat, 2003). Both articles are referred to in more depth elsewhere in this thesis.

3.6.1 Types of individuals who cycle and walk

This Section considers the types of individuals who cycle and walk, before an examination of the non-motorised mode market segmentation studies (Section 3.6.2). Since this study concerns those within the population who might be encouraged to use non-motorised modes, a starting point is the section of the population who currently use non-motorised modes.

Forrester (1994) considers that there are two different guiding principles amongst engineers regarding the design of facilities for cyclists. Firstly there was the "vehicular-cycling principle" whereby cyclists travel on the road network. They act and are treated as drivers of vehicles. Secondly there was the "cyclist-inferiority superstition" whereby roads are too dangerous for cyclists. They cannot operate safely as drivers of vehicles, and therefore special, safer facilities must be made for cyclists. This difference applies to cyclists as well as the engineers that design facilities. Some cyclists prefer to stay in traffic whilst others prefer to avoid the traffic. In the West Edinburgh survey, the difference was tested. Respondents were asked whether cyclist facilities should be on-road or off-road. It is difficult to categorise or segment cyclists according to other characteristics, since it has become increasingly apparent that cyclists do not form a homogeneous group (Harrison, 2001).

Surveys have shown that most individuals would never consider cycling whatever the circumstances. In one example, a household survey in Santiago, Ortuzar et al (2000) stated that of all trips considered by respondents, 87% of them were not considered to be suitable for cycling. Individuals considering cycling therefore constitute a small proportion of the population, perceived as a specific market niche or segment.

Whilst only a small proportion of the population regularly cycles, almost everyone walks. In one survey, of car drivers in Scotland, 85% of individuals walked (for at least ten minutes) at least once a fortnight (Stradling, 2002). Walking is something that most people like to do, at least on occasion (Handy, 1996b). It is the most universal and widespread mode, yet does not have the tradition in policy, surveys or models.

A person's travel patterns are affected at different ages and stages of life. Travel behaviour changes in response to key life decision points, such as change of home and employment relocation. At these times, a journey origin or destination changes, influencing modal choice and travel behaviour. Life stage has been shown to be an important factor in cycling in Section 2.3 (Davies et al, 1997). The presence of children upon a household greatly affects travel behaviour. Households with young children tend to be less mobile than households without young children. In terms of targeting segments, individuals aged 16 or 17 would be a valuable target, as identified by Lawson and Morris (1999), prior to the life stage decision point of applying for a driving licence.

3.6.2 Market segmentation of non-motorised mode users

Many studies concentrate on the promotion of non-motorised modes for exercise, health and obesity reasons (Pearce, 1999; Higgins and Higgins, 2003). One example examining cycling and health, Pearce (1999), shows that the least healthy group are males aged between 17 and 29 in the lower socio-economic groups. By segmenting the sample in this manner, this group can be targeted in a campaign to promote cycling for health reasons. Cyclists' Touring Club (1993) also discusses the cost-benefit links between cycling and health. Increasing the levels of cycling could reduce the incidence of coronary heart disease, by impacting the contributing health risk factors of a sedentary lifestyle, poor fitness levels, obesity and poor mental health. Exercise, health and obesity have become recent inter-related United Kingdom transport policy issues, outlined in Section 4.2.

As established in Section 3.3, market segmentation is a technique that has been applied to a variety of motor car characteristics; these techniques have also been applied to studies of non-motorised mode users. In terms of using market segmentation techniques to determine the type of people who use non-motorised modes, Titheridge, Hall and Hall (1999) identify five segments with high levels of walking and cycling. They are individuals living in high residential density (local employment opportunities), households with an absence of car ownership, certain social classes (semi-skilled, unskilled, skilled non-manual for just walking), areas with a high percentage of recent immigrants and individuals in part-time employment (because more likely to be local). Lawson and Morris (1999) segment their sample according to utility and leisure cyclists, showing that leisure cyclists are over-represented in higher social groups, whilst utility cyclists are more evenly distributed across the various social groups. Higgit (1999) shows that the amount of walking an individual undertakes depends on their age, level of fitness and social background.

Rethati and Rekai (2001) use cluster analysis to produce five cyclist type groups from 16 attitudinal statements recorded in a survey. The cyclist type groups are everyday cyclist, bicycle rejection, bicycle fear (have safety concerns about cycling), hobby cyclist and motorists. In order to have an improved overall cycling rate, they recommend that utility trip measures be aimed particularly at the motorist group, and to a lesser extent everyday cyclists and hobby cyclists. Furthermore, they suggest that leisure trip measures be aimed at all except the bicycle fear group.

Lawson and Morris (1999) categorise 1,000 motorists according to their likelihood to cycle. Firstly, motorists were split into those that can (92.5%) and those that cannot (7.5%) cycle. Secondly, those that can cycle are split into those that do and don't cycle at the time of the survey. Finally, these two groups are further split into those who cycle into 'leisure' or 'non-leisure' cyclists, and those who don't cycle into 'may start again' or 'unlikely to cycle again'. Another study from the Automobile Association (Automobile Association, 1993) includes cycling decision-making models. Initially, the individual has a reason and buys a bike. Then they assess the trip and, so long as they do not reject cycling, form a habit.

Qualitative research from the Transport Research Laboratory develops a conceptual framework of contemplation and motivation to change as part of a change in travel behaviour from the car to the bicycle (Davies et al, 1997). Four categories are developed according to current cycle use: those who cycle already, those who wouldn't take much persuasion to change, those who would take a lot of persuasion, and those who would always use a motor car. Of the current cyclists, five types are produced:

- Practical cyclists - young, fit, male commuters, most efficient way to get to work.
- Ideal cyclists - eccentric, anti-car, environmentalists.
- Fairweather - short, undemanding, off-road, female.
- Lifestyle - weekends, car accessory, off-road, couples.
- Mainstay - little choice compared with the car e.g. children, students, others limited access.

Of these cyclist types, the first four are considered to be newly emerging and infrequent cyclists. The fairweather and lifestyle cyclists tend to cycle off-road and are more car-orientated. Davies et al (2001) extend the work to be more rigorous, using a quantitative rather than qualitative approach. Cluster analysis is performed (using the mean square distance to the nearest neighbour algorithm) on a survey sample of 300 individuals. Variables include bicycle ownership, bicycle usage, socio-economic data and attitudes towards cycling. The nine cyclist categories produced are shown in Table 3.2.

Table 3.2. Sub-population clusters developed from a quantitative study of individual attitudes towards cycling

Cluster - Level of cycling	Characteristics (Estimate of proportion of adult national population)
1. "Committed cyclists" - Almost always cycle	Cycle on average four days a week; limited opportunities to increase cycling, but need to maintain current use (7%)
2. "Regular cyclists" - Cycle quite often	Largely male, cycle less frequently than cluster one but would share the same views (8%)
3. "Occasional cyclists" - Rarely cycle or cycle sometimes	Most own bicycles but the median level of cycling would be only once in about three weeks (15%)
4. "Toe-dippers" - Rarely cycle or cycle sometimes	Most own bicycles but the median level of cycling would be less than once in about three weeks (5%)
5. "The unconvinced" - Not consider cycling	Two-thirds female, very few own a bicycle that works and think there are too many obstacles preventing them from cycling (27%)
6. "The unthinking" - Not consider cycling	Seem fairly positive towards cycling but non-commital towards cycling (18%)
7. "No-needers" - Not consider cycling	Three-quarters female, two-thirds over 44 years old; no-one owns a bicycle or cycles at all (12%)
8. "The self-conscious" - Not consider cycling	Almost wholly female, half are under 26 years old; would feel self-conscious cycling and too many obstacles preventing them from cycling (6%)
9. "Youngish lads" - Not consider cycling	Predominantly male, half are under 26 years old; no-one owns a bicycle or cycles at all because they do not need to (3%)

From: Davies et al (2001) Table 13. Contemplation of change and description in Section 5.2 Sub-population profiles

Davies et al (2001) link contemplation of change towards cycling to national statistics. It appears that approximately 15% of the population would cycle at least occasionally and 66% of the population would not consider cycling.

3.6.3 Factors affecting non-motorised modes

As has been shown from the background to this study (Section 1.2), non-motorised modes have advantages of being convenient, cheap, environmentally-friendly, healthy and socially inclusive. The main disadvantage of non-motorised modes is that they are much slower than other modes. The cost, in that most people can afford to own and run a motor car, and convenience of the motor car makes it the dominant transport mode.

Factors affecting non-motorised modes directly affect the propensity an individual will have to use non-motorised modes. As with most non-motorised mode research, more emphasis has been put on cycling than walking. There are very few studies that examine the factors affecting walking levels, although personal safety is considered to be an important factor. Pikora et al (2003) show that the main factors affecting walking, at a neighbourhood level, are personal safety, the attractiveness of the streetscape and the nature of the journey destinations. Many attitudinal studies in this Section highlight the factors affecting cycling. It should be noted that there is a distinct different between reasons why current cyclists travel by bicycle and the barriers preventing non-cyclists travelling by bicycle. Due to the fact that the majority of the population does not cycle, studies primarily refer to factors preventing non-cyclists travelling by bicycle.

In terms of cycling, safety, stemming from a fear of traffic, is widely acknowledged as a major reason why many people do not cycle (Hopkinson and Wardman, 1996; Cyclists' Touring Club et al, 1997; Davies et al, 2001; Costley, 2002; Pikora et al, 2003). Porter et al (1999) summarise from previous research, providing a conceptual model of the factors affecting non-motorised modes. The general factors are split into route characteristics (at both a link and network level), supporting policies, population characteristics, weather, characteristics of other modes and land use. Ortuzar et al (2000), reviewing other literature, show factors that affected bicycle use are distance (length of trip, travel time), hilliness and safety (safe places to ride, lack of secure cycle parking, fear of crime). Another aspect, the cultural tradition of a locality, has been shown to affect bicycle use (Rietveld and Daniel, 2004).

Ortuzar et al (2000) then use focus groups and an expert panel to identify the factors affecting cycle use, with the aid of an expert psychologist. Most factors coincided with what had been found elsewhere. The only new factor to come out of the qualitative research is that for many people in Santiago, particularly of higher income levels, using a bicycle is perceived as an "embarrassing situation" (only gardeners or blue collar workers would use it). In Edinburgh there may be some local factors acting as a barrier to cycling, such as the weather and topography, which are not prevalent in other locations.

The effect of the weather upon cycling is investigated by Bergström and Magnusson (2003), from a survey in two Swedish cities. They examine the potential of transferring motor car trips to bicycle journeys during the Winter. Sweden has similar cycling levels to the United Kingdom, although the seasonal differences would be less extreme in the United Kingdom. In Gothenburg, cycling levels can be down to half those of the Summer months. The survey by Bergström and Magnusson (2003) establishes that temperature, precipitation and road condition are the most important factors to Summer-only cyclists. It was easier to convince men and the young to cycle in the Winter. Of those that did travel by bicycle in the Winter, exercise is the most important reason to cycle.

The Automobile Association (1993) shows from a motorist survey the practical considerations why some individuals do not cycle. Practical reasons for not cycling are shown to be trip chaining and carrying luggage. These are trip-specific rather than person-specific factors, an important distinction for this study. An obvious link is also stated: motorists most likely to cycle are those owning a bike, as well as those seeing a need to get fit.

Porter et al (1999) recommend that further research is needed into three types of factor influencing bicycle and pedestrian travel behaviour, with an emphasis on identifying key factors that can be included in forecasting models. Firstly, facility design factors, such as specific non-motorised mode facilities and difficult junctions. Secondly, factors relating to the environment of the non-motorised mode user, as illustrated by an example of the attractiveness of a local area. Thirdly, other environmental and policy variables, such as bicycle parking and showers, are presented. It is hoped that this study can help with understanding some of these factors that affect non-motorised mode usage. Of the factors identified that affect non-motorised mode use, many of them such as the weather and topography, cannot be changed. However, there are some policy-sensitive factors that can be implemented as initiatives to encourage non-motorised modes. These are considered in Chapter 4.

3.6.4 Cost benefit analysis of non-motorised modes

Non-motorised modes tend to be promoted on environmental rather than economic grounds. However, several studies have quantified the costs and benefits of non-motorised modes. The Cyclists' Touring Club (1993) estimate the general costs and benefits of cycling, concluding that a significant shift to cycling could reduce the costs of motorised transport by £1.3 billion to £4.6 billion per year, sufficient to justify a huge expansion in provision for cycling. Sælensminde (2003) incorporate the non-motorised mode benefits of reduced insecurity (from personal and traffic safety) and health (from improved fitness) into cost–benefit analyses of walking and cycling track networks in three Norwegian cities. The benefits of investments in such networks were estimated to be at least four or five times the costs.

A more detailed study, Litman (2001), estimates that shifting travel from automobile to walking and cycling would provide economic benefits (not including health and enjoyment to users) worth between $1.05 and $3.58 per trip. A shift from driving to non-motorised travel for a typical 2-2.5 mile (4km) trip, under three road conditions of urban peak, urban off-peak and rural trips, is considered. There are nine benefits (quantified in cents) per non-motorised mode trip for each of the three road conditions. These benefits are congestion reduction; roadway cost savings; parking cost savings; user savings; air pollution; noise; road safety; regional economic development; and additional environmental and social benefits. This study concerns individual response to price changes in the mode choice decision. Of the variables within the cost benefit analysis, parking cost savings are the quantifiable benefit of most relevance for inclusion in the stated preference part of the West Edinburgh survey questionnaire, and represent a variable in the propensity to walk experiment.

3.6.5 Implications of the non-motorised mode research for this study

Most people walk to some extent but there has been no evidence in the literature of the segmentation of pedestrians. Conversely, few people cycle but segmentation studies have categorised the population into a number of propensity to cycle groups. This study will develop upon such studies, segmenting those with the greatest propensity to walk and cycle.

Sophisticated statistical techniques are not frequently used in this field of study, due in part to low levels of non-motorised mode use. Studies are typically attitudinal. Davies et al (1997) assert that most research is descriptive rather than analytical. A follow-up study by Davies et al (2001) provides a useful starting point for this study, since they produced some interesting clusters based on background socio-economic and transport availability variables, as well as cycle use and attitudes towards cycling. The stated preference experiments in this study takes the research further for both propensity to cycle and propensity to walk, including how mode choice is affected by a change in circumstances. In a similar vein to Davies et al (2001) factoring their results up for the United Kingdom, this study factors up the West Edinburgh survey results for the Edinburgh area, using the Scottish Household Survey data.

It has been stated in this section that safety fears from traffic are acknowledged as the main barrier to cycling, but other factors such as journey time, cycling facilities, the weather and topography influence cycling levels. All of these factors are considered as part of the attitudinal statements designed within the West Edinburgh survey questionnaire. Some walking attitudinal statements are also included. The implications of these attitudinal responses for policy measures will also be considered.

3.7 Modelling of non-motorised modes

A background to model development has been provided in Section 2.5. This Section concentrates on the modelling of non-motorised modes within the literature.

As interest in non-motorised modes has increased within transport research, so have attempts to incorporate them into existing models. Review papers have called for more work to be undertaken to progress model development in this respect (Katz, 1995; Eash, 1999; Porter et al, 1999). This is particularly the case for urban and regional transport models, typically the four stage transport models (outlined in Section 2.5). In the mid 1990s a framework to provide detailed information on the type of variables to consider in a model was proposed (Sharples, 1995a) and applied to Wilmslow Road in Manchester (Sharples, 1995b). An increase in computing speed has enabled the development of fine zoning systems required to model of non-motorised modes, due to the short distances that individuals walk and cycle.

In the United States there was a policy change in the 1990s towards a greater encouragement of non-motorised modes (documented in Section 4.4). Much effort has been undertaken to incorporate non-motorised modes into existing United States regional and city transportation models (Turner et al, 1997; Eash, 1999; Rossi, 2000). The various non-motorised models reviewed by Turner et al (1997) tend to be too simplified (using basic assumptions), do not include a mode choice element and do not include non-motorised mode assignment to a bicycle or pedestrian network. The difficulty of incorporating walking and cycling into travel forecasting models can be summarised as follows (Eash, 1999):

1. Different scales of non-motorised mode and motor vehicle trips. Traffic analysis zones and coded networks are typically too coarse, with most non-motorised mode trips made within a defined traffic zone.
2. Motor vehicle models are also based on certain theories of travel behaviour that seem inappropriate for non-motorised travel. Motor vehicle models tend to measure weighted travel time and cost; non-motorised modes tend to be more concerned with the safety or attractiveness of routes.

The design of the West Edinburgh survey reflects these difficulties. Firstly, in terms of scale, the focus is primarily on non-motorised modes at a small-scale neighbourhood level. Analysis zones are postcode sectors. Secondly, in terms of modelling variables for non-motorised modes, the factors affecting cycling and walking (examined in Section 3.6) are collected as part of the West Edinburgh survey (e.g. journey time, cyclist facilities on route).

Porter et al (1999) outline the four forecasting methods of non-motorised travel to be aggregate level methods, attitudinal methods, discrete choice models and regional travel (four stage) models. Of interest to this study are the two modelling techniques rather than the more simplified, crude methods. Discrete choice models provide a sophisticated analysis of the various factors that influence non-motorised modes and the trade-offs individuals make between factors. Regional travel models include a spatial dimension, but are often on a city-wide scale, too large to incorporate non-motorised modes. The focus of this thesis is on the development of disaggregate discrete choice models incorporating non-motorised modes rather than the larger scale four-stage transportation planning models. Disaggregate models are often used as inputs into such larger-scale models.

Disaggregate discrete choice models of non-motorised modes can be divided in two types. Firstly, there are route and destination choice models, outlined in Section 3.7.1. Secondly, there are mode choice models, similar to the type used in this study and examined in Section 3.7.2. Walking tends not to be considered in disaggregate discrete choice models, and those for cycling tend to be route choice rather than mode choice models. Modelling implications for this study, from these models, are presented in Section 3.7.3.

3.7.1 Route and destination choice models

Several studies have estimated the demand for cyclist route choice using stated preference based disaggregate logit models. One of the first European examples using stated preference techniques examined cyclist's route choice to work in Delft (Bradley and Bovy, 1984; Bovy and Bradley, 1985). A sample of 134 of those that cycled to work at least twice a week to Delft University was collected. Of the four variables within the Delft stated preference experiment, two known important attributes (total travel time and traffic level) are mixed with two new attributes (type of facility and quality cycling surface). Of these variables, travel time is the most influential. Surface quality is also influential, whilst traffic level and facility type have a minor influence. It is a useful initial study with credible findings, albeit with a small sample. The authors conclude that "a larger and more varied sample would be valuable in segmentation analysis to gain more insight into difference in cycling behaviour" (Bradley and Bovy, 1984, p52). This illustrates the need in this study of a large sample to facilitate segmentation.

Hopkinson and Wardman (1996) use a stated preference survey to evaluate the demand for new cycling facilities in Bradford, West Yorkshire. The values of different attributes for four alternative cycle routes are estimated using both revealed and stated preference models. The factors examined relating to cycling journeys are journey time and a number of cycle route facilities (wider nearside road lane, segregated cycle paths, bus lanes permitting cyclists, cycleway). A stated preference experiment was given to 155 cyclists relating to time, cost and cycling facilities. Results show that safety is valued more highly than time and that some new cycle schemes can be economically justified on the basis of benefits to current cyclists, even in circumstances of relatively low cycle use. Of the routes, segregated cycle paths and purpose built cycleways are the most favoured amongst respondents.

An innovative stated preference survey for cyclists in Calgary is presented in Abraham et al (2002). The survey is an input into a larger area-wide transportation planning model. To investigate cycling sensitivities, a stated preference survey was conducted on 547 cyclists. The scenarios proposed to respondents are that they had moved to a new home and job within the city. The three journey to work options include the variables of cycling time (split by off-road and on-road cycling time), parking facilities at the destination (type and cost) and other facilities available at the destination (changing room with lockers and cost). The results show that cyclists are attracted to shorter journeys, but are also willing to travel substantially further to ride on specific types of routes and/or to destinations with specific destination facilities. Cyclists, perhaps understandably, preferred off-road and quieter roads.

Stinson and Bhat (2003) analyse cyclist commuter route choice for the journey to work. A large sample of 3,145 individuals was achieved using an internet survey of United States bicycle enthusiasts, although such a method produces self-selection bias. A key aspect of the Stinson and Bhat (2003) survey was the inclusion of link (roadway class, parallel parking permitted, cycle lane facility, bridge type, hilliness, riding surface) and route characteristics (travel time, facility continuity, number of stop signs, number of red lights, number of major cross streets) within the experiments. Of the variables, travel time is the most influential although the cycle facility variables (including the new variables of cycle facility continuity and cycle facility availability on bridges) also affect route choice. Adapting the model to include the interaction effects of the cyclist characteristics, the commuter's age and residential location (but not income) were shown to affect the perceived utility associated with some variables.

The studies described in Section 3.7.1 have shown time and safety to be the greatest determinants upon a cyclist's route choice. They show the preference of cyclists for off-road and quieter routes. There is scope for extending the research of cyclist route choice to incorporate more detailed analysis of facility measures, socio-economic aspects and other variables such as topography and weather. This study is broader than cyclist surveys, sampling households to determinate the propensity to use non-motorised modes of respondents.

3.7.2 Mode choice models

This section concentrates specifically on mode choice modelling studies that successfully incorporate non-motorised modes. As stated previously, mode choice is an important aspect in transport research, with models traditionally concerning trade-offs between the motor car and public transport. Several studies now incorporate cycling as a mode choice available, although the difficulty remains that cycling journeys constitute a small proportion of the trips individuals make.

Noland and Kunreuther (1995) develop a revealed preference based model on choices between car, bus, bicycle and walking in Philadelphia, assessing the difference of short-term, pro-cycling measures against a background of long-term change in car use. Their sample includes 640 cyclists and 175 randomly selected individuals from the population. Cyclists rated risk on a scale from one to seven. Many of the overall sample consider bicycle commuting to be "too dangerous" (50%); over 60% of the sample state that there was "too much car traffic" for cycling. There are some interesting results. The propensity to cycle is affected by the perceived level of risk of roads with no shoulders and the availability of cycle parking. However, the models developed lack robustness in that the variable relating to safety is not significant, showing the difficulty of incorporating safety into mode choice modelling. It confirms that the choice to cycle typically depends on more than the time and cost that determine motor car and bus mode choices.

Although a route choice model application, Hopkinson and Wardman (1996) discuss the difficulty in developing robust mode choice models that include cycling, due to the large number of variables to account for. Although they state a need for more cyclist route choice modelling, there is a greater need for mode choice models that incorporate non-motorised modes, because this choice set contributes more to the alleviation of current transport problems. The choice between whether to cycle or take another mode of transport relates to encouraging individuals to use the motor car less, as opposed to the choice cyclists make between routes, which are only appropriate to a minority of the population.

Wardman et al (1997) develop a mode choice model producing benefit values of segregated and unsegregated cycle lanes. A stated preference experiment for the commute trip propensity to cycle was relevant and conducted by just under half of the households contacted (221 out of 461); of the remainder the most popular reasons are for not completing the stated preference game are retirement, a lack of interest or their commute journey was not appropriate for the experiment. Of the overall households contacted, 3% cycled to work and were discounted from the experiment. Those completing the stated preference experiment are evenly split between car (114) and bus (107) users. The experiment has six attributes (each of three levels) of car versus bus time, car versus bus cost, cycle time, cycle facilities on route, weather and cycle facilities at end destination. Values of time for each mode and facility type are presented. Forecasting, using the sample enumeration technique, is attempted. The forecasts generated are unrealistic, a 24% cycling share amongst current motor car users and a 25% cycling share amongst current bus users. In conclusion, they recommend joint revealed-stated preference models to be developed and to expand the modelling for leisure as well as commuting trips.

The work reported in Wardman et al (1997) has been extended in an ESRC mode choice study 'Cycling and mode choice' (Wardman et al, 2000a; more information on the modelling is in Wardman et al, 2000b). One objective of the study is to understand the interactions between car, bus, cycle and walking in an urban context. The study combines an existing revealed preference national data set, the National Travel Survey, with a stated preference survey of propensity to cycle (1,966 individuals). Another objective is to forecast the effect of a range of improvements to cyclist facilities on mode choice. The joint revealed-stated preference study examines both mode (car, passenger, bus, train, walking and cycling) and route choice (current route, new cycleway). Akin to the previous study, the revealed preference survey screens those who would consider cycling to work. The mode choice model involves the development of a hierarchical logit model to simultaneously estimate parameters to the two forms of revealed preference and stated preference data in a single model. Most of the key findings in Wardman et al (2000a) relate to value of time (also shown in Section 3.7.3), for the cyclist facilities tested. There are broadly 50% of the population that would "never" cycle. The probability of considering cycling for the journey to work in the study is greater for males, in flatter areas and was less for those who travelled by bus or car than those who walked to work.

Logit model forecasts were generated by Wardman et al (2000a) for a range of scenarios (effect of cycle lanes, daily payment and facilities at the workplace), with a base market share of 4.5% cycling to work. The maximum market shares cycling to work from the scenarios are 7.3% for cycle lanes (completely segregated cycleway), 19.3% for daily payments to cycle (£5 per day) and 6.3% for the facilities at the workplace (showers and indoor parking).

Wardman et al (2000a) highlight eight future research needs relating to cycling and mode choice. These are the need to look at actual cycle facility improvements; to examine hilliness; to examine the Census as an alternative to the National Travel Survey; to extend commuting to other journey purposes; to examine specific cycling improvements (such as Advanced Stop Lines, Toucan crossings); to use revealed preference for existing cycle facilities; to examine health implications; and to quantitatively model the benefits of improved facilities for pedestrians. The attitudinal variables within the West Edinburgh survey concerned hilliness and the nature of cyclist facilities. The propensity to cycle stated preference experiment considers similar variables to the Wardman et al (2000a) study; the propensity to walk experiment represents more of an innovative aspect.

Ortuzar et al (2000) is the first city-wide disaggregate modelling study on the demand for cycling, estimating demand for a cycle network in Santiago. They consider a dense network of cycle-ways, fully segregated from motorised traffic and adequate bicycle shelter facilities at Metro, suburban train and selected segregated bus-way stations. A sample of 851 households were interviewed, including a stated preference experiment in which respondents stated either "yes they would consider using bike" or "no they would not even consider it" for a series of journeys; these choices were modelling as a binary logit function. The stated preference attributes (all with two attribute levels) are weather, type of cycle path, travel time by bike, travel time on current mode, bike shelter charge, public transport fare and car costs. A stated preference mode choice model was run for the modes of car, Metro, bus or shared-taxi, Park & Ride, feeder bus, bicycle and bike-Metro. There are three important findings from the study:

- There were sectors of the city where bicycles could be used for more than 10% of trips;
- On average bicycle use could rise from 1.6% to 5.8%; and
- Trip length was a fundamental variable, and therefore the development of urban sub-centres could be significant for cycling.

Model estimation shows that the respondents most willing to cycle are the young, with low income, without a car in the household and with a low educational level. Another interesting outcome of the research is that even with a cycle-way network in the city, an improved public transport network and increased congestion, for 87% of trips under consideration respondents in the study "did not consider" cycling as a valid option.

The study by Sanches and Arruda (2002) incorporates non-motorised transport into a mode choice model, using travel diaries from 130 staff and students at the Federal University of São Carlos. Cycling journeys were excluded from the modelling because of too few trips. However, they did illustrate that walking was primarily affected by length of trip (shorter), age (younger), presence of children (fewer), whilst car use was primarily affected by car availability. Rodríguez and Joo (2004) have also modelled non-motorised mode choices for university commuters, focusing on the local physical environment affecting the non-motorised mode choice. Local topography and sidewalk availability are shown to be significantly associated with the attractiveness of non-motorised modes.

Therefore, only a handful of studies have tried to estimate the demand for cycling using discrete choice models; several small-scale studies have also included the demand for walking. This study aims to produce similar models for Edinburgh, incorporating walking as well as cycling journeys.

3.7.3 Implications for the modelling in this study

It has been shown from the literature that the modelling of non-motorised modes tends to concern large-scale transportation models or smaller scale cycling stated preference surveys. Due to the scale of this study, the latter has been chosen as the modelling methodology, including walking as well as cycling within stated preference experiments. New non-motorised mode variables have been incorporated, providing knowledge on travel behavioural change and improvement in long-term travel models.

For the propensity to cycle, the journey to work is considered, the most appropriate trip for cycling. There are cost and time variables in the modelling, together with two facility-based variables concerning the route to work (can link to route choice model results) and the facilities at work. A simpler experiment for the propensity to walk is also included, representing an original aspect of the thesis. The development and design of these two experiments is provided in Chapter 6.

A large sample is required, so that after filtering out those for whom the stated preference experiment is not relevant, a sufficient number of respondents remain for the modelling. It is hoped the sample in the West Edinburgh survey is of a sufficient size to enable robust model forecasting, akin to the Wardman (2000a) example shown in Section 3.7.2.

3.8 Summary

As a starting point for the literature review (Section 3.2) the relationship between urban form and travel behaviour has been explored. There has been much debate on the effect of the motor car upon urban form, the rate of urban sprawl and suburbanisation, the impacts of residential density, the sustainability categorisation of cities and possible urban design solutions. Although the focus in urban areas tends to be on the motor car and public transport, a greater role for non-motorised modes has been argued. Edinburgh is a high density, compact city, at the more sustainable end of all United Kingdom cities and has demonstrable potential to encourage more individuals to use non-motorised modes.

The literature has shown that the United Kingdom population is dependent on the motor car (arguably completely encased in a car culture) making a change in travel behaviour difficult (Section 3.3). Therefore, it is important to identify those individuals and segments of the population that are the least car dependent. Socio-economic factors affecting motor car ownership and use have been determined in the literature; individuals with the greatest propensity to own and use a motor car include those of working age, those who are male, those on higher incomes and those who have children.

Section 3.4 concerns individual responses to the problems associated with the motor car. Most motorists acknowledge the two main problems of air pollution and congestion but are unwilling to change their personal travel behaviour. Very few people act altruistically, although many are constrained by having no alternative to the motor car for certain trips. It has been shown that motorists can be segmented into smaller sub-groups according to their attitudes towards the problems, and that there is a minority willing to change mode away from the motor car. Such segments could be targeted with sustainable transport measures, in this case non-motorised mode initiatives.

Many viable alternatives to the motor car have been postulated, as shown in Section 3.5, often on a larger scale than the impact of non-motorised modes and using new technology. Non-motorised modes, although not always stated, are considered by some to have potential. Whilst many do not see much of a role for non-motorised modes, it can be argued that in some urban areas of the United Kingdom cycling and walking could impact upon traffic levels. If such a shift could occur anywhere in the United Kingdom then Edinburgh, a city with favourable land use patterns and sustainable transport policy, would be a prime candidate.

It has been shown that segmentation studies have focused on cycling, a minority activity, whilst few have concerned walking, even though most people walk (Section 3.6). Such studies have increased understanding of the types of individuals that could be policy measure targets to encourage cycling. Much attitudinal literature has examined the factors affecting non-motorised modes. Of these factors, safety is the primary concern amongst individuals, whether as personal safety for pedestrians or traffic safety for cyclists.

The methodological study approach, outlined in Chapter 2, concerns the application of tried and tested discrete choice modelling to non-motorised mode choices. A review of the literature on non-motorised mode modelling (Section 3.7) has shown that only a handful of studies attempt to estimate non-motorised mode demand. This represents a research gap; models in this study will examine the trade-offs for both cycling and walking journeys.

3.8.1 Methodological implications of the literature review

The debate on urban form and travel behaviour (Section 3.2) has influenced the selection of two variables to be collected as part of the West Edinburgh survey. The variables are housing type as a surrogate for density, and distance from the city centre. The socio-economic factors of age, gender, income and children present in the household, shown to affect motor car ownership and use (Section 3.3), are also collected. Many of the studies examining individual responses have been attitudinal (Section 3.4), lacking in-depth statistical or model-based analysis. Several studies, such as Cullinane (1992), included non-motorised mode measures amongst other transport policy measures given to survey respondents who travel by motor car (Section 3.5). This type of question has been replicated in the survey and given to motorist respondents.

The non-motorised modes research (summarised in Section 3.6) provides insight into suitable variables for collection. It is the aim to develop upon the segmentation studies reviewed in this Section, to provide some information on factors affecting non-motorised mode choice using attitudinal statements, and to provide cost-benefit values from the stated preference modelling. The review of non-motorised modelling (Section 3.7) has provided insights into the design of the stated preference experiments. The propensity to cycle experiment concerns the journey to work, developing upon the study by Wardman et al (2000a) and the propensity to walk represents a relatively new experimental field. Collecting data on non-motorised modes, particularly for walking, makes this research an important contribution to current understanding.

3.8.2 Relating the literature review findings to the research objectives

Market segmentation and discrete choice model examples for the propensity to use non-motorised modes have been provided in this Chapter. This study incorporates both techniques to achieve the first research objective, "to identify segments of the population with the greatest propensity to use non-motorised modes". Relevant non-motorised mode research tends to concern cycling; this study will also add to knowledge the identification of population segments with the greatest propensity to walk. Furthermore, this study adds to the most advanced non-motorised mode literature on cluster analysis (Davies et al, 2001) and mode choice modelling (Wardman et al, 2000a; Ortuzar et al, 2000). By examining local population segments at a neighbourhood level this study is more disaggregate than many other studies on the interactions between the modes of motor car, cycling and walking, and thus the propensity to use non-motorised modes.

The second research objective, "modelling individual travel behaviour and thus the propensity to use non-motorised modes", is achieved through discrete choice model development, using stated preference data. Discrete choice models tend to concern either cyclist route choice or a mode choice that includes cycling. This study aims to develop mode choice models of the propensity to use non-motorised modes in more depth than examples in the literature. It is hoped to produce some new non-motorised mode outputs, to predict travel demand and to test policy measures. To enable the policy implications to be put into context, a review of transport policy is provided in Chapter Four.

4. TRANSPORT POLICY

4.1 Introduction

Chapter Four presents the transport policy response to problems associated with the motor car and the type of policy measures that can be introduced to encourage non-motorised modes. The transport policy change at a national United Kingdom level in the late 1990s was the starting point to this study, because it represented an increased focus on non-motorised modes. This is considered in Section 4.2. Transport policy at a local City of Edinburgh Council level is particularly relevant, since Edinburgh is the case study. This is considered in Section 4.3. Transport policy at other levels, in a European and Scottish context, is examined in Section 4.4. Finally, Section 4.5 outlines the development of policy initiatives tested in the West Edinburgh survey.

4.2 The United Kingdom transport policy context

This section presents a background to United Kingdom transport policy, and then focuses on measures to increase non-motorised modes. Associated land use and sustainable development policy are also outlined.

4.2.1 A background to United Kingdom transport policy

In the second half of the 20th Century motor car ownership and use increased rapidly in the United Kingdom, to current levels shown in Section 1.3. In the 1960s there was a realisation, as documented in the influential "Traffic in towns" Buchanan report (Ministry of Transport, 1963), that unlimited use of the motor car could not reasonably be sustained, particularly in urban areas. However, the policy to provide road building and associated infrastructure to accommodate the motor car continued between the 1960s and 1990s. Over the last ten years or so, the policy focus has changed from traditional "predict and provide" road building as solutions to the problems of increasing traffic, to more efficient "travel demand management" of the United Kingdom transport system, as defined and outlined in Section 2.2. Instead of building new roads, the Government's new approach was to maintain existing roads and manage the road network more efficiently to improve reliability. This new approach to the problems posed by the strategic trunk network has since encouraged multi-modal studies (Department of the Environment, Transport and the Regions, 2000c), whereby all modes of transport, including non-motorised modes are considered.

The policy change towards travel demand management has been the starting point to this study, coinciding with the Integrated Transport White Paper in 1998. The Integrated Transport White Paper "Transport: A new deal" (Department of the Environment, Transport and the Regions, 1998), represented a change in Government transport policy, heralding the so-called "Integrated Transport Strategy". It represented an increase in transport policy emphasis towards non-motorised modes. An underlying theme of the White Paper is to reduce the need for travel for individuals, achieved by encouraging a modal shift to sustainable transport modes such as public transport and non-motorised modes, and reducing car dependency, the phenomenon reviewed in Section 3.3. Policy goals include providing choice between the different transport modes, ensuring efficient integration between the different modes of transport and setting targets for sustainable policies. Choice is an important concept in this study, one of the policy goals of the Integrated Transport White Paper. People have a freedom of choice between the modes within imposed constraints such as finance and vehicle availability. The emphasis on choice within the Integrated Transport White Paper makes discrete choice modelling an appropriate methodology for analysing the trade-offs between the motor car and non-motorised modes.

Since the Integrated Transport White Paper, a Ten Year Plan was produced in the year 2000 (Department of the Environment, Transport and the Regions, 2000b) focusing on transport delivery. It was concerned more with investment in roads and railways than with non-motorised modes. It represents a policy shift back towards the motor car and road building, and away from the environmental concerns, although both aspects were evident in the transport policy. An updated White Paper was published in July 2004 (Department for Transport, 2004b), setting out the future transport policy agenda. Non-motorised modes continue to be promoted, "providing a positive choice" for individuals (Department for Transport, 2004b).

Rising fuel prices have had an impact upon transport policy in recent years, as documented by Swift (2001), Ison et al (2002) and Lyons and Chatterjee (2002). The

United Kingdom Government were committed to a 'fuel tax escalator', inaugurated in 1994, whereby fuel taxes were raised by a percentage (initially 5%, latterly 6%) above the rate of inflation in each annual Budget. The level of fuel prices became increasingly controversial, culminating in the United Kingdom mass popular fuel protests of September 2000. The 'fuel tax escalator' was withdrawn by the Government in the 2000 Budget, although petrol prices in the United Kingdom are substantially higher than in Continental Europe.

Two strands of transport policy have arisen on the policy agenda of particular interest to this study, namely social inclusion and concerns over obesity, because of their links to non-motorised modes.

There has been a growing recognition that transport can be a significant barrier to social inclusion. A United Kingdom Government body, the Social Exclusion Unit, was established in 2001 to explore, and make recommendations to overcome, the problems experienced by people facing social exclusion in reaching work and key services. Social Exclusion Unit (2003) examines the links between social exclusion, transport and the location of services, mainly concerned with the accessibility of local services and activities. It particularly focuses on access to opportunities with most impact upon life-chances, such as work, learning and healthcare. Non-motorised modes are one component of an approach to tackle social exclusion. There are many examples in the United Kingdom where low-cost cycling projects at a community level can increase cycling levels and bring cycling to a wider audience (Elster, 2000). Other benefits of these projects include community development, the provision of activities for young people, crime diversion and training opportunities.

A House of Commons Health Affairs Committee report on obesity includes recommendations that relate to non-motorised modes (House of Commons Health Affairs Committee, 2004). The concern is that two-thirds of the population (in England, a similar trend is evident in Scotland) are overweight or obese, caused by a combination of poor diet and inactivity. In terms of activity, measures to encourage non-motorised modes, such as safe routes to schools, are strongly recommended in the report. A further recommendation of the report is that the Department of Health has stronger links with the Department for Transport in the promotion of healthier forms of transport.

Sustainability has been a key concept since the Bruntland report (World Commission on Environment and Development, 1987), as shown in Section 1.4. Parallel to sustainable transport policy has been sustainable development policy. The United Kingdom strategy for sustainable development is outlined in Department of the Environment (1994) and Department of the Environment, Transport and the Regions (1999). There are four main aims: social progress that recognises the needs of everyone; an effective protection of the environment; the prudent use of natural resources; and the maintenance of high and stable levels of economic growth and employment. A balanced approach is, therefore, required to ensure that social, environmental and economic objectives are all met. This can prove difficult in practice, attempting to balance environmental concerns against economic development.

4.2.2 Critiques of United Kingdom transport policy

Despite the many United Kingdom policy documents, there is much scepticism as to whether the sustainable transport policy agenda can deliver (e.g. Docherty and Shaw, 2003). From the mid-1990s there has been concern over the influence of these documents in delivering travel behaviour change. The Road Traffic Reduction Act, a pre-cursor to the Integrated Transport White Paper has been criticised because it "lacked teeth" (Chisholm, 1997). Although the principles behind the Integrated Transport White Paper have been widely welcomed and agreed upon by most commentators, during the late-1990s the primary problem associated with the transport policy has been identified as policy implementation (Goodwin, 1999).

The Integrated Transport White Paper (Department of the Environment, Transport and the Regions, 1998) attempted to tackle the 'twin pillars' of air pollution and congestion (Begg and Gray, 2004). Air pollution and congestion are shown to be the main problems associated with the motor car, in Section 1.3. Begg and Gray (2004) argue that a combination of public dissatisfaction with progress in transport, political shocks (primarily the national fuel duty protests) and institutional change have led to a policy shift away from integrated transport. With more focus since the Integrated Transport White Paper on the problems of congestion (at the expense of air pollution) and the provision of transport infrastructure, they assert that the 'marriage' between transport and the environmental policy is over. It is argued that the Government ought to focus less on the unsustainable "side-show" of road building (Goodwin, 2003, p242).

Much of the impetus of national United Kingdom transport policy depends on local authorities and it is the implementation of sustainable transport initiatives at a local level that has arguably been one of the main successes of the United Kingdom Integrated Transport Strategy (Goodwin, 2003). A framework has also been implemented to provide for more resources directed at non-motorised modes. As Gaffron (2000) shows from a survey of British local authorities, there has been an increase towards non-motorised modes in local authority transport policy. Many now have their own cycling and walking strategies. This is particularly the case for cycling (as shown by the survey in Gaffron, 2000); local authorities are more likely to have a local cycling than walking strategy (46% compared with 12%), have a designated cycling than walking officer (52% compared with 23%) and policies assisted by the cycling than walking national policy framework (64% compared with 41%). Another survey (Lumsdon and Tolley, 2001) shows that 52 out of 167 local authorities did not have a cycling strategy. Authorities are categorised into two polar opposites: "adopters" who follow the 'Bikeframe' local authority cycling guidelines closely, and "resisters" who generally ignore the guidance. The study concludes that there is major variation in the local authority response to the development of a local cycling strategy. The same could be stated for local walking strategy development.

Tolley (2003) paints a mixed picture of the recent United Kingdom sustainable transport agenda impacts upon non-motorised modes. On the negative side there has been no sign of increase in non-motorised mode use, a lack of appropriate funding, a growth in car ownership, doubts over local authority policy delivery, and a decrease in bus use (knock-on decrease in walking levels). However, on the positive side, arguments to promote non-motorised modes are now mainstream, a National Walking Strategy could be developed at some point in the future, and there have been some successes at a local level. It is initiatives at the local level such as Safer Routes to School, Green Transport Plans, "walking buses" and car free days that could prove important to an increase in non-motorised mode use. The local level non-motorised mode initiatives for Edinburgh are outlined in Section 4.3.

4.2.3 Non-motorised mode United Kingdom transport policy

Amongst the transport policy measures within the Integrated Transport White Paper are those to encourage non-motorised modes. These have been categorised and are shown in Table 4.1. The Table illustrates that most of the measures to encourage non-motorised modes relate to infrastructure, either through facilities for cyclists and pedestrians or through traffic restraint measures. The responsibility for implementing such measures, as for much of the Integrated Transport Strategy, depends largely upon Government bodies at a smaller, more localised scale. The inclusion of non-motorised modes in the White Paper has elevated the provision of such modes higher up the transport policy agenda for most Local Authorities.

Table 4.1. Cycling and walking measures Local Authorities are encouraged to implement from the Integrated Transport White Paper

Category	Cycling	Walking
Strategy	1. Establish local strategy for cycling as part of local transport plans	
Cycling / walking facilities	2. Adapt existing road space to provide more cycle facilities 3. Make changes to traffic signalled junctions & roundabouts in favour of cyclists, giving them priority 4. Maintain cycle lanes adequately to avoid hazards to cyclists	1. Reallocate road space to pedestrians, e.g. wider pavements & pedestrianisation 2. Provide more direct & convenient routes for walking 3. Improve footpath maintenance & cleanliness 4. Provide more pedestrian crossings 5. Reduce waiting times for pedestrians at traffic signals & give them priority at junctions
Appraisal	5. Institute 'cycle reviews' of road system & 'cycle audits' of proposed traffic schemes	
Traffic restraint	6. Apply speed restraint more widely to support cycling strategies & provide for cyclists when applying speed restraint measures	6. Deal with characteristics of traffic that deter people from walking 7. Introduce traffic calming measures near schools, in 'home zones' & in selected country lanes
Parking	7. Increase provision of secure parking for bicycles	
Planning	8. Use planning powers to promote cycling through influencing land use mix, layout & design of development and through the provision of cycle facilities	8. Use planning powers to ensure that the land use mix, layout & design of development is safe, attractive & convenient for walking

Source: Department of the Environment, Transport and the Regions (1998)

The non-motorised mode policy approach can be holistic or targeted at specific journey types. As outlined in Section 2.2, the primary non-motorised mode journey types are the journey to work and the journey to school. This has been reflected in national policy with the introduction of 'Green Travel Plans' and 'Safe Routes to Schools' in an attempt to reduce peak time congestion. These schemes encourage employees and school children to make these journeys using non-motorised modes.

United Kingdom Government cycling policy was presented more fully in the 1996 National Cycling Strategy (Department of Transport, 1996a). The National Cycling Strategy proclaims "cycling has a bright future, contributing significant benefits to the nation" (p2). Targets were included to double cycling mileage by the year 2002 and quadruple it by the year 2012, from 1996 United Kingdom cycle trip figures (16 bicycle journeys per person per year). Local authorities, and other transport providers and trip generators, were encouraged to establish local targets to increase cycle use, thus aiding the national targets. An illustration of the wide-ranging nature of the National Cycling Strategy can be shown by the topics included: planning, cyclist safety, providing road space for cycling, cycle parking, cycle theft, attitudes to cycling, resources to implement the strategy, and monitoring the strategy. A National Cycling Forum was concurrently established to ensure development of a National Cycling Strategy and research was commissioned to accompany the National Cycling Strategy (Davies et al, 1998).

Other policy initiatives have been introduced to encourage cycling. The Government-led "Cycle Challenge" schemes in the late 1990s have supported innovative cycling projects in England, Wales and Scotland, with over £2.6 million given to 62 innovative projects. The Government has also been one of many public bodies supporting the transport charity Sustrans in developing a National Cycle Network, an 8,000-mile network of cycle routes. In 2002, the National Cycling Strategy Board was established to co-ordinate and to monitor the National Cycling Strategy, to assist in the attainment of the Government's target to quadrupling cycle use by 2012. In addition, a £2 million Cycle Projects Fund was set up to fund projects aiming to increase cycling and raise awareness.

Policy initiatives to encourage walking are not as advanced as cycling policy initiatives. It was intended to develop a National Walking Strategy (Department of Transport, 1996b), but the resultant policy document was an advice note on walking to Local Authorities in England (Department of the Environment, Transport and the Regions, 2000a). Unlike the National Cycling Strategy, there are no targets to increase walking levels, although a useful summary is provided of practical ways of encouraging walking. It emphasises the provision of high quality network consisting of people-friendly facilities, with supporting policy, development planning and promotion measures. The document's introduction states that walking policy initiatives will not make much difference to car mileage, air pollution or global warming, although the effects will be positive.

The 2000 Annual Report by the House of Commons Environment, Transport and Regional Affairs Committee (2000) criticised the Government for a lack of commitment to cycling and walking targets. The Committee "fully expects" the Government to abandon targets for trebling cycling by 2010 and quadrupling it by 2012, unless cycling is made much safer. The cycling targets were adjusted in the Governments Ten Year Plan (Department of the Environment, Transport and the Regions, 2000b) to a trebling of 2000 cycling levels by 2010. With reference to walking, the House of Commons Committee recommended that the Government reconsider the case for adopting a national target for walking (House of Commons Environment, Transport and Regional Affairs Committee, 2000).

The walking and cycling action plan (Department for Transport, 2004a) is a policy paper providing practical advice for England. It has more of an emphasis towards health than previous non-motorised mode policy. It is also more realistic than previous policy documents, stating the difficulty to reverse the long-term decline of non-motorised modes with competition from the motor car. Nevertheless, it provides many action points in the areas of improving the environment through planning, providing facilities and influencing travel behaviour.

Non-motorised modes, particularly cycling, have been encouraged in United Kingdom national policy, although it has yet to be seen whether the policy rhetoric will be realised in increased levels of cycling and walking. At a national level many non-motorised mode policy documents have been produced. Targets may have been set, but whether these targets are to be achieved is a separate issue, particularly when the targets are not legally enforceable. When setting targets they can be set as an aspiration not realistically attainable, or as an achievable aim with little encouragement. Arguably the former is the case for cycling. There has also been little quantitative analysis on the possible effects of cycling initiatives to ensure these targets can be met (Wardman et al, 1997). Furthermore, local authorities are required to produce similar targets without the monitoring facilities to provide an accurate baseline from which targets can be set.

4.2.4 Land use planning and transport policy

Policies to encourage non-motorised modes are also outlined in related land use and planning documents. Cycling and walking are considered in the report by the Urban Task Force (summarised in Urban Task Force, 1999) as part of a practical solution to remedy urban decline in England. The main recommendations of relevance are to commit a minimum of 65% transport public expenditure to walking, cycling and public transport in the future, and to introduce Home Zones, neighbourhoods where pedestrians are given priority. Motor cars have to travel at low speeds through these zones, and the report suggests that 20mph speed limits should be set in all residential areas and high streets. In addition to Home Zones are Clear Zones, whereby any part of an urban area can be targeted to reduce pollution and traffic (www.clearzones.org.uk – accessed 25th March 2005).

The Government produces planning and policy guidance notes to local authorities, some of which cover transport in the urban environment. They aim to reverse the trend of decentralisation and suburbanisation in cities, as shown from the relationship between urban form and travel behaviour in Section 3.2. Of particular interest to this study is PPG13: Transport (Department of the Environment, Transport and the Regions, 2001), although only applicable to England. Scotland has an equivalent document, NPPG17 (Scottish Office, 1999). PPG13 requires the consideration of alternative modes to the motor car in planning new developments (specifically mentioning cycling and walking) and sets out maximum parking standards. PPG13 states the Government's objectives for transport and land use are to work together more effectively. The main points are to:

- focus major generators of travel demand in city, town and district centres and near to public transport interchanges;
- ensure local day to day facilities are accessible by walking and cycling;
- increase intensity of development for housing and other uses at locations which are highly accessible by walking and cycling;
- ensure that development comprising job, shopping, leisure and services offers a realistic choice of access by public transport, walking and cycling, recognising this is less achievable in rural areas;
- locate rural development comprising housing, jobs, shopping, leisure and services in local service centres designated as focal points for this purpose; and
- use parking policies to promote alternatives to the car.

The transport aspects of land use planning policy can be shown to encourage non-motorised modes and restrain car use through a number of measures, but primarily through controlling development and parking.

4.2.5 Implications of United Kingdom transport policy for this study

Non-motorised modes have been high on the United Kingdom transport policy agenda since the Integrated Transport White Paper as a component of travel demand management measures. Despite the lack of a change in the level of non-motorised mode use and an increase in the emphasis of policy back towards road building, non-motorised modes remain high on the United Kingdom policy agenda. This is partly due to the support of non-motorised modes through associated social inclusion, health, exercise, obesity, transport planning and sustainable development policy. Many United Kingdom transport policy documents have been produced over the last ten years or so. It remains unclear whether these policies will result in a change in individual travel behaviour and an increase in the propensity to use non-motorised modes.

4.3 The Edinburgh transport policy context

This Section considers transport policy in Edinburgh, the case study in this research by City of Edinburgh Council area. The background to Edinburgh as a case study, in Section 1.4, shows it to be a compact, growing and prosperous city with a historic core. Furthermore, it represents a particularly interesting transport case study due to high-density development and sustainable modal split, in terms of walking and public transport, relative to other United Kingdom cities. Since Devolution in 1998, Edinburgh policy makers have been answerable to the Scottish Executive. Provision for transport in Scotland was outlined in the Transport (Scotland) Act 2001 (Scottish Parliament, 2001).

4.3.1 A historical background to transport policy in Edinburgh

Policy and planning documents from the Abercrombie report (Abercrombie and Plumstead, 1949) onwards have shown the primary transport-related problem in Edinburgh to be traffic congestion, particularly in the city centre, in the face of an increase in motor car ownership and use. The Development Plan for the city in 1965, (City and Royal Burgh of Edinburgh, 1965) states that major highway construction would be limited by requirements of preservation of character and form of areas of historic and architectural importance. The transport priorities were an inner ring road, traffic management measures and expansion of car parking space. The final report of City of Edinburgh Planning and Transport study (Freeman, Fox & Associates and Colin Buchanan & Partners, 1972) outlines possible future road schemes for Edinburgh including a City Bypass, an Intermediate Circular Route, a Western Approach Road and an Eastern Approach Road. Although the City of Edinburgh Corporation accepted these proposals, they did not satisfy public opinion and the plans for the expressways and inner-ring road were successfully opposed. Unlike many other United Kingdom cities during this period, the tendency to implement large-scale road building in Edinburgh was resisted.

The first Structure Plan for Edinburgh and the Lothians was produced in 1978 (Lothian Regional Council Department of Physical Planning, 1978). The proposed solutions, such as restricting private parking associated with new office developments in Central Edinburgh and safeguarding sites for Park and Ride, gave priority to buses and pedestrians. This may explain the comparatively high modal shift for these modes in contemporary Edinburgh. During the 1980s, the aim of transport planning and policy in and around Edinburgh was to get a balance between public and private transport (Lothian Regional Council, 1985). Rather than seeking a purely highways or public transport solution, the early 1990s transport strategy (Lothian Regional Council Department of Planning, 1993) sought an integrated package of measures that made best use of the resources and space available.

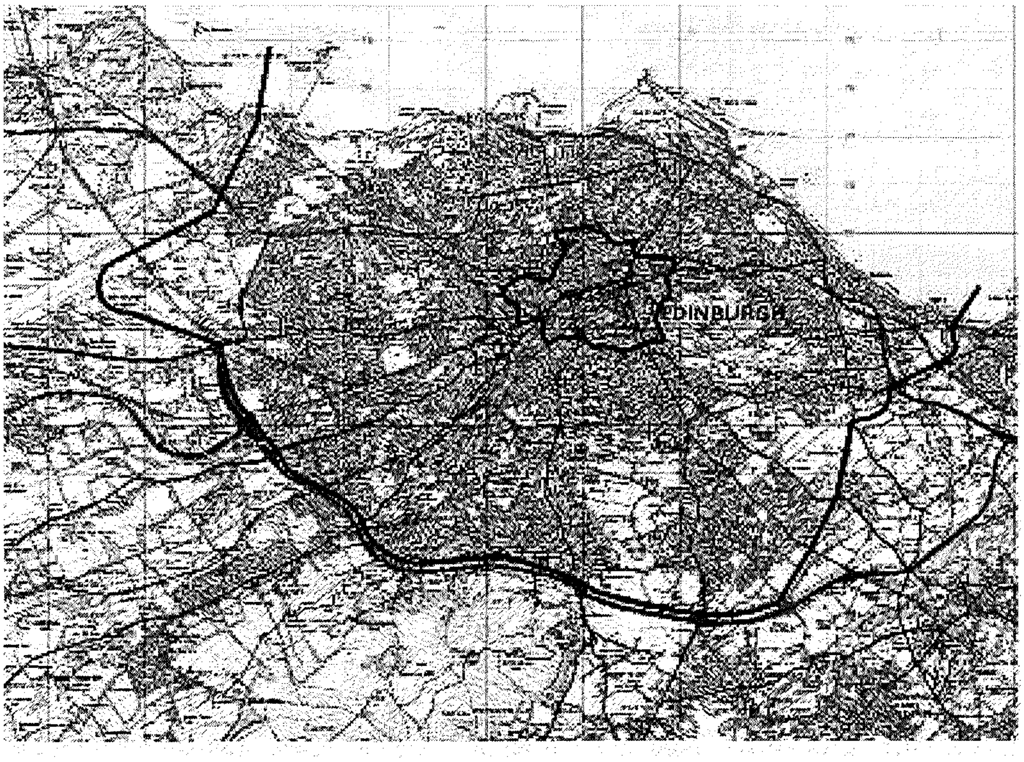
4.3.2 Current transport policy in Edinburgh

In 1996 the City of Edinburgh Council took over from two Councils, the Lothian Regional Council and the Edinburgh District Council. The latest transport policy is outlined in the Local Transport Strategy (City of Edinburgh Council, 2004b), developing upon the first transport strategy (City of Edinburgh Council, 2000). The vision within the current Local Transport Strategy (City of Edinburgh Council, 2004b) is to have less use of the motor car, particularly for short trips, and to provide a choice between different modes. Focus is also on developing an urban form that reduces the need to travel longer distances and by motor car. The emphasis of the strategy is to improve alternatives to the motor car and to alleviate congestion.

A core component of current transport policy in Edinburgh was proposals for a congestion charging scheme, developed by the City of Edinburgh Council (City of Edinburgh Council, 2004a; City of Edinburgh Council, 2004b) under legislation, The Transport (Scotland) Act 2001 (Scottish Parliament, 2001). In February 2005 the proposals, consisting of two cordons (an inner and an outer cordon – shown in Figure 4.1) and a single £2 inbound charge (City of Edinburgh Council, 2004c), were rejected by Edinburgh city residents in a referendum. They have been subsequently discarded.

The Integrated Transport Initiative, a package of transport improvements including tram lines, bus and rail projects, and Park and Ride schemes, can still be implemented without the congestion charging scheme, but on a smaller scale.

Figure 4.1. A map of the cordons for the proposed Edinburgh congestion charging scheme



Source: Map supplied by Transport Initiatives Edinburgh Ltd, May 2004

The structure plan for the Edinburgh and the Lothians city region to 2015 was approved in June 2004 (City of Edinburgh Council et al, 2004). It concerns the development needs of a prosperous and growing region, set against a need to protect and enhance the environment. Within the transport policies, is the provision of safe, secure and attractive routes for non-motorised modes. Of particular relevance to this study, the survey area of West Edinburgh (principally the stretch of the A8 from the South Gyle / Edinburgh Park area to Newbridge) is regarded as having potential for long-term "national" (Scotland-wide) economic development. West Edinburgh is becoming increasingly attractive as an area of choice for economic development, mainly due to its proximity to the airport and road access to the Central Belt. The Structure Plan stipulates that no Green Belt land be released during the time period of the plan.

4.3.3 Non-motorised mode policy in Edinburgh

In terms of non-motorised modes within the Local Transport Strategy, the vision of reduced motor car use and a choice between modes "implies that walking and cycling in Edinburgh should be much more pleasant, without continual obstruction and danger from traffic" (City of Edinburgh Council, 2004b, p2). The objective for non-motorised modes in Edinburgh is to provide a city in which they are an "attractive, safe and secure option" for all short journeys, and in addition, cycling as a viable option for all medium journeys. Within the Local Transport Strategy non-motorised mode policies are acknowledged to contribute to the key appraisal themes of the environment, accessibility, safety and integration, but are not judged to contribute to the economy. The numbers of individuals cycling and walking have been falling in the four years to 2001, but have been stable over the last few years. Non-motorised mode information within the Edinburgh Local Transport Strategy (City of Edinburgh Council, 2004b) is shown in Table 4.2 and Table 4.3.

Table 4.2. A summary of non-motorised mode achievements, targets and proposed schemes within the Edinburgh Local Transport Strategy

	Cycling	Walking
Achievements since 1999	1. On and off road cycleways implemented in 21 locations across the city 2. Advanced cycle stop lines added to 50 junctions 3. Leith to Straiton Quality Bus Corridor includes major cycle facilities	1. New lit surfaced path from the new Royal Infirmary to Craigmillar 2. Improved pedestrian access on Royal Mile due to new traffic restrictions 3. Pedestrian phases added to 30 signalled junctions
Key targets	1. 50% reduction in cycle accident rate (per km travelled) by 2010 2. Produce a detailed cycling strategy by mid 2005 3. Modal split target for cycling trips by 2010: 6%	1. 40% reduction in pedestrian accident rate (per km travelled) by 2010 2. Produce a walking strategy by mid 2005 3. Modal split target for walking trips by 2010: 26%
Proposed schemes	Base strategy: Continue phased development of cycle network Preferred Strategy: Completion of city wide cycle network	Base strategy: Continue upgrading pedestrian phases at junctions and installing pedestrian crossings. Produce pedestrian friendly design guide by the end of 2004 and walking strategy by mid 2005 Preferred Strategy: Wide range package of pedestrian improvements

Table 4.3. A summary of non-motorised mode policies within the Edinburgh Local Transport Strategy

Cycling	Walking
C1. Expand cycle network in consultation with cycle groups	W1. Develop design standards
C2. Presumption in favour of new traffic managements always incorporating measures for cyclists	W2. Presumption of new schemes to incorporate measures for pedestrians
C3. Presumptions against new one-way streets, although if implemented would favour contraflow cycle lanes	W3. Presumption against introduction of new pedestrian guard-rail
C4. Presumption against new roundabouts in built up area, due to poor cyclist safety record	W4. Design and review of controlled parking zones will be an opportunity to improve pedestrian environment
C5. Segregate from pedestrians (with raised white line) at new and heavily used cycle/pedestrian paths	W5. Presumption in favour of pedestrian phase provision at traffic signal controlled road junctions
C6. Install secure bicycle parking (particularly cycle lockers) at railway stations and Park & Ride sites	W6. Pelican crossings to have minimum return period of 20 seconds
C7. Retain cycle / pedestrian routes on former railway routes used by tram	W7. At signalled junctions (where permitted), when a pedestrian phase is called, it will be the next cycle stage
C8. Policies implemented through use of expanded audit of new and large maintenance scheme	W8. To support city centre and other shopping areas by seeking opportunities to improve pedestrian facilities (considering pedestrianisation)
	W9. Maintenance of pavements in areas with high numbers of "trips and slips" accident claims will be a high priority
	W10. Action taken to solve problems of parking where dangerous and obstructive to pedestrians
	W11. Action taken to improve lighting and CCTV in areas where problem of personal security
	W12. Presumption in favour of pedestrian-friendly schemes in transport assessment of new developments

Most of the emphasis of the non-motorised mode measures is on facilities and provision, which are relatively easy to implement. Targets within the Local Transport Strategy have more of a safety focus, an easy indicator to measure. It should be noted that these targets were reduced after the first Local Transport Strategy (City of Edinburgh Council, 2000). The non-motorised mode policy within the current Local Transport Strategy (City of Edinburgh Council et al, 2004) is to be commended. However, a criticism of non-motorised mode policies at a local level, particularly those for cycling, would be the tendency for ad hoc facilities on the back of larger schemes, rather than strategic and network-based measures.

There are also positive cycling and walking messages within 'Safer Routes to Schools', 'Travel Awareness' and 'Travel Plans' policies of the Edinburgh Local Transport Strategy (City of Edinburgh Council et al, 2004). Safer Routes to Schools provide safe walking and cycling routes for children. To date there have been 19 Edinburgh schemes implemented and 2010 targets of 6% cycling and 60% walking to school have been set. 'Travel Awareness' programmes, such as the current SESTRAN "Travelwise" campaign, aim to educate and raise public awareness on issues such as encouraging alternatives to the motor car. 'Travel Plans' aim to give employees a greater choice in their travel to work and are geared towards employers with more than 50 staff.

4.3.4 Associated Edinburgh-based transport policy measures

Aside from non-motorised mode policies, other Edinburgh transport measures are outlined in the Local Transport Strategy (City of Edinburgh Council, 2004b). Many of these measures determined the location of the West Edinburgh survey and the variables collected within the questionnaire, as outlined in Chapter 6.

The associated transport policy measures relate either to motor car restraint or the encouragement of public transport. Motor cars are already restricted in their access to the centre of Edinburgh on Princes Street. Vehicular traffic, except for buses and taxis, is currently banned travelling eastbound along Princes Street (this layout is shown in Figure 4.2). A plan within the Local Transport Strategy is for this vehicular traffic also to be banned from travelling westbound. This plan also includes priority for pedestrians on George Street and a new cycle route through the city centre.

Figure 4.2. A photograph to show the current layout of Princes Street, motor vehicles only permitted in one direction (eastbound)

As has been shown in Section 3.2, parking is one facet of the urban transportation problem and, as outlined in Section 2.4, can be a stick to enforce a change in travel behaviour. Parking policies include controlling supply and enforcing regulations. Current Edinburgh parking policy is to expand the city centre Controlled Parking Zone (City of Edinburgh Council, 2004b). The expansion is expected to occur during the period 2005-2007. Residents have to pay for parking permits in Controlled Parking Zones; even so, demand for parking tends to exceed the space available for parking in such areas (City of Edinburgh Council, 2004b).

Transport measures to restrain motor car usage include encouraging land use planning objectives such as higher density accommodation and ensuring a strong city centre, and implementing 20mph speed limits across much of the city. Other initiatives widen choice away from the motor car. These include a car-free housing development in Slateford, a City Car club as an alternative to personally owning a car and car free festivals. A photo of the car-free housing development, Slateford Green, the first car-free housing development in the United Kingdom, is shown in Figure 4.3. The rationale behind car-free housing is that any land that would have been used for car parking and car access can be freed up for other uses including more green space, safe play areas for children, and an environment with better local air quality and less noise. Residents are obliged to sign a pledge that they will not keep a motor car on site, although they can still own a motor car. The first United Kingdom Car Club was launched in Edinburgh in March 1999 whereby club members share access to a fleet of cars, to reduce both car ownership and car use (Rye et al, 1999). Although the scheme closed in March 2001, it was successfully re-opened by Smart Moves Ltd in October 2001 and is currently in operation.

Figure 4.3. A photograph of Slateford Green car-free housing development in Edinburgh

Greenways are bus priority measures that have been introduced from 1997 by the City of Edinburgh Council on five main radial routes into Edinburgh city centre. Their features include strictly enforced bus lanes on main radial routes; policing by a dedicated warden force; use of distinctive red lines and green bus lanes; priority given to public transport, cyclists and pedestrians; bus priority technology at traffic lights; and improved bus passenger facilities and information. An evaluation of Greenways showed that bus reliability had been improved (Scottish Executive, 2000a). From the Greenway monitored (the A8), the measures appear to be safer for pedestrians and cyclists than a conventional corridor, although the data does not enable a change in cycle use to be estimated. Another bus priority measure, the West Edinburgh Busway, a guided busway, was opened in Autumn 2004.

An extensive out-of-centre business park has been developed at the Gyle, to the West of the city. Although much travel to this area is by the motor car, Rye and McGuigan (2000) highlight sustainable transport initiatives introduced at the business park as examples of how business can encourage commuters to switch from the motor car onto the bus and bicycle. Initiatives include the introduction of a shuttle bus to and from Gyle Station, changes to the traffic control system at the Gyle roundabout, a new rail stop and improved bus links. Specific cyclist provision within the green commuter plans evaluated (Rye and McGuigan, 2000) concerns cycle parking, showers and lockers.

4.3.5 Implications of local transport policy for this study

Edinburgh tends to be heralded as a city in the United Kingdom taking the lead on sustainable transport issues (Hazel, 1998; Lumsdon and Tolley, 1999). If sustainable transport policy is to make an impact anywhere, then Edinburgh would seem a prime candidate. As discussed, the City of Edinburgh Council has a progressive transport policy, with non-motorised modes measures and a number of associated innovative schemes to encourage sustainable mobility. Therefore, the policy framework appears to be in place at a local Edinburgh level, as well as at a national level, for a change in travel behaviour from the motor car to non-motorised modes. In terms of the two main problems associated with the motor car, transport policy in Edinburgh is geared more towards solving congestion than air pollution. The question remains whether individuals will change mode. It could be argued that a more localised, neighbourhood level strategy is required to encourage the use of non-motorised modes, due to the limited length of trips currently undertaken by cyclists and pedestrians in Edinburgh.

4.4 Transport policy at other spatial levels

4.4.1 Transport policy in a Scottish context

A Scottish White Paper "Travel Choices for Scotland" (Scottish Office, 1998) was published at the same time as the United Kingdom Integrated Transport White Paper and follows similar policy themes. It recognises that Scotland has four distinctive transport challenges that differ from the rest of the United Kingdom. Firstly, Scotland has a physical geography including mountains, islands, and lochs. Secondly, Scotland has a population density that is generally very low, but extremely high in Glasgow and Edinburgh. Thirdly, Scotland faces problems of being on the fringe of the United Kingdom and Europe, which places a heavy emphasis on road, rail and air links to locations in these areas. Fourthly, Scotland has lower car ownership rates compared to the rest of the United Kingdom. Of interest to this study, and as described in the introduction to Edinburgh as a case study in Section 1.4, Edinburgh has higher population density rates and lower car ownership rates in comparison with much of the rest of the United Kingdom.

In terms of cycling, the organisation Cycling Scotland, funded by the Scottish Executive, was formed in 2003 to establish cycling as an "acceptable, attractive and practical lifestyle option for people in Scotland" (http://www.cyclingscotland.org/about.asp, accessed 28th August 2004). Many cycle-friendly facilities (e.g. advanced stop lines (ASLs), Toucan crossings and contra-flow cycle schemes), cycle routes and networks (including the Sustran's National Cycle Network) have been developed in Scotland in recent years. These have been promoted in association with cycling policy measures such as promotional events, advertising campaigns, secure cycle parking facilities, employer initiatives (e.g. Green Transport Plans), school initiatives (e.g. Safer Routes to Schools) and integrated transport initiatives. Although there has been a recent significant rise in local expenditure and activity to increase cycle use (as shown Scottish Cycling Development Project, 2002), this has yet to be translated into a modal shift towards cycling. Cycling levels remain low (journey to work or study in Scotland remains at the 1-2% level from 2001 Census and 2001/ 2002 Scottish Household Survey data), but due the many advantages of cycling and the recent policy measures, cycling in Scotland could see a renaissance in future years.

Although there is not a walking strategy at a United Kingdom level, the Scottish Executive set up a National Walkers Forum in the year 2000 and consulted on a Scottish Walking Strategy (Scottish Executive, 2003). The aim of the consultation is to have more people choosing walking as their first transport choice for short trips and a combination of walking and public transport for longer trips. The lack of progress in the development of a walking strategy is comparable to that of United Kingdom.

4.4.2 Transport policy in a European context

European transport policy tends to focus on larger scale issues than non-motorised modes. The most recent European Transport White Paper (Commission of the European Communities, 2001) emphasises road, rail and air transport in the goals and priorities for European Transport for the next twenty years, although there is reference to non-motorised modes in terms of improving safety for pedestrians and cyclists. Rapid growth in road traffic, congestion, pollution and transport accident are identified as key areas for future work in establishing a sustainable transport system for Europe.

There is a difference in modal share between continental Europe and the United Kingdom, particularly with regard to cycling. Of the fifteen European Union countries with a 1995 measure of km cycled per inhabitant per year, the United Kingdom ranked eleventh with 81km (European Commission, 1999, p19).

4.4.3 Transport policy in a United States context

Section 3.2 shows that many United States cities can be considered to be unsustainable, with extreme urban sprawl and car dependency. The United States has lower levels of non-motorised mode use than European counterparts. In 2001, the United States modal share for non-motorised modes was 9% of person trips and 1% of person-miles (U.S.

Department of Transportation, 2003 – Figures 29 & 30, using National Household Travel Survey data). Since the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 and the 1998 Transport Equity Act for the 21st Century (TEA-21), the promotion of walking and cycling has been encouraged. The United States Department of Transportation's National Bicycling and Walking Study has made policy recommendations for doubling the number of trips made by bicycling and walking (to 15%) and for decreasing pedestrian and bicyclist injuries and fatalities by 10% (Clarke, 2000).

4.5 Policy measures to be tested

The United Kingdom and Edinburgh transport policy outlined in this Chapter has implications for the data collection and analysis in the study. Various transport policy initiatives have been proposed to encourage non-motorised modes. Although specific policy measures are not recorded in the Scottish Household Survey, a series of questions were devised in the West Edinburgh survey to ensure that a variety of measures could be tested. The design for the West Edinburgh survey is elaborated further in Chapter 6.

There are three types of policy initiative questions within the questionnaire. Firstly, a range of attitudinal statements are incorporated on how individuals respond to policy initiatives. These include attitudinal statements on whether respondents agreed that congestion and air pollution were problems in Edinburgh, a core assumption behind transport policy. Non-motorised mode policy measures statements are also included. As shown from United Kingdom and Edinburgh policy in this Chapter, the primary non-motorised modes emphasis is on infrastructure. Therefore, it is considered to be of use to test the reaction of a respondent to cycle lane and footway improvements. More specifically, these improvements are on-road and off-road cycle lanes for cyclists, and pavements and road crossings for pedestrians.

Secondly, car drivers are asked to respond to policy initiatives, since policy tends to focus on reducing car use. One question within the questionnaire concerns car drivers' responses to six transport policy measures. Aside from national policy reflected in fuel price increases, these measures reflect local transport policy (outlined in Section 4.3).

Local transport policy measures include the £2 congestion charge; more severe parking penalties and restrictions; making most routes a 20mph speed limit; and increasing the frequency of local buses. The final of the six measures concerns an improvement of local cycle facilities, providing an indication of how car drivers rank a cycle policy measure amongst other transport measures. Another question concerns car driver responses to fuel price changes. For both questions, a range of responses is available to respondents on their motor car usage, to assess their position on a scale of travel behaviour change away from the motor car.

Thirdly, policy measures influence the variables used in the stated preference experiments on the propensity to use non-motorised modes. The attributes of the alternatives within the stated preference experiments are journey time, petrol cost and parking cost for the propensity to walk (against the motor car) and journey time, daily payment, cycling facilities at the workplace and the nature of the cycle route for the propensity to cycle (for the journey to work). For the propensity to walk experiment, policy measures concern both national (fuel price measures) and local (parking charges) changes to a user's costs. For the propensity to cycle experiment, a specific, regular trip of the journey to work or study was chosen. This helped overcome inherent difficulties in surveying the attitudes of school children. The findings from the propensity to cycle stated preference experiment could be used to inform Green Transport Plan policy measures, such as facilities on route and at the destination.

Policy measures affect population segments in different ways. As shown in the example of congestion pricing policy measure (Bhatt, 1993), some segments, such as users of high occupancy vehicle lanes and road users who value their time highly, will be "winners"; other segments, such as neighbourhoods affected by spill-over parking or traffic will be "losers". This thesis attempts to assess the population segments who are winners and losers in response to non-motorised mode policies.

4.6 Summary

Chapter Four presents the transport policy response to problems associated with the motor car and the type of policy measures that have been, and can be, introduced to encourage non-motorised modes. Non-motorised modes, particularly cycling, have been encouraged in the United Kingdom Integrated Transport Strategy since the mid-1990s, as shown in Section 4.2. This policy approach represents the starting point to, and the rationale behind, this study. Non-motorised modes have remained high up the United Kingdom transport policy agenda, even though current policy swings back and forth between protecting the environment and building new roads. The recent changes have seen a swing back towards favouring increased road building, with the Government unwilling to be seen by the general public as anti-car. However, there is still non-motorised mode policy momentum, particularly with recent policies concerning social inclusion and obesity.

Non-motorised mode policy tends to concern high quality facilities and infrastructure within a supporting policy, planning and promotional framework.

The City of Edinburgh Council has a transport policy that provides and promotes practical measures to encourage non-motorised modes, outlined in Section 4.3. These tend to include facilities (e.g. installing bicycle parking, improving pavements), and measures targeting specific trips (e.g. journey to school, journey to work). There have been associated measures to reduce motor car usage, such as the car club and car-free housing, pioneering in a United Kingdom context, and to improve public transport. Links are shown to transport policy in a Scottish, a European and a United States context (Section 4.4).

It remains to be seen whether the policy rhetoric will be translated into increased levels of cycling and walking. Many of the commentators remain sceptical. In order for policy to be considered a success, a political will, public support and sufficient funding are all required. The emphasis in this study is on public support, in terms of the travel behaviour choices that individuals make relating to non-motorised modes. Arguably, a fundamental change in underlying attitudes is required, in order for there to be a travel behaviour shift away from the motor car.

Policy, even at a local level, concerns the whole population. Rather, there should be targeted measures at certain segments of the population, such as with the journey to work and school policies. In this research, it is the intention to examine population segments (as outlined in the first research objective) and how they respond to transport policy initiatives, in particular to relatively new and un-tested non-motorised mode initiatives through the stated preference experiments within the West Edinburgh survey (and modelled to answer the second research objective). Policy measures tested (outlined in Section 4.6) in these experiments include changes in petrol and parking costs and the provision of cyclist facilities on route and at the destination. Policy implications are also shown from other questions within the West Edinburgh survey, namely the attitudinal statements and car driver responses to policy measures and fuel price changes.

The next two Chapters outline the data sets and survey design. Chapter Five explains the relevance and validity of the data source used in stage one of the research, the Scottish Household Survey.

5. STAGE ONE DATA SET. THE SCOTTISH HOUSEHOLD SURVEY

5.1 Introduction

Chapter Five explains the relevance and validity of the data source used in stage one data collection, the Scottish Household Survey. As established in Section 2.2, the Scottish Household Survey is a large, empirical data set with background transport and travel diary information. The analytical approach is inductive and links to the first research objective, "to identify segments of the population with the greatest propensity to use non-motorised modes". The Scottish Household Survey sample in this study contains information on 2,910 households in Edinburgh.

The two possible alternative data sources to the Scottish Household Survey, the National Travel Survey and the Census, are summarised in Section 5.2. The characteristics of the Scottish Household Survey are presented and the variables within the data set are presented in Section 5.3 and Section 5.4 respectively. The statistical techniques used in this study to analyse the Scottish Household Survey data are outlined in Section 5.5.

5.2 Transport data sets

Two possible alternative data sources to the Scottish Household Survey are the National Travel Survey and the Census. All three are large data sets containing transport and travel information relating to Edinburgh households.

The National Travel Survey is a household survey designed to provide regular data on personal travel and to monitor changes in travel behaviour over time in the United Kingdom. It is undertaken to assist the United Kingdom Government in transport policy formulation. The National Travel Survey could be considered to be the primary United Kingdom source for transport statistics. First conducted in 1965/66, the National Travel Survey became a continuous survey since July 1988, with an annual sample of 5,040 households. At the time of the consideration of data sets in this study, the Scottish sample consisted of only 2,000 individuals (Hine et al, 1998). This is much lower than the Scottish Household Survey; a sample of approximately 14,000 households a year was collected in the Scottish Household Survey in 1999 across Scotland (Scottish Executive, 2000b).

There are approximately 200 variables in the National Travel Survey, including household, vehicle and journey information as part of a travel diary. These types of variables are also within the Scottish Household Survey. Many studies have used non-motorised mode data from the National Travel Survey (Royles, 1995; Potter, 1997; Mackett and Robertson, 2000). In contrast, there has not been any such research on the non-motorised mode data within the Scottish Household Survey.

The Census is a questionnaire survey of the United Kingdom population held every ten years, the last being in 2001. Examples of transport research studies using the Census include analysis of commuting patterns by Titheridge et al (1999) and analysis of short trips by Mackett and Robertson (2000). No other data set provides such a comprehensive spatial coverage as the Census, but the main disadvantage with regard to usefulness for the purposes of this study is that the only trip recorded is the journey to work.

There is, therefore, a need for improved data on non-motorised modes for trips other than the journey to work. Highlighting the lack of data on cycling, although it could be equally applicable to walking, Gardner (1999) called for the setting up of an "omnibus" survey concerned with cycling. It would involve a very large representative group from the United Kingdom population, and be repeated over several years, cross-referencing with existing surveys not specifically concerned with cycling, such as the Census and the National Travel Survey. This type of survey would be welcome for both cycling and walking, enabling more long-term research of non-motorised modes.

5.3 The Scottish Household Survey

The Scottish Household Survey began in February 1999, and interviews 15,000 households per year across Scotland (Scottish Executive, 2001). It is the largest survey of private households in Scotland. The aim of the survey is to provide household and individual information for the Scottish Parliament, the Scottish Executive and other interested parties, particularly in the areas of Local Government, Social Inclusion and Transport. The specific aims of the Scottish Household Survey are to:

- provide household and individual information not currently available in Scotland, particularly to support the work of the Development Department's transport, local government and social inclusion policy areas and the work of the Scottish Parliament;
- permit disaggregation of such information both geographically and in terms of population sub-groups (such as families with children or the elderly);
- allow the relationships between social variables within households to be examined. This will support cross-departmental and inter-departmental policies such as those on social inclusion and welfare-to-work;
- allow early detection of national trends; and
- allow detailed follow-up surveys of sub-samples from the main survey sample, if required.

Therefore, amongst the specific aims of the Scottish Household Survey are those that correspond to the data needs of this study. Specifically, the Scottish Household Survey aims of particular interest are to inform transport policy and to permit disaggregate analysis of survey data.

The Scottish Household Survey was chosen above the other data sets because it contains more detailed information on non-motorised modes. One example would be the variables for cycling and walking journeys split by utility and leisure trips. The Scottish Household Survey also has the largest coverage of households for Edinburgh. In addition, it was a relatively new and, therefore, unexplored data set.

The sample structure and survey design of the Scottish Household Survey are outlined in Scottish Executive (2001), a Technical Report for survey data collected in the time period 1999 to 2000. Using a sampling frame of the small user Postcode Address File, data was collected from each of the 32 Local Authorities in Scotland. For the larger Local Authorities, including the City of Edinburgh Council, a systematic random sample of addresses is drawn, for each of the ten main summary groups of the geodemographics indicator Scottish MOSAIC. Geodemographic classifications, such as MOSAIC, are described in Section 2.3. The MOSAIC definitions were not supplied with the research sample data because of confidentiality issues.

There are two parts to each Scottish Household Survey interview (Scottish Executive, 2001). The respondent for the first part of the interview is the highest income householder or their spouse or partner, established at the outset of the interview. For the second part of the interview, one adult member (aged 16+) of the household is selected at random, and interviewed at a later date if necessary. The former is intended to generate data representative of Scottish households and the latter data representative of the Scottish adult population resident in private households. The two interviews combined take an average of 45 minutes per household.

The randomly chosen adult, in the second part of the interview, is asked to complete a travel diary of journeys (of more than a quarter of a mile, or five minutes on foot) made on the previous day. The three types of journey recorded are a single stage journey (e.g. driving from home to work), a journey with more than one stage (e.g. bus into town then a train to work) and a series of calls (e.g. doctor on rounds, salesman visiting clients, shopping trips).

In terms of travel diaries within the two data sets the National Travel Survey has advantages over the Scottish Household Survey of being more specialised on transport, containing a full seven days travel, concerning all members of the household and recording rather than recalling journeys. However, as stated previously, at the time of the consideration of data sets the Scottish sample size in Scotland is much larger (14,000 adults) than the National Travel Survey (300 households). Although the National Travel Survey travel diary data is more comprehensive and of better quality, the Scottish Household Survey is of a sample size that facilitates the variations within Edinburgh to be analysed by population segment.

5.4 The Scottish Household Survey variables

The Scottish Household Survey sample was split according to the framework outlined in Section 1.5, i.e. by socio-economic characteristics, background transport information and travel behaviour variables.

Socio-economic characteristics include household information (number of people, number of children, income, housing type) and individual characteristics (age, gender). The background transport information variables relate to motor car ownership and use (ability to drive, household access to vehicle and vehicle type), and bicycle ownership. Of the travel behaviour variables, the primary non-motorised mode journey information is a record of cycling and walking for both utility and leisure trips over the previous seven days. Respondents are asked to state trips out of the house the previous day in a travel diary, including postcodes of origins and destinations. Postcode information is provided by respondents for the household property, and if relevant their workplace and school.

The variables from the Scottish Household Survey are categorical, non-metric variables. Each individual within the sample had been allocated to one category for each variable. Categorical variables are not measurements and therefore do not facilitate parametric testing. However, categorical variables are suitable for association techniques such as Chi-square testing and cross-tabulation (Field, 2000, p59).

Due to confidentiality issues, the Scottish Executive stipulates that individuals in the survey cannot be identified from a Scottish Household Survey sample. Therefore, some of the sensitive data was aggregated for the Edinburgh sample of the Scottish Household Survey. For example, household income was grouped into four income bands. Furthermore, travel diary data is aggregated to postcode sector level rather than as individual postcodes. As stated in Section 5.3, MOSAIC definitions were also not supplied. Despite these restrictions, the amount of data in the sample, with 2,910 households, has enabled investigation of travel behaviour. Any data gaps have been improved upon in the stage two data collection, the West Edinburgh survey of travel behaviour.

The main aim of the Scottish Household Survey analysis is to develop relationships between socio-economic, transport availability and travel behaviour variables at an Edinburgh wide level. The components of this analysis include:

- Hypothesis 1: "The population is split into segments according to socio-economic characteristics"
- Hypothesis 2: "Car and bicycle availability affects the propensity to use non-motorised modes"
- Hypothesis 3: "Socio-economic and transport availability characteristics affects travel behaviour"

A secondary aim of analysis of the Scottish Household Survey data is to inform development of the stage two dataset.

5.5 Developing statistical analysis of the Scottish Household Survey data

Within multi-variate analysis there are many statistical techniques that can be employed (Sharma, 1996; Hair et al, 1998; Field, 2000; Kinnear and Gray, 2000; Pallant, 2001). In this study, an interdependence technique (i.e. where no single variable, or group of variables, is defined as being independent or dependent - Hair et al, 1998), has been employed on the socio-economic data. It is used as a data reduction method, breaking the data down into more manageable groups. Then, dependence techniques have been employed, incorporating the transport data as dependent variables, to ascertain the factors affecting travel behaviour.

Due to the categorical nature of the Scottish Household Survey data, only non-parametric tests can be used. Parametric tests have been applied to the second data collection stage data set, the West Edinburgh survey. Chi Square testing is a frequently used non-parametric statistical method to explore relationships among variables. It also works using categorical variables. Cluster analysis is the statistical technique employed on the socio-economic data and the rationale for choosing this technique is discussed in Section 5.5.1. As shown in Section 2.3, it is a technique widely used for market segmentation. SPSS Answer Tree was employed on the socio-economic and transport data to ascertain the factors affecting travel behaviour, and the rationale for choosing this technique is discussed in Section 5.5.2. Both of these statistical techniques incorporate Chi Square methods.

5.5.1 Cluster analysis

Cluster analysis, described in Hair et al (1998), is an exploratory, statistical technique for developing meaningful subgroups of individuals or objects. It classifies, using an algorithm, a sample of entities into a small number of mutually exclusive groups based on the similarities (or differences) among the entities, to reduce the data into manageable parts. Unlike discriminant analysis, the groups are not predefined. As it is a non-parametric test there are not strict assumptions, although the variables must be independent. Analysis should be undertaken without any pre-conceptions of the user, although results depend upon their judgement. It is a technique that provides suggested groups for review rather than definite solutions.

A wide range of transport research studies incorporate cluster analysis (viz. 'classification of the motor car dependence of cities' (Newman and Kenworthy, 1989), 'meta-analysis of twelve observations of public transport in different countries' (Nijkamp et al, 2000) and smaller scale cycling studies (Davies et al, 2001; Rethati & Rekai, 2001)), with a larger number of observations. Several use cluster analysis as part of market segmentation (Anable, 2002; Davies et al, 2001). Rethati & Rekai (2001) and Anable (2002) incorporate attitudinal variables alongside more traditional variables. Rethati & Rekai (2001) categorises attitudes towards cycling into four groups: environmental, security, practical and social attitude considerations. Unfortunately, the Scottish Household Survey does not incorporate attitudinal variables; these were added in the second dataset.

There are two characteristics of the final groups selected (Sharma, 1996). Firstly, each group or cluster is homogeneous or compact with respect to certain aspects, i.e. observations in each group are similar to each other. Secondly, each group should be different from other groups with respect to the same characteristics, i.e. observations of one group should be different from the observations of other groups.

Five steps for running cluster analysis (Sharma, 1996) are listed with the methods chosen in this study (within SPSS):

1. Select a measure of similarity.

Chi square was the measure used, the default for count (category) data.

2. The type of clustering technique to be used (e.g. hierarchical or non-hierarchical).

SPSS uses hierarchical and K means techniques. The hierarchical technique was used because it is the only one to permit categorical data.

3. The type of clustering method for the selected technique is selected (e.g. centroid method).

A number of clustering methods are offered in SPSS. All four methods were selected which meant four runs were undertaken (one using each method), enabling validation. The methods chosen are: between groups average; within groups average; centroid clustering; and Ward's method.

4. A decision is made regarding the number of clusters.

After some pilot runs, eight clusters were considered for each of the four runs, to produce between eight and twelve clusters.

5. The cluster solution is interpreted.

Using an iterative process, cluster groups were labelled according their characteristics.

A minor problem with hierarchical analysis is that computer memory can be too small for the analysis of large samples (Hair et al, 1998, pp. 497-498). SPSS is limited to 2,500 cases for hierarchical cluster analysis, so each of the four runs used 2,500 randomly selected cases from the sample of 4,016. The resultant groups were then applied to the overall sample.

5.5.2 SPSS Answer Tree

SPSS Answer Tree was employed to ascertain the factors affecting travel behaviour, and the segmentation hypotheses tested at that stage. The results were linked back to the population segments produced by the cluster analysis. Answer Tree is a non-parametric, exploratory data analysis tool. It is an algorithm based segmentation technique frequently used in market research. Answer Tree has four decision tree algorithms, and one of these, Exhaustive CHAID, because it is based on Chi square methods, was employed. Individual and overall effects upon the dependent variables can be visualised as percentages and significance values.

5.6 Summary

This Chapter summarises the relevance and validity of the Scottish Household Survey. The two possible alternative data sources, the National Travel Survey and the Census, have been outlined in Section 5.2. The Scottish Household Survey is examined in Section 5.3, and is justified as the chosen dataset due to its detailed information on non-motorised modes and large coverage for Edinburgh compared with other data sources.

The socio-economic, transport availability and travel behaviour variables within the Scottish Household Survey are outlined in Section 5.4 to test the three hypotheses. Section 5.5 presents the statistical techniques, based on Chi square methods, to analyse the Scottish Household Survey data, namely cluster analysis and the use of SPSS Answer Tree.

The main limitations of the Scottish Household Survey data variables are their categorical nature and the lack of attitudinal data within the sample. These two limitations were offset by the data collected in the West Edinburgh survey. Since the Scottish Household Survey contains only empirical information on current travel patterns, policy measures that would encourage a change in future travel behaviour could not be directly elicited. Such policy measures have been examined from the West Edinburgh survey, using discrete choice modelling the stated preference data.

Chapter Six applies a similar approach to this Chapter, justifying the relevance and validity of the data source used in stage two dataset, the survey of travel behaviour in West Edinburgh.

6. STAGE TWO DATA COLLECTION. THE WEST EDINBURGH TRAVEL BEHAVIOUR SURVEY

6.1 Introduction

Chapter Six explains the relevance and validity of the data sources used in collection of the stage two dataset, the survey of individual travel behaviour in West Edinburgh. The design of the West Edinburgh survey is outlined and justified in Section 6.2. Aspects of the survey are then presented: the design of questionnaire in Section 6.3, the sample design in Section 6.4, and the stated preference experiment design in Section 6.5. Links to the stage one dataset are shown in Section 6.6.

The extensive West Edinburgh survey, of 997 households, was conducted in July 2003 along a transport corridor in the West of the city. A grant from the Scottish Transport Studies Group facilitated the collection of a larger sample than originally anticipated. The large sample size enabled the data to be segmented by many variables. A 'call and post' method of survey data collection was employed. Questionnaire variables include socio-economic characteristics of the sample, background transport information such as car and bicycle ownership, details of the journey to work or study, agreement with various transport statements, and car driver responses to policy measures. A stated preference experiment was also conducted concerning hypothetical modal choices between travelling by motor car, by bicycle and on foot. Much of the originality of the study stems from these two stated preference experiments.

6.2 Design of the West Edinburgh survey

Data collection techniques include postal questionnaires, call and collect questionnaires, on-street interviews, household interviews, telephone interviews, focus groups and travel diaries. Telephone and postal surveys are low cost methods because they do not involve high personnel travel costs, but there can be difficulties in obtaining a representative sample due to low response rates.

Questionnaires were used in the West Edinburgh survey, involving more of a structured approach than a free-flowing interview. Within a questionnaire there are three types of question (Hague, 1993). Firstly, classification questions seeking information such as age, gender, location and type of house are used to group respondents and highlight differences. Secondly, attitudinal questions concern what the respondent thinks of, or why they do, something. Thirdly, behavioural questions elicit factual information about what a respondent is, does or owns. All three types were included in the West Edinburgh survey questionnaire.

There can be difficulties when questionnaires are used. Individuals are often irrational rather then logical when completing questionnaires. In addition, it is important that respondents fully understand the questions within a questionnaire. A self-completion questionnaire is an appropriate way of collecting quantitative data, enabling stated preference experiments to be incorporated. One problem recognised in this study is that behavioural change is long-term, and thus difficult to measure in a one-off survey. However, a one-off survey is the most appropriate method for the timeframe of this thesis.

Households were targeted in the survey. Households represent the most appropriate unit of measurement for this study, being the main base from which people travel, and also to tie in with data from the Scottish Household Survey. Alternative approaches could have included the following: car parks, if the study was targeting motor car users; employers, if the study was targeting the journey to work; or schools, if the study had targeted the journey to school. To enable the sample to be split into population segments, at least several hundred questionnaires were required from the survey. Therefore, more time-consuming individual experiments such as household interviews or in-depth travel diaries were discounted. Instead, as an alternative type of method to face-to-face interviews, carefully designed self-completion mailback forms were designed and incorporated into the survey. This technique was pioneered in Germany and referred to as the 'Kontiv' method (Bonsall and O'Flaherty, 1997). It is acknowledged that there may be non-response bias in the sample due to a proportion of households not responding to the survey.

The questionnaire was given to one adult within the household. Although giving a questionnaire to each adult in any one household would have saved time and money, it would have proved an extra complication during the survey and in the analysis to track household respondents.

Originally a ‘call and collect’ survey had been planned. This technique had been successful in a previous survey by a team including the author (Ryley et al, 2002) offering a more favourable response rate and use of resources than other techniques. A pilot survey of 58 households, undertaken in May 2003, tested two delivery methods. It proved difficult during the pilot to differentiate between the ‘call and post’ and ‘call and collect’ questionnaires on the return visits. A ‘call and post’ method was chosen for the main survey using self-completion questionnaires to make the system uniform, easy to understand for survey staff and to facilitate tracking of questionnaires. It also made economic sense with the resources available to use ‘call and post’ rather than ‘call and collect’, because the survey staff did not have to return to the same address and a large supply of self-addressed envelopes were readily available.

Delivery of self-completion questionnaires was undertaken on weekday evenings Monday to Thursday, between 6:30pm and 9:00pm, when household members were more likely to be at home. Survey staff “called” on a household with a questionnaire, asking them to complete the questionnaire, and “post” it back at their own convenience using an enclosed pre-paid return envelope. The intention was to sample every household within an area, including those not at home when the survey staff called. Calling on a household, therefore, involved either handing over a questionnaire on the doorstep if the individual agreed to take part in the survey, or posting the questionnaire (and pre-paid envelope) through the letter-box if the householder was not at home.

6.3 Design of the West Edinburgh survey questionnaire

Data collected within the survey included socio-economic variables, background transport information and travel behaviour - the same framework as the Scottish Household Survey data. Some of the key variables in the Scottish Household Survey data set were replicated to further enable links to be developed between the two data sets. Some questions were adapted from other questionnaires, namely the Census, the British Social Attitudes survey and the Sustainable Cities project questionnaire (shown in Cooper et al, 2001).

The review of literature, as summarised in Section 3.8, helped to inform some of the variables collected in the West Edinburgh survey. The debate on urban form and travel behaviour produced two variables to be collected, housing type as a surrogate for density, and distance from the city centre. The socio-economic factors of age, gender, income and children present in the household, shown to affect motor car ownership and use, were also collected. Several studies, such as Cullinane (1992), included analysis of non-motorised mode measures amongst other transport policy measures. This type of question was replicated in the survey. The segmentation studies within the literature were used to provide some information on factors affecting non-motorised mode choice using attitudinal statements. Factors incorporated were safety, the weather (too wet to cycle) and topography (too hilly to cycle).

The review of policy, as summarised in Section 4.6, also helped to inform some of the variables collected in the West Edinburgh survey. There were three types of policy initiative questions within the questionnaire. Firstly, there was a range of attitudinal statements on how individuals respond to policy initiatives. Secondly, car drivers were asked to respond to policy initiatives, since much of policy is focused on reducing car use. Thirdly, policy measures influenced the variables used in the stated preference experiments evaluating the propensity to use non-motorised modes.

A pre-survey focus group could have been undertaken to tease out the factors affecting use of non-motorised modes in Edinburgh. Ortuzar et al (2000) conducted a focus group as an input to a stated preference survey. As an alternative to a focus group, two qualitative, open-ended questions were included in the questionnaire to understand more fully the reasons behind mode choice and the reasons why respondents do not cycle to work or study. Incorporating such questions complemented the quantitative questions in the survey.

It is important to manage questionnaire length. Due to the amount of data often required, questionnaires can be lengthy and tedious to complete. As questionnaire length increases so does a respondent's fatigue and interest. A few interesting issues might have been explored, but were sacrificed in the interests of minimising survey length, in the hope of increasing questionnaire return rates. Such issues include: information on the school journeys of children in the households surveyed in addition to focusing on adult journeys; a travel diary with trip chaining information; attitudes towards exercise, such as gym membership; and travel behaviour and attitudes towards the neighbourhood within which the households surveyed live.

The questions posed in the questionnaire were refined following the pilot survey. A final list of questions, grouped according to section, is shown in Table 6.1 and Table 6.2. A copy of the questionnaire in full is inserted at Appendix A.

Table 6.1. Content of the West Edinburgh survey questionnaire (Sections A to C)

Questionnaire section and type of data	**Question (q)**
SECTION A. GENERAL HOUSEHOLD AND TRANSPORT INFORMATION Background socio-economic, transport and general travel behaviour data for segmentation purposes	q1 Number of adults within household q2 Number of children within household q3 Any travel undertaken, by various modes q4 Employment status of adults in household q5 Number of driving licences in household q6 Respondent's driving licence status q7 Number of cars owned or available to household q8 Number of cars available that respondent is main driver
SECTION B. JOURNEYS TO THE CITY CENTRE Background information on the importance of the transport corridor surveyed	q9 How often travel to or through city centre q10 Mode of travel to or through city centre
SECTION C. CYCLING AND WALKING JOURNEYS Background non-motorised mode use and bicycle ownership data	q11 Walked in last seven days q12 Cycled in last seven days q13 Bicycles available to household q14 If bicycles are available, where they are stored

Table 6.2. Content of the West Edinburgh survey questionnaire (Sections D to G)

Questionnaire section and type of data	Question (q)
SECTION D. JOURNEY TO WORK OR STUDY Data on the journey to work or study and information on why the respondent does not cycle to work or study	q15 Employment status q16 Respondent work from home q17 Address of work or study q18 Mode of travel to work or study q19 Reasons use mode to work or study q20 Minutes from home to work or study q21 Description of hours worked or study q22 If by car, company car q23 Parking car at work or study q24 If bus, details of journey q25 If not cycling to work or study, why not q26 Propensity to cycle stated preference experiment
SECTION E. ATTITUDES TO TRANSPORT Attitudinal data towards policy and travel behaviour	q27 Attitude statements
SECTION F. TRAVEL CHOICES Travel behaviour change of motorists in the sample, and stated preference experiment on the propensity to walk	q28 Reaction to petrol price change q29 Car use statements q30 Propensity to walk stated preference experiment
SECTION G. PERSONAL INFORMATION Background socio-economic data for segmentation purposes	q31 Gender of respondent q32 Age of respondent q33 Blue badge holders in household (for disability) q34 Income q35 Internet access q36 House type q37 Garage q38 Any questionnaire comments

Segmentation was undertaken on the socio-economic and transport information within the West Edinburgh survey. Variables relating to adults in household, children in household, age, gender, Blue badge holder and income were used in the cluster analysis.

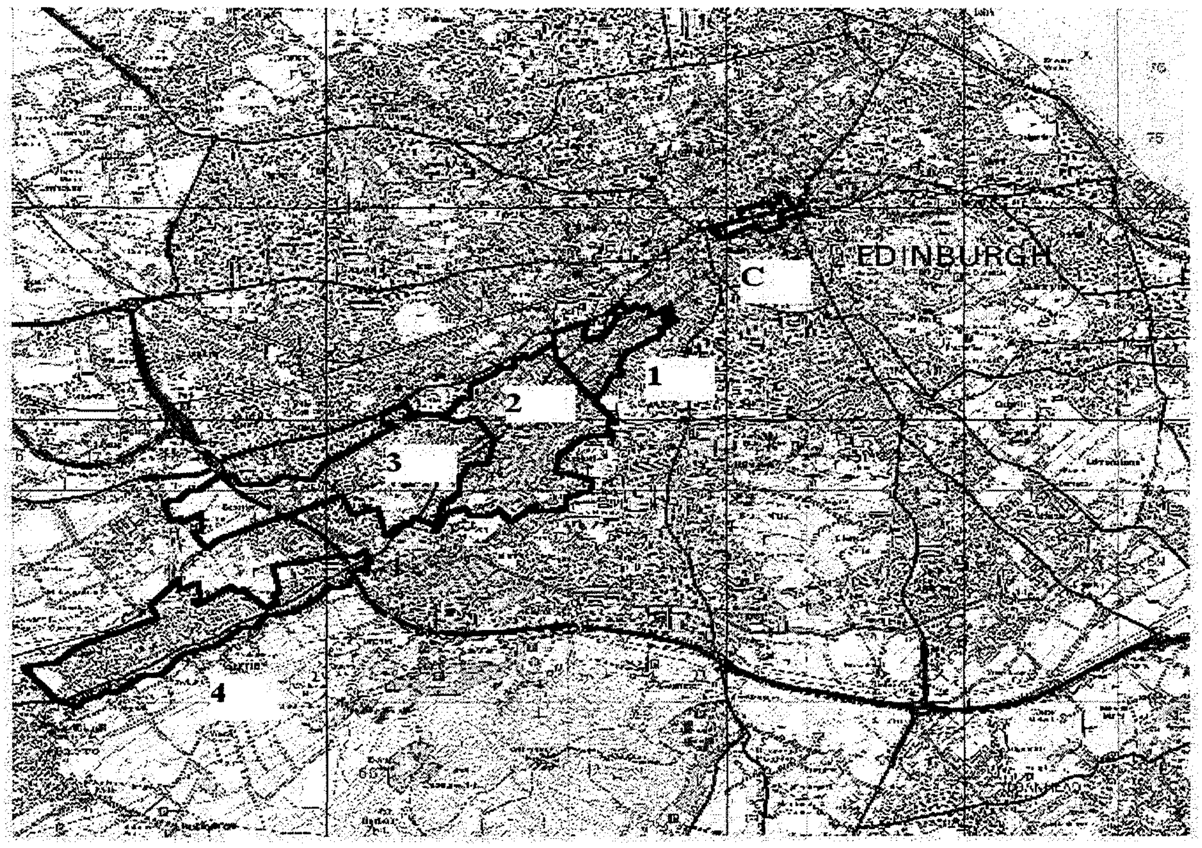
Most of the questions within the questionnaire are factual, with a few attitudinal and travel non-modelling variables. These variables explore travel behaviour in more depth than the Scottish Household Survey. It is also of interest to know the link between an individual's travel behaviour and their attitudes towards the behaviour. Attitudinal questions explore issues behind people changing mode. It is important to understand the perceptions people have of sustainable transport as alternatives to the motor car, and how they respond to sustainable transport policy measures.

In Section E of the questionnaire, respondents were questioned as to their agreement with eleven statements relating to issues associated with the motor car, cycling and walking. A five-point scale was presented to respondents (Strongly agree, Agree, Neither agree or disagree, Disagree and Strongly disagree). Agreement with statements helps to clarify perceptions of the main problems associated with the motor car (congestion, air pollution), strength of feeling towards providing facilities for non-motorised transport and possible constraints for use of non-motorised transport (e.g. safety, too wet, too hilly).

6.4 Selection of areas to survey

Originally the survey plan concerned examination of one postcode sector zone identified from the Scottish Household Survey data. With the grant from the Scottish Transport Studies Group, it was possible to expand the survey area to four postcode sectors, enabling the study of a transport corridor into Edinburgh. A map of the four postcode sectors is shown in Figure 6.1. The design of the West Edinburgh survey along a key transport corridor ensured a realistic behavioural setting within the wider policy context. Transport corridors are high-capacity arterial routes into the centre of urban areas, offering a self-contained unit of study. Furthermore, the study of a transport corridor enables the comparison of households living at different distances from the centre of Edinburgh. The centre of a city tends to be the most frequent trip destination. For journeys to the city centre, public transport is more competitive, along radial rather than orbital routes. Cycling may be more competitive on an orbital corridor but journey information is easier to analyse in a radial corridor study.

Figure 6.1. A map of the four postcode sector areas in the West Edinburgh survey



Key:

1. Dalry

2. Slateford

3. Wester Hailes

4. Currie

C. Centre of Edinburgh

The map is an output from the Geographical Information System, originally downloaded from DIGIMAP (described in Section 2.8).

The key transport corridors into Edinburgh were considered to be Leith Walk, Corstorphine Road, Gorgie Road, Slateford Road, Liberton Road, Morningside Road, London Road, Queensferry Road and Inverleith Row. The intention was to study a corridor up to 8km from the city, to include distances not possible by bicycle to the city centre. This ruled out those corridors to the North, and to a lesser extent the East of the city due to the spatial limits of the Firth of Forth.

A West Edinburgh transport corridor consisting of the Gorgie Road and the Slateford Road was chosen for a variety of transport, spatial and socio-economic criteria. Many of the reasons relate to the Edinburgh transport policy measures described in Section 4.3. The West Edinburgh transport corridor is clearly defined. Both the Gorgie Road and Slateford Road have Greenways as bus priority measures, making them particularly suited to bus journeys. The spatial dimensions of the postcode sector areas with the transport corridor made it suitable to survey. All four postcode sector areas are of a similar size across the transport corridor. Indeed, one of the corridor boundaries is particularly well-defined, as a railway line into the centre of Edinburgh.

There are further reasons for the choice of the West Edinburgh transport corridor. Non-motorised modes, particularly cycling, have a potential safe and convenient alternative route into the centre of Edinburgh from the West of the city, along the Union Canal. In terms of employment locations, journey to work destinations can be compared between those working in the centre of Edinburgh and those at a large out-of-town employment area, Edinburgh Park, in West Edinburgh.

The choice of West Edinburgh also enabled the examination of social inclusion aspects. One of the four postcode sector areas, West Hailes, was a Social Inclusion Partnership area, one of four spatial areas in Edinburgh identified for policy measures to tackle social exclusion. One of the four postcode sector areas, Dalry, as the nearest to the city centre, is likely to become part of the Controlled Parking Zone in the next few years (outlined in Section 4.3) and be compared with the other three postcode sectors in this respect. A contrast exists between Currie and the other postcode sectors: Currie could be considered an "urban fringe" area, the only postcode sector of the four areas outside the city bypass.

The sampling strategy for the West Edinburgh survey was to deliver questionnaires to three streets or sub-areas within four chosen postcode sectors at regular distances from the centre of Edinburgh, approximately 0-2km, 2-4km, 4-6km and 6-8km. Distances were included that are suitable for non-motorised mode travel to the city centre. In each postcode sector area, three households were randomly selected from the Electoral Register. There were 250 households sampled in close proximity to these households as a sub-area. The strategy concerned a combination of clustered and stratified random sampling to cut down on field costs. The strategy tallies with those recommended in the survey (Moser and Kalton, 1979; Bonsall and O'Flaherty, 1997) and transport application (Ortuzar et al, 2000) literature. It is of interest to make comparisons both within sub-areas, as households might be expected to have similar transport perceptions and decision-making process to their neighbours, and between postcode sector areas. As in any survey, sampling variability and non-response bias may affect the results, and it was important to minimise these effects. The analysis incorporates a series of spatial weights to boost under-represented areas and thus minimise non-response bias.

Edinburgh's population varies throughout the year. The composition of households sampled was therefore dependent on a number of factors such as tourist seasons, student term times and school holidays. For practical reasons, and due to the timing of the Scottish Transport Studies Group grant, the West Edinburgh travel behaviour survey was undertaken during July 2003. In July many individuals are away on holiday and many students studying in Edinburgh would have returned home. In the West Edinburgh survey, those away for a short period could have returned their questionnaires by post. The level of non-motorised mode use is much higher in Summer months, although only one question, concerning non-motorised mode usage over the previous seven days, reflects this. For cycling, statistics show that August is the peak cycling month, with more than twice the number of cycling journeys than in December, the month with the lowest level of cycling journeys (Department for Transport, 2003b).

6.5 Stated preference experiment design

The two stated preference experiments represent an original contribution. The first experiment examines the propensity to walk for current car drivers, the second the propensity to cycle for the journey to work or study. Before the design of these two experiments is outlined in Sections 6.5.1 and 6.5.2, general stated preference design aspects are outlined.

Stated preference experiments can be designed to produce three possible types of measurements - ratings, rankings and choices of respondents. Since the focus of this research is on travel behaviour choices, respondent choice is the measurement used. Choice is the most common, simplest and most reliable of the three measures. Choice is an appropriate metric because in reality individuals make decisions by comparing a set of alternatives and choosing one. In each experiment, a simple choice was requested, between walking and taking the motor car for a general trip, and between the bicycle and current mode for the journey to work or study. Technically "stated choice" is the correct term to use rather than the more generic "stated preference". However, the more commonly used "stated preference" was considered a more appropriate term for this study.

The format of the stated preference experiments was based on two surveys designed by a team including the author as part of two EPSRC Sustainable Cities projects. The first was a Belfast survey conducted in Summer 1998 (Cooper et al, 2001), the second, a comparative Belfast and Edinburgh survey conducted in Summer 2001 (Ryley et al, 2002).

The following series of tasks in experimental choice design are presented in Hensher (1994):

1. Identification of the set of attributes
2. Selecting the measurement unit for each attribute
3. Specification of the number and magnitudes of attribute levels
4. Statistical design, where the attribute levels are combined into an experiment
5. The experiment designed in task four has to be translated into a set of questions and show cards for execution in the data collection phase
6. The selection of an appropriate estimation procedure will be dependent on the metric of the response variable and the level of aggregation of the data for modelling
7. Estimated parameters are used in a simulated choice context to obtain choice probabilities for each alternative for each sampled individual

This process was adhered to in the design of the stated preference experiment. The choice of attributes, their related levels and how they correlate with each other is important, to ensure that individuals make realistic choices. In order to avoid bias, the order of presentation of exercises and scenarios within the experiments was randomly selected.

A consideration at the outset was to use a block design, whereby different attributes and attribute levels are set in a stated preference experiment given to respondents. Although more attributes and attribute levels can be tested in this manner, it makes aggregation of results difficult. Since travel behaviour can be complex to analyse, the focus is on specific aspects of modal shift from the motor car to non-motorised modes. From the motor car to walking, a general journey was considered with assumptions to make the trade-off realistic. From the motor car to cycling the journey to work or study was considered, as the most common cycling trip.

A factorial design is needed to disentangle complex sets of interrelationships and allows analysis of several variables in combination. If qualitative variables are used they are limited by the precision of verbal and visual descriptions. The orthogonal plan used for both stated preference experiments is taken from Kocur et al (1982) and shown in Table 6.3.

Table 6.3. Orthogonal design, of four attributes and three levels, for the two stated preference experiments in the West Edinburgh survey

1	2	3	4
0	0	0	0
0	1	1	2
0	2	2	1
1	0	1	1
1	1	2	0
1	2	0	2
2	0	2	2
2	1	0	1
2	2	1	0

With four variables in the propensity to cycle experiment, all four columns were used. Since the propensity to walk experiment uses three variables, columns one, two and four of this plan, were used.

A design was tested in the pilot survey and subsequently adapted to ensure respondents could easily understand the experiments. As outlined in the literature review, in Section 3.7, tentative attempts have been made to model mode choices that involve cycling, but not for walking. Therefore, the propensity to walk is a simpler design than the propensity to cycle experiment. The review of non-motorised modelling within the literature review gave insights into the design of the stated preference experiments. The propensity to cycle concerns a journey to work or study experiment, building upon the study by Wardman et al (2000a). It enables the behavioural change concerning the propensity to cycle in multiple stages to be examined, in a similar manner to the Davies et al (2001) study. The propensity to walk represents a new experimental field.

6.5.1 Propensity to walk for motorists

In the absence of previously published work examining walking trade-offs, a simple experiment of nine scenarios was designed using three time and cost variables. These variables are journey time, petrol or diesel price, and the cost of parking at the destination. A fourth, more qualitative variable, had been considered, such as the weather, carrying objects, an index of safe pedestrian routes, a percentage delay in traffic, and dark or light conditions. However, these variables can be difficult to set to ensure that individuals make valid decisions. Since this type of stated preference experiment has not been undertaken before, it was considered more appropriate to focus on standard time and cost values. Time and cost values associated with the motor car and public transport are typically used in the mode choice element within traditional four-stage models (Section 2.5), and were adapted for trade-offs between taking the motor car and walking. The cost values of car parking and fuel price are stick measures to motorists and topical policy measures (described in Section 2.4 and Section 4.6).

The choice set for a given journey was solely between the motor car and walking. Therefore, only current car drivers were considered for the experiment. The journey considered was one from their home to a destination in and around Edinburgh. Assumptions were provided: the respondent was travelling on their own, had nothing to carry, and the weather was dry. These make the trade-off between the motor car and walking more likely, because otherwise the motor car may have dominated choices. The journey time in the experiment was ten minutes door to door by motor car, which represents a short trip in and around Edinburgh.

The price of petrol or diesel at the time of the survey was approximately 80p per litre, so this figure was used as the base level from which realistic petrol rises could be attributed. Parking costs appropriate to Edinburgh were designated, in that parking may or may not incur a charge. It should be noted that these costs, unlike car insurance or depreciation of vehicle, are up-front in the sense that an individual notices every time they pay. The attribute levels in the pilot survey resulted in respondents tending to choose cost over time. Therefore, the cost values were reduced in the final form of the West Edinburgh survey to ensure the respondents made realistic choices.

The three attributes for the propensity to walk stated preference experiment, shown as differences between the two modes, are as follows:

- Door to door journey time: 10 minutes for all motor car choices; 15 minutes, 20 minutes and 30 minutes for the walking choices. This represented an extra journey time of 5 minutes, 10 minutes and 20 minutes to walk.
- Petrol or diesel price: No cost for all walking choices; 80p, £1 and £2 petrol costs for the motor car choices. This represented an extra cost of 80p, £1 and £2 to travel by motor car.
- Cost of parking car at destination: No cost for all walking choices; no cost, £2 and £5 parking charge for the motor car choices. This represented no extra cost, £2 extra and £5 extra to travel by motor car.

The journey times are higher for the walking choices, with the motor car trip always taking ten minutes. Obviously, there are not petrol or parking costs for the walking option.

6.5.2 Propensity to cycle for the journey to work or study

As shown in Section 2.2, the journey to work is the one most appropriate to study for cycling, as is borne out in the literature (Noland and Kunreuther, 1995; Gardner and Ryley, 1997; McDonald and Burns, 2001). A review of journey to work surveys (Gardner and Ryley, 1997) recommends that, of facilities at the workplace, the most cost-effective means to encourage cyclists are to provide secure bicycle parking and then to install cycle lockers and changing rooms. Other recommended employer measures to encourage cycling are installing shower facilities, introducing a relaxed dress code, enabling more flexible working hours and providing financial incentives such as cycle purchase loans, a reasonable cycle mileage allowance and cash alternatives to car parking spaces. The propensity to cycle experiment included the journey to study as well as the journey to work to boost the sample.

The design of the stated preference experiment is similar to that in Wardman et al (1997) whereby current mode (bus and motor car) is considered against cycling choices. In Ortuzar et al (2000), each respondent in the stated preference experiment stated either "yes, they would consider using bike" or "no, they would not even consider it" for a series of journeys, subsequently modelled as a binary logit function. It should be noted that this does not mean they would actually choose to cycle for the journey. The choice of words in this experiment was "my preferred choice would be".

As cycling to work or study is a minority activity, a qualifying question was set to categorise respondents according to their propensity to cycle. Individuals that would never consider cycling, whatever their circumstances, would not make trade-offs presented to them in the experiment. The reasons for never cycling could be personal. Alternatively, they could be due to the nature of the respondent's work or study e.g. the distance travelled could too far to cycle or the nature of their work makes cycling inappropriate. It was important to make the stated preference experiment appropriate for as many of the sample as possible. It is assumed in the experiment that a bicycle was available in the household for cycling to work or study. The experiment also considers only the morning journey from home to work or study, simpler to understand than both journeys.

The experiment compares current method of transport to work or study by motor car, by bus or by walking against travel by bicycle. Each scenario lists door-to-door journey time, cost (measured as a daily payment for cycling to work or study), the cycling facilities at the respondent's place of work or study, and the nature of the cycle route.

The study most relevant to the design of this stated preference experiment is Wardman et al (2000b), who used two different stated preference cycling mode choice experiments. Both experiments used time and cost of current mode with a range of cycling alternative variables. These alternatives included different types of cycling facilities, the number of people cycling, a payment received for cycling and the level of cycle trip end facilities. The experiment within their study of most relevance used the following attributes and attribute levels:

- Time taken by current mode: One of a range of 4 times based upon journey times in revealed preference questionnaire
- Cost by current mode: One of a range of 4 costs based upon costs calculated from revealed preference questionnaire
- Payment received: A daily payment of either 50, 100, 150 or 200 pence
- Facilities at work: Either 'no facilities', 'outdoor cycle parking', 'indoor cycle parking' or 'shower, changing facilities and indoor cycle parking'

The respondent had to choose between 'Current mode', 'Cycle', 'Another mode' or 'Not make journey'.

The stated preference experiment on the propensity to cycle in this study is at a smaller scale. It uses similar variables and contains only the choice between current mode and cycling to work or study. The attribute levels were carefully chosen to ensure respondents did not always choose the non-cycling option. The four attributes for the propensity to cycle stated preference experiment are as follows:

- Door to door journey time: Same as current for all bicycle choices; same as current, 10 minutes longer and 20 minutes longer for the current mode choices. This represented no extra journey time, an extra journey time of 10 minutes and an extra journey time of 20 minutes to use the current mode.
- Cost incentive, a daily payment for cycling to work or study: No incentive for all current mode choices; no incentive, 50p and £2 for the bicycle choices. This represented no extra payment, an extra payment of 50p and an extra payment of £2 to travel by bicycle.
- Cycling facilities at your place of work or study: For the bicycle choices, no cycle parking facilities, cycle parking facilities and a combination of cycle parking and shower / changing facilities.
- Nature of the cycle route: For the bicycle choices, the choice of cycling on-road with no cycle lanes, on-road with cycle lanes and off-road with cycle lanes.

Background information on the nature of the journey to work or study information is within Section D of the questionnaire (see Table 6.2). Some of this information is included as segmentation variables for the propensity to cycle discrete choice models (e.g. if the respondent was employed full-time or part-time).

6.6 Links to stage one data set

The second stage data set is smaller in scale and size than the first stage, the Scottish Household Survey data set, being reduced from a citywide data set to a transport corridor study i.e. a data set of 997 households compared to 2,910 households for the Scottish Household Survey. However, the West Edinburgh survey collected more in-depth data on transport information and travel behaviour than is included in the Scottish Household Survey data set. The West Edinburgh survey also has the advantage of being designed solely for this research, unlike the Scottish Household Survey.

The Scottish Household Survey data set has two levels of data - household and individual levels. This was replicated in the second stage dataset. The Scottish Household Survey data set contains facts about individuals and trips, but not about attitudes, motivations and propensity to use non-motorised modes. These are explored in the West Edinburgh survey analysis. Furthermore, the Scottish Household Survey does not measure the effect of transport policy measures, examined in the West Edinburgh survey analysis.

There are linkages between the two datasets (outlined in Section 2.2). Links between the two data sets are established through the application of population segments, the testing of transport availability and travel behaviour relationships, and the aggregation of the discrete choice model forecasts.

6.7 Modelling implications

The aim of the second research objective, "modelling individual travel behaviour and thus the propensity to use non-motorised modes", is to develop robust models, and from these discrete choice models produce practical outputs. The two stated preference experiments within the West Edinburgh survey enabled discrete choice models to be developed relating to the propensity to use non-motorised modes. Model development includes estimation of the models, models run by segment and model forecasting. The models run by segment include those split by individual segmentation variables and the population segments developed as part of the Scottish Household Survey analysis. The modelling results are shown in Chapters Nine and Ten. They include new non-motorised mode outputs, travel demand predictions and the direct policy testing of attributes within the stated preference experiments.

6.8 Summary

Chapter Six explains the relevance and validity of the data collected as part of the household survey of individual travel behaviour along a transport corridor West Edinburgh. As outlined in Section 6.2, concerning the design of the survey, the data collection technique was an innovative 'call and post' method. Section 6.3 presents the survey questionnaire, developed using a similar framework of variables (socio-economic characteristics, transport availability, travel behaviour) as the Scottish

Household Survey. Some variables are replicated from this survey; other variables are either drawn from other surveys or designed specifically for the West Edinburgh survey. The literature and policy reviews (Chapter 3 and Chapter 4) also aided questionnaire design.

The selection of the areas to survey is justified in Section 6.4. A transport corridor consisting of the Gorgie Road and the Slateford Road was chosen, sampling three streets or sub-areas (each with a target of 250 households) within four postcode sector areas at regular distances from the centre of Edinburgh. Differences between the four postcode sector areas enable policy measures to be examined (e.g. social inclusion, parking measures).

The design of the two stated choice experiments is outlined in Section 6.5. The first experiment examines the propensity to walk for current car drivers, with trade-offs between journey time, petrol or diesel price, and the cost of parking at the destination. The choice set, between driving and walking, represents a novel approach. The second experiment concerns the propensity to cycle for the journey to work or study. Developing on previous discrete choice modelling concerning the propensity to cycle (particularly Wardman et al, 2000b), trade-offs are presented between journey time, a cost incentive to cycle and cycling facilities (both on route and at the destination). A novel aspect is the categorising of respondents according to their propensity to cycle, ensuring that only those likely to trade-off between their current mode (by motor car, bus or on foot) and travel by bicycle answer the stated preference experiment.

Links to the stage one dataset are shown in Section 6.6. The West Edinburgh survey data set develops upon the empirical strengths of the Scottish Household Survey data set. In particular the West Edinburgh survey provides attitudinal variables and two stated preference experiments that focus on the propensity to use non-motorised modes. The links between the two data sets include the use of the same population segments, the testing of similar transport availability and travel behaviour relationships, and the aggregation of the discrete choice model forecasts. In addition to the forecasting, the modelling implications of the West Edinburgh survey data are segmentation by a range of variables and the direct policy testing of attributes within the stated preference experiments, as shown in Section 6.7.

Data from the survey of travel behaviour in West Edinburgh is used to test segmentation (in Chapter Eight) and modelling hypotheses (in Chapters Nine and Ten) hypotheses.

The data sets and survey designs from both stages have been outlined in Chapters Five and Six. Results from these two stages, testing the segmentation hypotheses, are presented in Chapters Seven and Eight.

7. ANALYSIS OF THE SCOTTISH HOUSEHOLD SURVEY DATA

7.1 Introduction

Chapter Seven presents analysis of the Scottish Household Survey data. The data set consists of 2,910 Edinburgh households taken from the 1999/2000 Scottish Household Survey sample. An outline of the sample is provided in Section 7.2.

There are three components of the Scottish Household Survey analysis. Firstly, the development of population segments based on current socio-economic characteristics is shown in Section 7.3. Secondly, in Section 7.4, the population segments are related to transport availability data. Thirdly, travel behaviour patterns within the Scottish Household Survey are examined in Section 7.5.

These three sections relate to the first three hypotheses:

- Hypothesis one: "The population is split into segments according to socio-economic characteristics"
- Hypothesis two: "Motor car and bicycle availability affects the propensity to use non-motorised modes"
- Hypothesis three: "Socio-economic and transport availability characteristics affect travel behaviour"

The implications for the stage two methodology and model development are also provided, in Section 7.6 and Section 7.7 respectively.

A Scottish Household Survey sample of 1,203 Edinburgh households, interviewed in 1999, was obtained and analysed in 2001 (Ryley, 2001). This was a pilot exercise, to become familiar with the Scottish Household Survey data set and to test some initial relationships concerning motor car and bicycle availability. A number of significant relationships were established using Chi square statistics: amongst the households, motor car and bicycle availability increased with household income and the presence of children. Furthermore, as car availability increased in a household, so did bicycle availability. These results show there to be a large population segment of higher income households with children present, who would have access to both a motor car and a bicycle.

7.2 The sample

Overall, 30,227 interviews were conducted across Scotland in 1999 and 2000 as part of the Scottish Household Survey. The 1999 and 2000 Scottish Household Survey sample analysed in this study (2,910 households) was obtained from the Scottish Executive in November 2001. All households are located within the City of Edinburgh Council area. Of these 2,910 households, 2,481 were collected by the Scottish Executive during 1999 and 2000, and 429 were collected on behalf of the City of Edinburgh Council as part of a boost survey between April and June 1999. The Scottish Household Survey sample consists of six data sets. Two of the data sets were not considered appropriate to this thesis and were excluded from the analysis. These data sets concern the travel of a randomly selected school child within the household, if relevant, and the characteristics of any motor vehicles available to a household. The remaining four Scottish Household Survey data sets, and the variables considered in the analysis, are shown in Table 7.1.

Table 7.1. Data sets and variables within the Scottish Household Survey sample

Data set	Variable
Household information	Number of adults in the household
	Number of children in the household
	House type (detached, semi-detached, terraced or flat)
	Banded net annual income
	Highest income householder
	Number of motor vehicles available
	Bicycles available for use by adults in the household
Random Adult information	How random adult usually travels to work
	Main reasons for using method of travel
	Type of car or van usually travel to work
	Where vehicle is parked
	Main reasons for not using public transport
	Would it be possible to use public transport
	Miles personally driven in past year
	Miles paid for by employer or business
	Main reasons chose not to drive nowadays
	Why never learnt to drive
	Cost of fares for transport excluding business
	Public transport costs for trips abroad or business
	Number of previous week trips taken by bicycle going somewhere
	Number of previous week trips taken by bicycle for pleasure
	Number of previous week trips on foot going somewhere
	Number of previous week trips on foot for pleasure
	Home postcode sector
	Work postcode sector
Person information	Age group
	Gender
	Current status (in education, employment or retirement)
	Current driving licence status
	Frequency of driving
	Main reasons for driving
	Travel pass ownership
	Pay reduced bus or rail fares
	Orange badge holder (have a disability)
Travel diary stage information	Main mode of transport
	Journey number of trip
	Journey purpose
	Type of journey
	Journey start time
	Journey end time
	Date of travel
	Day of week
	Origin postcode sector
	Destination postcode sector

7.3 Developing population segments based on socio-economic characteristics

The initial aim of the Scottish Household Survey analysis is to produce distinct household category groups, of a similar size and sharing certain socio-economic characteristics, using cluster analysis. The reason for working with similar sized groups is to facilitate further statistical analysis. The technique of cluster analysis has been justified in Section 5.5.

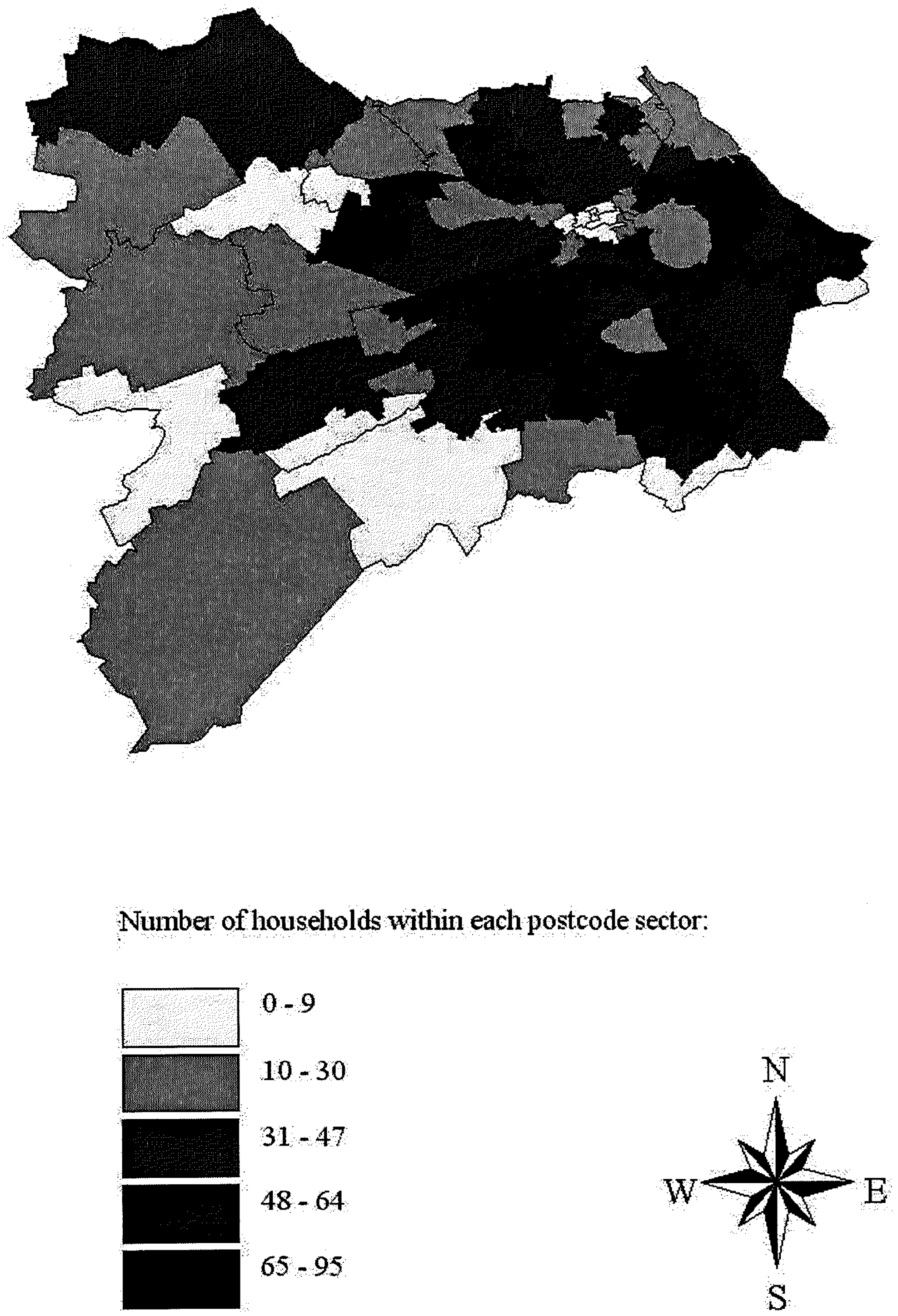
Hypothesis one, "the population is split into segments according to socio-economic characteristics", is tested. The technique of market segmentation (outlined in Section 2.3) and examples of the market segmentation are shown from the literature, of motorists in Section 3.3 and non-motorised mode users in Section 3.6. The resultant segments inform the statistical analysis of transport availability and travel behaviour, outlined in Sections 7.4 and 7.5 respectively.

7.3.1 Assessing socio-economic variables for cluster analysis

There are eight socio-economic variables within the Scottish Household Survey data set. Of these, four relate to the household and four relate to the individual respondent. The household variables are: the number of adults in the household; the number of children in the household; household net annual income; and house type. The respondent variables are: age; gender; current status; and if the individual has a disability (held an Orange badge).

In terms of household characteristics, most of the 2,910 households in the Scottish Household Survey sample contain one adult (1,045 households, 36%) or two adults (945 households, 33%). Just less than a quarter of households, 675 (22%), contain children. Most households, 1,673 (58%), live in flats; the remainder live in terraced, semi-detached or detached houses. A map of the spatial distribution of the households, according to home postcode sector, is shown in Figure 7.1.

Figure 7.1. A map of the spatial distribution of households within the Scottish Household Survey data set, according to home postcode sector



The map is an output from the Geographical Information System, of the 74 postcode sectors in Edinburgh.

Household income is provided in five separate income bands, measured in terms of net annual household income from employment, benefits and other sources. It refers to combined income coming into the household via the highest income householder and their spouse or partner. The income bands for 2,613 households (297 had missing data) are relatively evenly distributed amongst the sample. Of these households, 391 have an income between £0 and £6,000 (15%), 522 between £6,000 and £10,000 (20%), 561 between £10,000 and £15,000 (22%), 370 between £15,000 and £20,000 (14%) and 769 over £20,000 (29%).

In terms of respondent characteristics, there are 6,380 individuals in the sample, including children. Gender is fairly evenly split between male (3,001, 47%) and female (3,379, 53%) respondents. The sample population is divided into only four age bands: infant, child, working age and retired. Of these, only working age and retired were are relevant, since this study solely concerns adults. The age band and status categories have therefore been combined to produce life stage groups. Life stage group is considered a preferable description of the age bands. As defined in Section 2.3, a life stage can be defined as a specific, optional event such as learning to drive, moving home, moving job and choosing to have children. Travel behaviour changes in response to these choices. The ten most common life stage groups, amongst 5,904 of the 6380 individuals (93%), are shown in Table 7.2.

Table 7.2. The ten most common life stage groups in the Scottish Household Survey data set

	Frequency	**Percent**
1. Full time employment, working age	1971	30.9
2. Permanently retired from work, retired age	1045	16.4
3. Children (5-15) at school	771	12.1
4. Part-time employment, working age	526	8.2
5. Higher/further education, working age	425	6.7
6. Pre-school, pre-school age	343	5.4
7. Self-employed, working age	271	4.2
8. Working age, looking after home/family	256	4.0
9. Permanently sick/disabled, working age	156	2.4
10. Unemployed and seeking work, working age	140	2.2

From the 6,380 individuals, those with missing data (863), those permanently sick (127), Orange badge holders (158), children at school (853) and pre-school children (363) were taken out of the sample to leave 4,016 individuals for the cluster analysis. It should be noted that the children life stage groups of 'children (5-15) at school' and 'pre-school, pre-school age' are not included in the cluster analysis, since the focus is solely on adults. There are only 158 Orange badge holders in the sample (3%), which was considered to be too small a sample for the cluster analysis. The socio-economic characteristics within the data sets relating to households and individuals have been combined, according to each individual within the sample. Cluster analysis was performed upon the six socio-economic variables shown in Table 7.3.

Table 7.3. The socio-economic characteristics of the cluster analysis sample of 4,016 individuals from the Scottish Household Survey

Socio-economic variable	Split in the cluster analysis sample (n = 4,016)
1. Number of adults in household	1 : 910 (22.6%)
	2 : 2031 (50.5%)
	3 : 653 (16.2%)
	4 : 331 (8.2%)
	5 : 67 (1.6%)
	6 : 18 (0.4%)
	7 : 6 (0.1%)
2. Household income	£0 - £6000 : 434 (10.8%)
	£6000 -£10000 : 616 (15.3%)
	£10000 - £15000 : 782 (19.4%)
	£15000 - £20000 : 632 (15.7%)
	£20000+ : 1552 (38.6%)
3. House type	Flat : 2118 (52.7%)
	Terraced : 640 (15.9%)
	Semi-detached : 639 (15.9%)
	Detached : 619 (15.4%)
4. Life stage of individual	Full time employment : 1783 (44.3%)
	Self employed : 233 (5.8%)
	Higher/further education : 342 (8.5%)
	Looking after home/family : 221 (5.5%)
	Unemployed and seeking work : 125 (3.1%)
	Part-time employment : 467 (11.6%)
	Permanently retired from work : 845 (21.0%)
5. Gender of individual	Female : 2144 (53.3%)
	Male : 1872 (46.6%)
6. Number of children in household	0 : 2870 (71.4%)
	1 : 564 (14.0%)
	2 : 430 (10.7%)
	3 : 122 (3.0%)
	4+ : 30 (0.7%)

7.3.2 Performing cluster analysis on the Scottish Household Survey sample

Four hierarchical technique cluster analysis runs were undertaken. The aim is to produce up to eight clusters of population segments. Any cluster with less than 50 cases was discounted, to produce six (between groups average), eight (within groups average), three (centroid clustering) and eight (Ward's method) clusters respectively. From the variables being used to split the sample, it was evident that the life stage group was the most influential variable. For example, for the centroid clustering measure the three groups were split between those in education, those in full-time employment and those retired. It was considered desirable to create similar sized population segments of between 100 and 400 individuals, to enable further analysis. Comparing the clusters from the four runs, the large clusters were split in an iterative fashion to produce ten clusters. After life stage group, the three variables of number of adults, income and children present are the most influential. Where a cluster group had more than 90% of a socio-economic characteristic, the remainder were removed, to make the population segments more representative.

The cluster analysis produces the following ten groups, re-organised in approximate life stage order: 'students', 'in-between jobs', 'mid earners', 'high earners without children', 'part-timers without children', 'child minders', 'high earners with children', 'part-timers with children', 'retired couples' and 'retired living on own'. Key life stages from these clusters are, therefore, gaining employment, having children and retiring. Characteristics of the final ten population segments, consisting of 2,324 individuals are shown in Table 7.4. Thus, 58% of the 4,016 adults in the sample are allocated to one of the ten groups, reducing the sample to manageable groups of homogeneous individuals and facilitating the identification of relationships.

Apart from population segment ten 'Retired living on own' (the only category of individuals living on their own) there could be more than one adult from the same household within the same population segment. Furthermore, individuals in the same household appear in different population segments. The 2,324 adults in the final ten population segments are split across 1,664 households.

Table 7.4. Characteristics of the ten population segments from the cluster analysis of the Scottish Household Survey data

	Number	%	Key characteristics	Other characteristics
Group 1 – Student	127	5.5%	In higher or further education	3-5 adults in household; mainly low household income (73% < £10K pa); all flat-dwellers; 58% male; no children
Group 2 - In-between jobs	124	5.3%	Unemployed and seeking work	1-4 adults in household; mainly low household income (80% < £15K pa); mainly flat-dwellers (80%); 64% male; 65% no children
Group 3 - Mid earner	310	13.3%	Full-time employment, all mid income (£10K-£20K pa)	1-2 adults in household; all flat-dwellers; 50% male; all no children
Group 4 - High earner without children	349	15.0%	Full-time employment, all high income (over £20K pa); all no children	All 2 adults in household; mainly flat-dwellers (54%); 55% male
Group 5 - Part-timer without children	130	5.6%	Part-time employment; all no children	1-2 adults in household; even income spread; mainly flat-dwellers (64%); 74% female
Group 6 - Child minder	127	5.5%	All looking after home or family; all have children	1-2 adults in household; even income spread; mainly flat-dwellers (55%); all female
Group 7 - High earner with children	268	11.5%	Full-time employment, all high income (over £20K); all have children	All 2 adults in household; even accommodation spread; 75% male
Group 8 - Part-timer with children	205	8.8%	Part-time employment; all have children	1-2 adults in household; mid to high income (54% > £20K pa); even accommodation spread; all female
Group 9 - Retired in a couple	359	15.4%	All 2 adults in household; all permanently retired	Mid to low income (84% < £15K pa); flat most popular (47%); 52% female; no children
Group 10 - Retired living on own	325	14.0%	All 1 adult in household; all permanently retired	Mainly low income (all < £15K pa); mainly flat (70%); 75% female; no children
Total	2324	100%		

Further cluster analysis was undertaken to reduce further the larger groups amongst the ten population segments. The five groups with more than 250 cases were broken into two sub-groups each according to a mutually exclusive socio-economic variable, to produce fifteen population segments. As before, four hierarchical technique cluster analysis runs were undertaken. The results are as follows:

- Group 3 - Mid earner: 310 cases were split according to income, 184 with £10,000-£15,000 per annum and 126 with £15,000-£20,000 per annum
- Group 4 - High earner without children: 349 cases were split according to house type, 188 living in flat accommodation, 161 living in non-flat accommodation
- Group 7 - High earner with children: 268 cases were split according to house type, 115 living in flat or terraced accommodation, 161 living in semi-detached or detached accommodation
- Group 9 - Retired in a couple: 359 cases were split according to house type, 167 living in flat accommodation, 192 living in non-flat accommodation
- Group 10 - Retired living on own: 325 cases were split according to income, 133 with less than £6,000 per annum and 192 with £6,000-£15,000 per annum

7.3.3 Assessment of hypothesis one

Hypothesis one, "The population is split into segments according to socio-economic characteristics", is accepted on the basis of the results from the cluster analysis. Most individuals within the data set (2,324, 58% of the sample) can be attributed to one of the ten homogeneous population segments, based on socio-economic characteristics. The most influential variable upon ten population segments is life stage. The life stages of gaining employment, having children and retiring primarily determine the nature of the population segments. A further breakdown of the population segments, into fifteen groups, also proves to be useful. It illustrates that household income and house type, more than household composition (number of adults, number of children) and gender, are important variables in the classification of individuals into population segments.

The population segments developed from the cluster analysis are used in further hypotheses tested in this thesis. The socio-economic variables within the Scottish Household Survey data set that had been aggregated, in particular age and household income, were collected at a more disaggregate level as part of the West Edinburgh survey.

7.4 Relating transport availability data to the population segments

Section 7.1 outlines relationships from a pilot Scottish Household Survey data set, which demonstrate that motor car and bicycle availability increases with household income and children present. These relationships were confirmed using the larger sample of 2,910 Edinburgh households, as initial analysis of the main sample. In addition, it was shown that both motor car and bicycle availability decrease as housing density increases. The house type variable was used as a surrogate for density. Flats were considered the highest density, through terraced and semi-detached houses, to detached houses as the lowest density. These relationships have been established from other research studies on urban form and travel behaviour, as presented in Section 3.2.

From the literature review of market segmentation studies (Sections 3.3 and 3.6) it has been confirmed that vehicle availability, whether a motor car or a bicycle, affects usage of that mode. The variables of motor car and bicycle availability are linked to the population segments developed in Section 7.3. Availability is preferable to ownership because it provides a clearer indication that the mode is ready to use when required by an individual.

Hypothesis two is tested: "Motor car and bicycle availability affects the propensity to use non-motorised modes". Propensity to use non-motorised modes from the transport availability data is assessed. From the sample of 2,910 households, motor car (1,158, 40% of the sample) and bicycle (919, 32% of the sample) availability is considered. Individuals without a motor car available have a greater propensity to use non-motorised modes than individuals with a motor car available, because there is no competition from the motor car. Furthermore, if a bicycle is available, an individual within the household appears to have a greater propensity to cycle, since they will not have to go through the stage of buying (and possibly saving up for) a bicycle before cycling. Propensity to cycle, to walk and to use public transport, according to motor car and bicycle availability, is shown in Table 7.5. Two caveats should be highlighted here: firstly, household availability of a particular mode of transport is not attributed to a specific individual within the household; and secondly, availability does not equate to use of the mode.

Table 7.5. Propensity to cycle, to walk and to use public transport according to motor car and bicycle availability

		Motor car available	
		Yes	**No**
Bicycle available	**Yes**	Likely to use motor car for most journeys, but bicycle available for some journeys	Greatest propensity of the groups to cycle, since no temptation to use the motor car instead of cycling
	No	Greater propensity to use motor car, less propensity to cycle	Greater propensity to use other modes such as walking and public transport, with no motor car or bicycle available

7.4.1 Assessing motor vehicle and bicycle availability by population segment

Inspection of the data, by the ten population segments, shows that almost all of the individuals in high earning households (91% of those without children, 94% of those with children) have motor vehicles available and could be regarded as car dependent. The population segments with lowest motor car availability are the population segments 'retired living on own' (17%), 'students' (26%) and 'in-between jobs' (38%).

In terms of adult bicycle availability, the primary difference observed between population segments from the variables analysed, relates to the presence of children within the household. The bicycle availability percentages for 'high earners with children' and 'part-timers with children' are 66% and 59% respectively; the equivalents for the same households without children are much lower at 46% and 33%. The three population segments with the highest proportion of adult bicycles available are 'high earners with children' (66%), 'part-timers with children' (59%) and 'students' (51%).

The four combinations of motor car and bicycle availability, presented in Table 7.4, for each of the ten population segments were examined and are presented in order of propensity to cycle (lowest propensity first):

1. **No adult bicycle available, but motor car available (36%).** This group appears to have the least propensity to cycle and would be the most car dependent. The main population segments within this group (in order) are those 'retired with others' (56%), 'high earners without children' (49%) and 'mid earners' (40%).
2. **Neither adult bicycle nor motor car available (26%).** This group would have greater propensity for walking and public transport journeys, since bicycle and motor car journey would not normally be an option. The main population segments within this group (in order) are those 'retired living on own' (82%), 'in-between jobs' (45%) and 'retired in a couple' (34%).
3. **Both an adult bicycle and a motor car available (32%).** This group is likely to use the motor car for most journeys, although with adult bicycles also available, may have potential for cycling. The main population segments within this group (in order) are 'high earners with children' (63%), 'part-timers with children' (52%) and 'high earners without children' (42%).
4. **Adult bicycle available, but no motor car available (7%).** This group would have the greatest propensity to cycle, since there is no competition from the motor car. However, it is a very small population segment (7%) and the proportion decreases as individuals go through the life cycle. The main population segments within this group (in order) are 'students' (45%), those 'in-between jobs' (17%), 'part-timers without children' (11%) and 'mid earners' (11%).

The key conclusions of the transport availability variables in this analysis, relating to the four availability types, are:

1. Particularly car dependent groups without bicycles are **retired individuals living with others** and **high earners without children**.
2. Those **retired** are particularly suited to walking and public transport, since they may not be able or are too old to drive and/or cycle.

2&4. Those **in-between jobs** could be targeted with all sustainable transport modes (non-motorised modes and public transport).

3. **Households with children** and **higher income households** tend to have both a motor car and bicycle available, and could, therefore, be targeted with cycling initiatives.
4. The primary segment with adult bicycles available and no motor car present is **students**.
4. Only a small proportion of the population (7%) is captive to cycling, being in a position where they have an adult bicycle but no motor car.

7.4.2 Assessment of hypothesis two

Hypothesis two, "Car and bicycle availability affects the propensity to use non-motorised modes", can be assessed. Although this hypothesis does not directly relate to travel behaviour and did not use any rigorous statistical techniques, propensity to use non-motorised modes has been described. Of the ten population segments, it has been shown that students have the greatest propensity to cycle. They are more likely to have a bicycle than a motor car available. Possible population segments to target for walking could be those retired and those in-between jobs. The hypothesis has, therefore, been accepted.

7.5 Examining travel behaviour patterns based on socio-economic and transport availability data

In this section hypothesis three is tested: "socio-economic and transport availability characteristics affect travel behaviour". Travel behaviour is examined from the three journeys recorded in the Scottish Household Survey. Firstly, non-motorised journeys, over a quarter of a mile, made the previous week are considered in Section 7.5.1. Secondly, the journey to work is examined in Section 7.5.2. Thirdly, journeys made the previous day, as recorded in a travel diary, are analysed in Section 7.5.3. Modal split statistics for these three journeys within the Scottish Household Survey are shown in Table 7.6.

Table 7.6. Modal split statistics for the three journeys recorded in the Scottish Household Survey

Description	**Sample**	**Motor car driver or passenger**	**Cycle**	**Walk**
General walking or cycling for a particular purpose (utility trip)	2,730 adults		115 (4.2%) adults	1,758 (64.4%) adults
General walking or cycling for pleasure (leisure trip)	2,730 adults		102 (3.7%) adults	1,113 (40.8%) adults
Journey to work	1,438 working adults	568 drive (39.5%), 92 passenger (3.4%)	57 adults (4.0%)	296 adults (20.6%)
Journeys made the previous day, from travel diary entries	6,381 journey stages	3,337 stages by car (52.3%)	83 stages (1.3%)	1,674 stages (26.2%)

7.5.1. Non-motorised modes journeys the previous week

Walking and cycling journeys made the previous week by adults randomly selected from the survey population, split by the ten population segments, are shown in Table 7.7 and Table 7.8 respectively.

Table 7.7. Cycling journeys the previous week recorded in the Scottish Household Survey data set

	Bicycle utility trip		**Bicycle leisure trip**		**Any bicycle trip**		
	Count	%	Count	%	Count	%	Total (100%)
Group 1 – Student	4	14.3%	2	7.1%	5	17.9%	28
Group 2 – In-between jobs	7	8.6%	6	7.4%	9	11.1%	81
Group 3 - Mid earner	14	6.0%	12	5.1%	22	9.4%	234
Group 4 - High earner without children	11	7.1%	8	5.2%	14	9.0%	155
Group 5 – Part-timer without children	1	1.4%	1	1.4%	2	2.7%	74
Group 6 - Child minder	1	1.3%	0	0.0%	1	1.3%	79
Group 7 – High earner with children	9	7.8%	12	10.4%	18	15.7%	115
Group 8 – Part-timer with children	4	3.3%	8	6.5%	10	8.1%	123
Group 9 - Retired in a couple	2	1.1%	0	0.0%	2	1.1%	179
Group 10 - Retired living on own	1	0.3%	1	0.3%	2	0.6%	325
TOTAL OF SEGMENTS	54	3.9%	50	3.6%	85	6.1%	1393
OVERALL TOTAL	115	4.2%	102	3.7%	174	6.4%	2730

Table 7.8. Walking journeys the previous week recorded in the Scottish Household Survey data set

	Walk utility trip		**Walk leisure trip**		**Any walk trip**		
	Count	%	Count	%	Count	%	Total (100%)
Group 1 - Student	24	85.7%	7	25.0%	24	85.7%	28
Group 2 - In-between jobs	61	75.3%	30	37.0%	67	82.7%	81
Group 3 - Mid earner	161	68.8%	106	45.3%	188	80.3%	234
Group 4 - High earner without children	103	66.5%	69	44.5%	122	78.7%	155
Group 5 – Part-timer without children	65	87.8%	27	36.5%	66	89.2%	74
Group 6 - Child minder	61	77.2%	28	35.4%	63	79.7%	79
Group 7 - High earner with children	68	59.1%	58	50.4%	91	79.1%	115
Group 8 – Part-timer with children	88	71.5%	48	39.0%	104	84.6%	123
Group 9 - Retired in a couple	103	57.5%	76	42.5%	124	69.3%	179
Group 10 - Retired living on own	177	54.5%	93	28.6%	202	62.2%	325
TOTAL OF SEGMENTS	911	65.4%	542	38.9%	1051	75.4%	1393
OVERALL TOTAL	1758	64.4%	1113	40.8%	2052	75.2%	2730

Cycling numbers are very small within the Scottish Household Survey data set, with 174 (6% of the sample) having made a trip the previous week. These figures are too small to draw conclusions from. However, the results provide some useful insights. The three population segments containing the highest proportion of cyclists, in order, are 'students' (18%), 'high earners with children' (16%), and those 'in-between jobs' (11%). A comparison can be undertaken with the three population segments containing the highest proportion of adult bicycles available, 'high earners with children' (66%), 'part-timers with children' (59%) and 'students' (51%). It shows that households with children are those most likely to have an adult bicycle available but do not necessarily use it.

The Scottish Household Survey data for cycling the previous week shows there are almost no cyclists amongst some segments. It is note-worthy that only 1% of individuals in each of the 'child minder' and the two retired segments make any trip by bicycle the previous week. For the overall sample there is an even split between utility and leisure trips (4% in each). It is noticeable that only a quarter of cyclists (43 out of 174 cyclists) made both utility and leisure trips. Therefore, the minority who cycle tend to be either utility or leisure cyclists.

Three quarters of the sample make a walking trip the previous week. Individuals that had not made a walking trip the previous week tended to be retired; many within the retired population segments would have found it difficult to walk. All of the population segments have more individuals making utility than leisure walking trips, indicating walking is more of a utility mode than cycling from this data. The population segments with the highest proportion of utility walkers, namely 'students', 'part-timers without children' and 'child minders', tend to conduct leisure walking the least.

7.5.2. Journey to work

For the journey to work, respondents listed reasons for their mode choice. Over half of the motorists surveyed (57%) state that the motor car is the most convenient mode; 36% of motorists state that it is the quickest mode. The primary mode choice reasons amongst the 57 adults who cycle to work are convenience, speed and exercise. Over 40% of respondents mention each of these reasons. The most popular reasons amongst the 296 adults who walk to work are the close proximity of the workplace to the home (57%), convenience (32%), exercise (30%) and speed (16%).

Speed and convenience are considered as reasons for non-motorised mode use, but these are also common reasons given across all transport modes. It is difficult to interpret the 'convenience' reason, since convenience is a word with many meanings. Scottish Household Survey interviewers do not probe any further to illicit more information relating to the reason for using a particular mode. In relation to this study, it is of particular interest that exercise is provided as a reason by many of those cycling and walking to work. Exercise is a key advantage specific to non-motorised modes and is becoming increasingly important in our fitness and health conscious society, and borne out in recent policy strands on health and obesity, outlined in Section 4.2.

Five of the ten population segments are not relevant to the journey to work analysis: 'students', those 'in-between jobs', 'child minders' and the two retired segments. Of the five population segments in work, the most car dependent are 'high earners with children' (65% driving to work); this group has the lowest proportion of individuals walking to work (10%). The other four groups have at least 20% of their population segment walking to work. The greatest proportion is for 'part-timers without children' (31%). Cycling numbers are too low to discern differences between population segments (the proportion cycling to work is between 2% and 6% for the five segments).

Due to only five population segments being of relevance for the journey to work analysis, individual socio-economic and transport availability variables are considered in the analysis rather than the population segments. SPSS Answer Tree was employed on the socio-economic and transport data obtained from the Scottish Household Survey to ascertain the factors affecting travel behaviour for the journey to work. Within Answer Tree, the mode choice (Yes or No) for the five modes of cycle, walk, motor car (driver and passenger) and bus were tested according to eight variables. These variables are the number of adults in the household, the number of children in the household, household income, house type, gender of respondent, motor car availability, bicycle availability and journey distance. Journey distance was calculated between postcode sectors for each journey to work within the dataset using the Geographical Information System.

Of the eight variables, distance is the most influential variable affecting mode choice. Distance splits by mode show the dominant modes: walking, between 0km and 1.87km; bus, between 1.87km and 3.19km; and the motor car, from 3.19km upwards. The statistics re-emphasise the point that non-motorised transport requires short distances to be competitive. Most journeys to work on foot (90%) are less than 2.8 kilometres. Although cycling is suitable for longer journeys than walking, it does not dominate for any journey length (as shown by the Answer Tree analysis) and still remains inappropriate for many journeys to work, given that many respondents commute over a long distance. A variety of distance statistics for the journey to work are shown in Table 7.9.

Table 7.9. Distance travelled statistics for the journey to work recorded in the Scottish Household Survey

Mode	Number of adults	Number with distance statistic	Ten percentile	Ninety percentile	Mean
Motor car driver	568	365	1.2km	9.2km	4.9km
Motor car passenger	92	51	1.0km	7.3km	4.0km
Bus	379	269	1.5km	7.9km	4.4km
Cycling	57	42	0.2km	7.0km	3.2km
Walking	296	222	0.0km	2.8km	1.4km

Note: this analysis includes 'within postcode sector' trips, recorded as 0.0km

Table 7.9 shows there are not distance statistics for many adults within the journeys to work data set. This is due to either the respondent working outside the City of Edinburgh Council area or respondents not recording a distance statistics (e.g. the individual may work in several locations).

Further Answer Tree analysis was undertaken without the distance variable. As expected, the main influencing variables upon driving to work, in order, are car availability and then income. For the cycling journey to work, the main influencing variables in order, after bike availability, are house type and then gender. An individual is more likely to cycle to work if they are male and live in a flat. For walking, the main influencing variables are house type and then the number of adults in the household.

An individual is more likely to walk to work if they live in a flat and are in a household of two or more adults. One of the disadvantages with the methodology employed is the complex interplay of factors affecting mode choice, and it was not possible to control for certain factors (e.g. income) to assess the effect of other variables (e.g. mode availability) upon mode choice.

The analysis shows that an individual is more likely to cycle or walk to work if they live in a flat. Although residents in flats may have fewer bicycles available than those in other house types, they are more likely to use them, certainly for the journey to work. Car ownership is often not possible amongst flat-dwellers due to the lack of available parking space. The housing distribution in Edinburgh is pronounced, with many flats located towards to the city centre. Flat-living in Edinburgh is, therefore, more suited to travel by non-motorised modes, since living near to the city centre makes journeys shorter than on the periphery. Of the five population segments that work, this finding is relevant to 'mid earners', the only group in which every individual lives in a flat.

7.5.3. Journeys made the previous day

There are 2,730 adults and 446 school children within the travel diary data set. Of these individuals, 2,166 made at least one journey the previous day (a total of 6,381 journeys). Of the 6,381 journeys, 3,337 (52%) were by motor car or van (driver or passenger), 1,674 (26%) were walking and 83 (1%) were by bicycle. Each journey is classified according to trip purpose. Cycle trips are small in number (83) and only in double figures for journeys to educational establishment, journeys to work and trips made by those participating in sport. Walking can be seen to compete with the motor car for some trip purpose types such as shopping, educational establishment, eating or drinking, and day trips. However, the motor car is dominant across trip purpose. The number of motor car trips (combining driving and passenger) is greater than cycling and walking for all of the trip purposes.

It is possible to link 926 walking trips within the travel diary to the ten population segments. The primary walking trip purpose for the segments is to the workplace, to an educational establishment or, if neither of these two options were relevant, to the shops. For each of the six segments that work or study, walking to the shops represents the second most frequent trip on foot, at between 15% and 22% of all trip purposes. The second most frequent walking trip was a 'day trip' for the two retired population segments and 'visiting friends or relatives' for those 'in-between jobs' and 'child minders'.

The travel diary data is split into journeys to or from the city centre and within postcode sector. Distance information was calculated using the Geographical Information System. The modal split, showing the proportion of city centre trips and within postcode sector trips, is shown in Table 7.10.

Table 7.10. Modal split of travel diary journeys recorded in the Scottish Household Survey

Mode	Number of journeys with distance information	Number to or from the city centre	Number within postcode sector
Motor car driver	1773	196 (11%)	140 (8%)
Motor car passenger	608	77 (13%)	58 (10%)
Bus	838	339 (41%)	30 (4%)
Cycling	70	8 (11%)	11 (16%)
Walking	1338	228 (17%)	457 (34%)

The information presented in Table 7.10 emphasizes the importance of the bus as a mode of transport serving the city centre of a city, and the role of non-motorised transport (in particular walking) as important for local, neighbourhood trips. Improving city centre development encourages higher bus patronage and measures to promote local, neighbourhood trips will encourage more walking.

7.5.4. Assessment of hypothesis three

Hypothesis three, "socio-economic and transport availability characteristics affect travel behaviour" has been accepted for non-motorised journeys made the previous week, the journey to work, and journeys made the previous day. The level of cycling varies amongst population segments. Higher levels exist amongst 'students', 'high earners with children' and those 'in-between jobs'. Of these population segments, 'students' tend to be at an early life stage. Households with children are most likely to have adult bicycles not being used. There are very low cycling levels amongst 'child minders' and those who have retired. Most of the sample had made a walking trip the previous week, apart from some retired individuals who are presumably physically unable to do so. The analysis of non-motorised mode trips in the previous week shows that people tend to be either utility or leisure cyclists. This compensatory nature of utility and leisure cycling could also be applicable to walking.

From the journey to work data, exercise is perceived as a specific advantage for non-motorised modes. Close proximity to the workplace is also shown to be an advantage for walking to work; most of these journeys (90%) are less than 2.8 kilometres. Distance has been shown to be the primary determinant of the mode choice to work. If distance is removed from the equation, house type is the most influential variable. Higher levels of cycling and walking to work are undertaken by those living in flats. The modal split for the journey to work has been examined for the five relevant population segments. Of these groups, 'high earners with children' are the most likely segment to drive to the workplace, 'part-timers without children' are the most likely segment to walk.

The travel diary data provides more detailed information on individual modal choices, as it covers all modes and all trip purposes. The motor car dominates across trip purposes, but the principal walking and cycling trip purposes have also been shown. For cycling, journeys to educational establishments, journeys to work and participating in sport feature most often. For walking, shopping trips, journeys to educational establishments, eating or drinking trips, and day trips feature most often. Amongst the ten population segments, shopping is the most frequent walking trip purpose, aside from those who walked to work or to study. An examination of the journey distances confirms that non-motorised modes are particularly suited to local neighbourhood trips.

Having few cyclists amongst the sample for all three journeys creates problems for the analysis. This is because the percentage of cyclists making journeys (for all three journeys it is less than 5% of the sample) is much lower than bicycle availability (bicycle ownership is 32% of the sample). This shows the need for the data within the West Edinburgh survey, focusing on the larger proportion within the population who do not currently cycle. Analysis of the West Edinburgh survey data examines the reasons why these individuals do not cycle and what might encourage them to cycle. This is shown in Chapter 9.

7.6 Summary

Chapter Seven presents analysis of the Scottish Household Survey data, with the comprehensive sample of 2,910 Edinburgh households summarised in Section 7.2.

Using the cluster analysis technique, there are ten distinct population segments identified using the socio-economic Scottish Household Survey data, in Section 7.3. With most individuals within one of the ten population segments (58% of the sample), the first hypothesis of "the population is split into segments according to socio-economic characteristics" has been accepted. The ten population segments deduced from the Scottish Household are arguably in more depth than the socio-economic population segment summaries in Transport Visions Network (2001) and are more relevant for Edinburgh households than the United Kingdom Census based demographic classifications of MOSAIC and ACORN (outlined in Section 2.3). This is reinforced by the particular socio-economic characteristics associated with Edinburgh: a higher proportion of young adults, households on higher incomes and a lower proportion of families than the UK average (presented in Section 1.5).

Of the six socio-economic variables tested, the most influential variable upon the characteristics of the ten population segments is life stage. The key life stages identified are gaining employment, having children and retiring. Although the exploratory nature of cluster analysis denotes that the influence of specific variables could not be directly quantified, it enabled further clusters to be explored. A further breakdown of the population segments, into fifteen groups, illustrates that household income and house type, more than household composition (number of adults, number of children) and gender, are important variables in the classification of individuals into population segments.

An examination of the literature concerning the market segmentation of non-motorised mode users (Section 3.6.2), shows that only one study considers the cluster analysis of socio-economic data (Davies et al, 2001), albeit with bicycle ownership, bicycle usage and attitudes towards cycling variables. A unique aspect of this study is that it considers cluster analysis separately as a prelude to travel behaviour analysis.

The ten population segments developed in the testing of the first hypothesis, are linked to transport availability variables in Section 7.4. Almost all high-earning households (over 90%), either with or without children, have a motor car available and could be considered a particularly car dependent population segment. The life stage of having children produces the greatest observed difference between availability and non-availability of bicycles.

The second hypothesis of "motor car and bicycle availability affects the propensity to use non-motorised modes" has been accepted because there are discernible differences between availability and propensity to use non-motorised modes amongst the ten population segments. It has been shown that 'students' have the greatest propensity to cycle, and those retired (both population segments) and 'in-between jobs' have the greatest propensity to walk. Only a small proportion of the population (7%) is captive to cycling, having a bicycle available but not a motor car. Due to the analysis not relating to travel behaviour and not using rigorous statistical techniques, further analysis is required to show more on the propensity to use non-motorised modes.

Travel behaviour is examined in Section 7.5. Hypothesis three, "socio-economic and transport availability characteristics affect travel behaviour" has been accepted for non-motorised journeys made the previous week, the journey to work, and journeys made the previous day.

Analysis of the non-motorised modes shows there are some population segments with almost no individuals cycling the previous week. Only 1% of each of the population segments of 'child minder', 'retired in a couple' and 'retired living on own' cycled the previous week. Assuming individuals within the 'child minder' population segment are in households with younger children than the other population segments with children, it can be asserted that households with younger children cycle less than those containing older children.

In terms of walking the previous week, the population segments with the highest proportion of utility walkers are 'part-timers without children' (88%), 'students' (86%)

and 'child minders (77%). Those that had not walked the previous week tend to have retired.

The compensatory nature between utility and leisure non-motorised mode trips is of interest. Policy should emphasise both types of trip, particularly cycling that has an even split between utility and leisure trips. Analysis of Scottish Household Survey pilot sample data established that leisure cycling is linked to high income households and households with children. Leisure cycle routes accessible to housing areas where children predominate could be promoted, in conjunction with cycling to school policies. Households with children have been shown to be the most likely amongst the population to own but not use bicycles. Higher-income households may be more likely to use these routes, but lower-income households should also be targeted for social inclusion reasons (social inclusion policy is outlined in Section 4.2). In addition, cycling initiatives should be targeted at utility routes to areas of study and work.

From the reasons individuals provided for their journey to work mode choice, exercise emerges as a particular advantage for travelling by non-motorised modes. This can be linked back to recent policy developments on health; promoting exercise through non-motorised mode use is a measure to encourage a healthier nation. Close proximity to the workplace has also been shown to be an advantage for walking to work. With most walking journeys (90%) under 2.8 kilometres and distance being shown to be the primary determinant of the mode choice to work, there should be a stronger land-use policy to encourage employers to locate close to residential areas. Mixed land use, particularly for residential and employment functions, should be encouraged.

The importance of local trips within the residential neighbourhood has been highlighted in the travel diary analysis. Travelling on foot, and to a lesser extent by bicycle, as shown by the journey to work analysis, can be strongly linked to high-density accommodation. There is a spatial dimension, since those living in high-density accommodation tend to reside nearer to the centre of Edinburgh. Individuals tend to travel to undertake activities. Therefore, activities need to be planned so that they are close at hand if individuals are to walk to them, with associated provision of local pedestrian facilities. United Kingdom transport statistics state shopping as the primary walking trip purpose (Section 2.2.3). The survey data has shown shopping to be one of the two primary walking trips for all ten population segments; particular focus should be on provision of local shopping facilities within walking distance of residential areas.

One relationship established from the initial Scottish Household Survey data analysis has been greater availability of the motor car and bicycle in lower density housing. Yet, as shown in the relationship between urban form and travel behaviour (Section 3.2), non-motorised modes are suited to higher density housing. The analysis of the journey to work data highlights a link between living in flats and cycling or walking to the workplace. In terms of cycling, there is, therefore, a need to develop schemes to enable bicycle storage in tenements, whether using space on the footway, the shared green or car parking spaces. There is also a need to develop routes linking lower density housing areas, encouraging households with bicycles to use them more frequently.

From the literature on car dependency (Section 3.3), it has been determined that those with the greatest propensity to own and use a motor car include those of working age, male, on higher incomes and who have children. The analysis of the journey to work data confirms these relationships, with 'high earners with children' being the population segment containing the highest proportion of individuals driving to the workplace.

This Chapter has provided insights in the propensity to use non-motorised modes between different population segments ('inter-segment'). It would be of interest to explore further and examine differences within population segments ('intra-segment'). There are some individuals on high incomes, with children and a car available that still choose to cycle. It would be of interest to understand some of the reasons why these individuals cycle, while others within the same population segment choose not to. The Scottish Household Survey did not permit the analysis of reasons behind mode choice; this is explored in the analysis of the West Edinburgh survey data.

One aim of the Scottish Household Survey analysis has been to inform development of the stage two data collection. The disaggregate variables collected within the West Edinburgh survey provide more detailed information on the choices individuals make when deciding whether to walk or whether to cycle. Obtaining a sufficiently large data set of cyclists presents problems. For this reason, the journey to work, the most popular cycling trip, was chosen for the stated preference experiment concerning the propensity to cycle in the West Edinburgh survey. The design and analysis of the survey also concerns the larger proportion within the population who do not currently cycle, focusing on the reasons why these individuals do not cycle and what might encourage them to cycle.

The analysis of the Scottish Household Survey data, testing three hypotheses, has been presented in Chapter Seven. A further two hypotheses, using West Edinburgh survey data, are tested in Chapter Eight.

8. ANALYSIS OF THE WEST EDINBURGH SURVEY DATA

8.1 Introduction

Chapter Eight presents results from analysis of data from the West Edinburgh survey. The dataset consists of 997 households along the transport corridor consisting of the Gorgie Road and the Slateford Road. An outline of the sample collected is presented in Section 8.2.

There are two components of the West Edinburgh survey analysis presented in this Chapter. Firstly, car driver responses to the problems associated with the motor car are examined in Section 8.3 to test hypothesis four: "Car drivers acknowledge the problems associated with the motor car but are unwilling to change travel behaviour". Secondly, the propensity to use non-motorised modes is deduced from the attitudinal statements in Section 8.4 to test hypothesis five: "Attitudes towards non-motorised modes vary greatly amongst the population segments". Each of the hypotheses is tested against individual socio-economic and transport availability variables. Important relationships developed are also examined against the postcode sector areas and the population segments defined as part of hypothesis one in Chapter Seven. The relationships developed in this Chapter are tested against a series of weights in Section 8.5, to compensate for non-response bias.

8.2 The sample

The survey was undertaken between the 8th and 30th July 2003. There were 3,000 questionnaires delivered to households along the West Edinburgh transport corridor; 750 questionnaires were delivered in each of the four postcode sector areas, from EH11 1 in Dalry to EH14 5 in Currie. The questionnaires were equally distributed within each postcode sector to three randomly selected sub-areas.

8.2.1 Postcode sector areas

A brief description of each of the four postcode sector areas is provided, as a background to the West Edinburgh survey data. Information sources include the Scottish Household Survey sample and the 2001 Census data for the journey to work.

Journey to work data by the four postcode sectors was downloaded from the 2001 Census website (http://www.scrol.gov.uk/scrol/common/home.jsp - Table KS15 Travel to work and place of study). This data, adapted for this study, is shown in Table 8.1. A distance statistic from the town centre (from postcode sector area centroid to the centroid of the most central postcode sector area in Edinburgh, EH2 2) and the size of the postcode sector area were also incorporated, from the Geographical Information System database.

Table 8.1. Modal split for the journey to work or study for the four postcode sectors within the West Edinburgh survey, using data from the 2001 Census

Area	**Individuals in work or study**	**Work or study mainly at or from home**	**Travel to place of work or study by:**				
			Bus, minibus or coach	**Driving a car or van**	**Passenger in a car or van**	**Bicycle**	**On foot**
Scotland	2,510,494	6.1%	14.0%	50.0%	8.3%	1.4%	14.1%
Edinburgh (Council area)	252,414	5.8%	26.2%	36.1%	4.7%	3.3%	20.8%
EH11 1 "Dalry"	8,880	3.9%	34.6%	28.4%	3.5%	4.9%	21.8%
EH14 1 "Slateford"	4,428	4.8%	31.7%	42.2%	5.1%	2.9%	10.6%
EH14 2 "Wester Hailes"	4,241	5.0%	33.3%	37.4%	6.1%	1.4%	13.5%
EH14 5, EH14 4 "Currie"	6,130	9.3%	15.5%	42.2%	4.4%	1.6%	24.5%

Note: The sample was composed solely of individuals aged 16-74 in employment or studying. The modes "underground, metro, light rail, tram", "train", "motorcycle, scooter or moped", "taxi or minicab" and "other" are excluded from the table because they are not of interest to this study. EH14 5 could not be accessed on it's own – it had to be combined with EH14 4.

Of the four postcode sector areas, EH11 1 (Dalry) is the smallest and closest to the centre of Edinburgh. It has an area of $0.9km^2$ and is 2.5km from the city centre. From the Scottish Household Survey sample of 95 individuals, the highest representation of the ten population segments are for 'mid earners' (23), 'high earners without children' (9) and those 'retired on their own' (7). Almost all of the housing within this postcode sector is three or four storey tenements. An example of such a tenement, in Bryson Road, is shown in Figure 8.1. The 2001 Census data for the journey to work shows that, of the four postcode sector areas, cycling to work is highest in Dalry (4.9%).

EH14 1 (Slateford) has an area of $3.0km^2$ and is 4.2km from the city centre. From the Scottish Household Survey sample of 71 individuals, the highest representation of the ten population segments is for individuals 'retired on their own' (13), individuals 'retired in a couple' (6) and 'mid earners' (5). There is a mixture of housing in the Slateford postcode sector area, of both flats and houses. For example, one of the three sub-areas consists of tenements (Moat Street), whilst another contains semi-detached and detached houses (Colinton Road).

EH14 2 (West Hailes) is $3.4km^2$ and 6.5km from the centre of Edinburgh. West Hailes is a Social Inclusion Partnership area, reflected by individuals 'in-between' jobs (7) having the greatest representation amongst the Scottish Household Survey ten population segments from the 43 households in Wester Hailes. From the 2001 Census data, households driving to work or study increases with distance from the city centre, except for the lower-income postcode sector area of Wester Hailes. Of the three sub-areas surveyed in West Hailes, two contain four storey tenements (Dumbryden Gardens, Murrayburn Place). An example of this tenement housing, from Murrayburn Place, is shown in Figure 8.2. The remaining sub-area (Redhall Bank Road), outside the Social Inclusion Partnership area, contains a mixture of houses and flats.

EH14 5 (Currie), at $7.8km^2$ and 9.5km from the city centre, is on the urban fringe, the only postcode sector outside the city bypass. From the Scottish Household Survey sample of 46 individuals, the highest representation of the ten population segments is for individuals 'retired in a couple' (9) and individuals 'retired on their own' (8).

Figure 8.1. Bryson Road - an example of a tenement in the Dalry postcode sector

Figure 8.2. Murrayburn Place - an example of a tenement in the Wester Hailes postcode sector

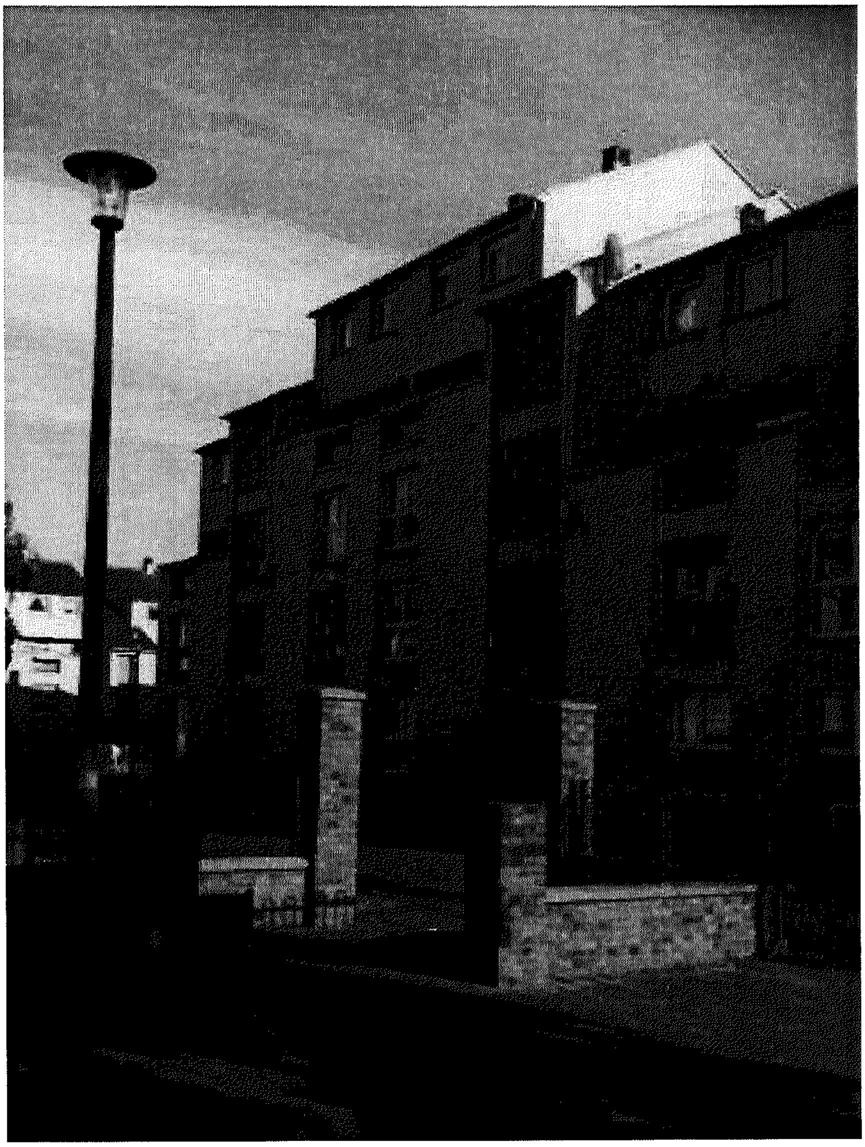


Figure 8.3. Curriehill Castle Drive - an example of housing in the Currie postcode sector

Almost all residents in Currie live in terraced, semi-detached and detached houses. These three house types are evenly represented amongst the three sub-areas surveyed in Currie. An example of a house in the Currie sub-area of Curriehill Castle Drive is shown in Figure 8.3. Since Currie is the furthest of the four postcode sectors from the city centre, travel on foot to work or study is higher than expected from the 2001 Census data. This may have been due to students living in Currie and walking to study at the nearby Riccarton campus of Heriot-Watt University. Currie has a much lower bus patronage for the journey to work or study than the other three postcode sectors, possibly reflecting the strength of the transport corridor within the city bypass.

8.2.2 A summary of the sample

Of the 3,000 questionnaires delivered, 1,269 were physically handed to householders and 1,731 were posted through letterboxes. There were also 212 refusals (14% of the 1,481 households where someone was in when the survey team called). The refusal rate by sub-area was unevenly distributed, ranging from 3.5% in Curriehill Avenue to 26.5% in Forthview Avenue. A difference in refusal rates may be due to a high number of door-to-door surveys and sales people in some sub-areas, deterring individuals from responding to the West Edinburgh survey.

Of the 3,000 questionnaires delivered, 997 were returned. This represents an overall response rate of 33%. It is a satisfactory response compared with previous surveys, of similar sizes, undertaken by teams including the author; a postal household survey in Belfast had a response rate of 18% (Cooper et al, 2001) and an Edinburgh-based household survey using a mixture of post and 'call and collect' methodologies had a response rate of 41% (Ryley et al, 2002). Surveys only tend to have higher response rates when they are targeted at a specific employer, whether as a university (Hole, 2004) or company (Bergström and Magnusson, 2003).

There were 591 questionnaires returned when they had been handed over on the doorstep (47% response rate) and 399 questionnaires returned when they had been posted through the letter-box (23% response rate). Those returned include seven questionnaires returned with valid results, but that could not be linked to a sub-area because the respondent had deleted or taken off the questionnaire number and thus the street identifier. Most of the questionnaires came back within a week (64%), and almost all were returned within four weeks (96%). Table 8.2 shows the questionnaires returned according to the four postcode sector areas and the twelve sub-areas.

Table 8.2. West Edinburgh survey questionnaire returned by postcode sector and sub-area

	Number delivered	Number returned	Percentage response rate
Area 1 – Dalry - EH11 1	**750**	**221**	**30%**
Bryson Rd	250	74	30%
Hermand Crescent	250	90	36%
Stewart Terrace	250	57	23%
Area 2 - Slateford - EH14 1	**750**	**311**	**42%**
North Meggetland	250	120	48%
Moat St	250	70	28%
Colinton Rd	250	121	48%
Area 3 – Wester Hailes – EH14 2	**750**	**169**	**23%**
Redhall Bank Road	250	92	37%
Dumbryden Gardens	250	29	12%
Murrayburn Place	250	48	20%
Area 4 – Currie - EH14 5	**750**	**289**	**39%**
Forthview Avenue	250	67	27%
Curriehill Castle Drive	250	110	44%
Corslet Road	250	112	45%
Total		**990**	
Missing a street identifier		**7**	
Total		**997**	

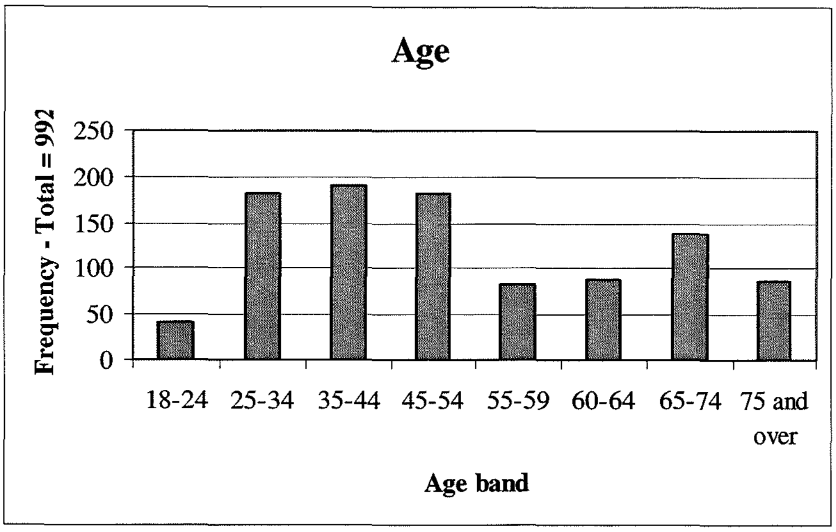
The distribution of the 990 questionnaires according to postcode sector area is as follows: 221 from Dalry (22%), 311 from Slateford (31%), 169 from Wester Hailes (17%) and 289 in Currie (29%).

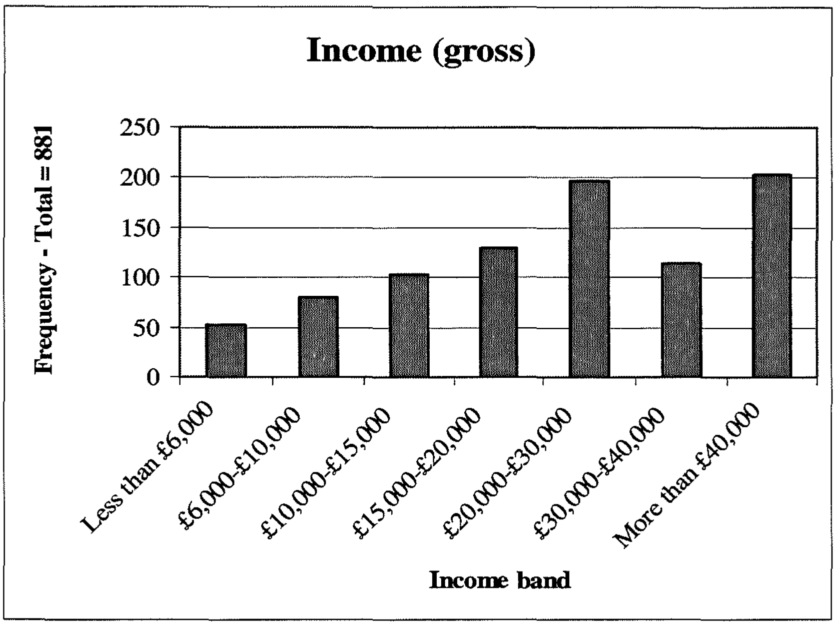
There is a very different response rate between areas and streets. Response rates are greater in sub-areas containing higher income households and lower density housing, such as Colinton Road, North Meggetland, Corslet Road and Curriehill Castle Drive. The lower income and high-density housing sub-areas with poor response rates are Dumbryden Gardens and Murrayburn Place, both in Wester Hailes. The lower response rates in these sub-areas may be due to difficulties in accessing the stair entrance, and that in flats households are more likely to be out at the time of call. Section 8.5 weights the sample according to postcode sector area and sub-area, to take account of these spatial differences.

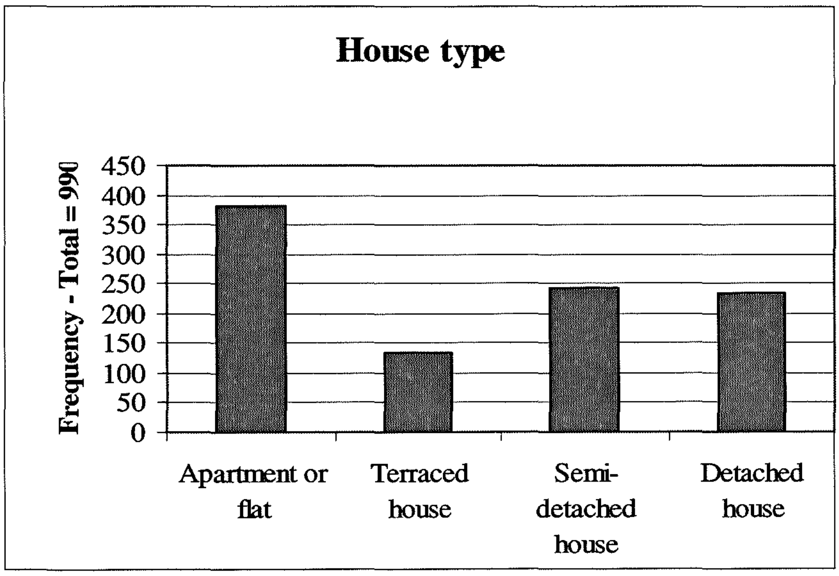
8.2.3 Socio-economic data

There is an almost equal split of respondents by gender, with 489 male and 498 female. There are 28 disabled respondents (holders of a Blue badge, 3% of the sample), and a further 24 households in which someone else in the household was disabled. Therefore, a total of 52 households survey contain someone with a Blue badge. Although small in number, this variable is used as a segmentation variable in the discrete choice modelling for the propensity to walk (in Chapter 10). Figure 8.4 shows some of the other socio-economic sample characteristics, namely age of respondent, income and house type.

Figure 8.4. Characteristics of the West Edinburgh survey sample







Note: Totals are less than 997 due to missing data

Figure 8.4 shows an even distribution amongst the sample by age band. Gross household income was requested from respondents, since they are more likely to know gross income than the net income variable within the Scottish Household Survey. The higher income bands have a greater representation in the West Edinburgh survey sample than the lower income bands. Although most respondents provided income information (876 respondents, 88%), many of those not providing income details strongly objected within the Comments section of the questionnaire.

House type, a surrogate for housing density, is closely linked to postcode sector area and sub-area. The high-density flats are nearer to the centre of Edinburgh, whereas the detached houses are further out, as shown in the description of the postcode sector areas (Section 8.2.1). Table 8.3 shows the number of adults and children present in households.

Table 8.3. Number of adults and children present in households within the West Edinburgh survey data set

Number of adults in household	**No children present**	**Children present**	**Total**
1 adult	305	24	329
% of Total	31%	2%	33%
2 adults	374	170	544
% of Total	38%	17%	55%
3 or more	94	27	121
% of Total	9%	3%	12%
Total	**773**	**221**	**994**
% of Total	78%	22%	100%

Note: Total less than 997 due to missing data

Of interest are that 22% of households in the sample had children and that the greatest adult-children combination was for 38% of households with two adults and no children. Table 8.4 shows the status of the questionnaire respondents.

Table 8.4. Status of the West Edinburgh survey respondents

	Frequency	**Percentage of respondents**
Employed full time	470	47.7
Permanently retired from work	271	27.5
Employed part-time	99	10.1
Self-employed	64	6.5
Looking after home or family	31	3.1
In education	21	2.1
Permanently sick or disabled	16	1.6
Unemployed and seeking work	8	0.8
Unable to work: short-term illness or injury	4	0.4
Government work or training scheme	1	0.1
Total	985	100.0
Missing	12	
Total	997	

Of the status categories, respondents in work or study are of the most use since they also complete Section D of the questionnaire, regarding their journey to work or study. There are 654 respondents in work or study, further split into 470 in full-time employment, 99 in part-time employment, 64 self-employed and 21 in education (only 2% of the sample). The very low student numbers reflects the fact that the four postcode sectors are not typical student residential areas. Approximately a quarter (271 respondents) are in retirement within the West Edinburgh survey sample.

8.2.4 Background transport and travel data

Respondents in the West Edinburgh survey were asked the mode and frequency of their travel to or through the city centre, along the transport corridor sampled. The main mode of travel (used by 57% of the sample) to or through the city centre of the sample is bus, a mode particularly suited to transport corridors. Travel by bus is the most popular mode to or through the city centre across all four postcode sector areas. The other modal shares of interest, for the whole sample, are 29% car driver, 2% bicycle and 7% walk. As expected, walking is popular for those near the centre, and the motor car for those near the city boundary. Frequency of travel is similar across modes, but respondents tended to travel more frequently to or through the city centre the closer they lived to the urban core.

A summary of headline statistics of the transport availability and general travel behaviour within the questionnaire is shown in Table 8.5.

Table 8.5. A summary of transport availability and travel statistics from the West Edinburgh survey

Segmentation variable	**Number of cases (Total = 997)**	**Number of variable categories**	**Headline statistic**
Car available	960	Free response	20% of households did not own or have a car available
Bicycle available	874	Free response	52% of households did not own or have an adult bicycle available
Travel as car driver	891	7	63% drove "most days", 14% "never" drove
Travel by bicycle	677	7	7% cycled "most days", 60% "never" cycled
Travel on foot	836	7	61% walked "most days", 2% "never" walked

Some of the responses, particularly to the cycling questions, are under-represented. It is assumed that respondents left questions blank if they considered them inappropriate. The travel behaviour statistics re-emphasised that travel by motor car and on foot are regular activities undertaken by most of the sample, whereas cycling remains an activity undertaken by a small minority. Most individuals never cycle (60%). Amongst the sample, there are 560 car drivers who drive "most days" (63%). Representation amongst this group is related particularly to certain income brackets and postcode sector areas. A comparison of the income bands shows that the proportion of the sample driving most days steadily rises through the seven income bands from 33% in the lowest income band (household income of less than £6,000) through to 74% in the highest income band (household income of more than £40,000). Individuals living further out from the centre of Edinburgh are more likely to drive "most days" (37% in the Dalry postcode sector up to 77% in the Currie postcode sector).

8.2.5 A comparison of the ten population segments between the two data sets

The Scottish Household Survey and the West Edinburgh survey have been compared with reference to the composition of the ten population segments within the two samples. The ten population segments (defined in Section 7.3) are shown in Table 8.6, both for the overall West Edinburgh sample and broken down by postcode sector area.

Table 8.6. The ten population segments within the West Edinburgh survey, for the overall sample and split by postcode sector area

Population segment	**Scottish Household Survey**	**West Edinburgh survey**				
		All four postcode sector areas	Dalry	Slateford	Wester Hailes	Currie
1 – Student	127 (5%)	21 (3%)	11 (6%)	4 (2%)	3 (2%)	3 (1%)
2 - In-between jobs	124 (5%)	8 (1%)	2 (1%)	2 (1%)	1 (1%)	3 (1%)
3 - Mid earner	310 (13%)	103 (12%)	60 (31%)	22 (8%)	15 (12%)	5 (2%)
4 - High earner without children	349 (15%)	225 (27%)	79 (41%)	67 (25%)	24 (20%)	55 (22%)
5 - Part timer without children	130 (6%)	47 (6%)	4 (2%)	20 (7%)	7 (6%)	16 (7%)
6 - Child minder	127 (5%)	17 (2%)	6 (3%)	5 (2%)	2 (2%)	4 (2%)
7 - High earner with children	268 (12%)	103 (12%)	12 (6%)	34 (13%)	17 (14%)	40 (16%)
8 - Part timer with children	205 (9%)	52 (6%)	3 (2%)	13 (5%)	10 (8%)	26 (11%)
9 - Retired in a couple	359 (15%)	140 (17%)	4 (2%)	56 (21%)	21 (17%)	58 (24%)
10 - Retired living on own	325 (14%)	115 (14%)	11 (6%)	46 (17%)	23 (19%)	35 (14%)
Total in population segments	2324 (100%)	831 (100%)	192 (100%)	269 (100%)	123 (100%)	245 (100%)
Sample total (% sample assigned to a population segment)	4016 (58%)	997 (83%)	221 (87%)	311 (86%)	168 (73%)	290 (84%)

There is a higher proportion of the sample within the West Edinburgh survey assigned to the ten population segments (83%) than the Scottish Household Survey (58%). The criteria for definition of the ten segments were not as strict for the West Edinburgh survey so that the segment size enabled analysis of individual segments. Although the samples for students (21), those in-between jobs (8) and child minders (17) are too small to permit disaggregate analysis, the remaining seven population segments are analysed in this Chapter.

The breakdown of population segment by postcode sector area confirms some of the characteristics of the Scottish Household Survey sample for these areas. These are the high concentration of retired individuals in Slateford and Currie, and the high proportion of 'mid earners' in Dalry. Indeed, Dalry has the most uneven distribution of the ten population segments; most individuals (72%) within the sample from Dalry are either 'mid earners' or 'high earners without children'. The spatial distribution of households with children is particularly pronounced, with a higher proportion of children present in households the greater the distance from the centre of Edinburgh. 'High earners with children' and 'part-timers with children' increase from 6% and 2% respectively in Dalry up to 16% and 11% in Currie.

The West Edinburgh survey has a much higher representation of 'high earners without children' (and to a lesser extent those 'retired in a couple') than the Edinburgh-wide Scottish Household Survey sample, at the expense of 'students', those 'in-between jobs', 'child minders', 'high earners with children' and 'part-timers with children'.

The 166 respondents within the West Edinburgh survey not classified according to the ten population segments primarily consists of the self-employed (64); those employed full-time on low incomes or with missing income data (39); those permanently sick or disabled (16); those retired but not living on their own or in a couple without children (16); and those staying at home but without children (14).

8.3 Car driver responses to the problems associated with the motor car and transport policy measures

In this Section, hypothesis four is tested: "Car drivers acknowledge the problems associated with the motor car but are unwilling to change travel behaviour".

Firstly, the respondents' perceptions of the problems associated with the motor car are examined, using responses to general transport attitudinal statements. These are presented in Section 8.3.1. Secondly, car driver responses to two questions relating to transport policy measures are analysed. The first question concerns the travel behaviour response to six transport policy measures and is examined in Section 8.3.2. The second question concerns response to price changes in petrol or diesel and is examined in Section 8.3.3. A range of responses was available to respondents, to assess their position on a scale of travel behaviour change away from their motor car. An assessment of the hypothesis is provided in Section 8.3.4 and policy measures to reduce car use are suggested in Section 8.3.5.

8.3.1 Attitudes to the problems associated with the motor car

Respondents were asked their level of agreement with eleven statements. Two of these statements concern the main problems associated with the motor car, congestion and air pollution. Almost all respondents in the sample agree that "congestion is a problem in Edinburgh" (86%). Indeed, this statement elicits the greatest level of agreement amongst respondents of all eleven statements. Most (68%) agree that "air pollution is a problem in Edinburgh", although many are unsure (23% neither agreed nor disagreed). The majority, 66%, agree or strongly agree with both statements. It can, therefore, be asserted from the survey that individuals perceive both congestion and air pollution to be problems in Edinburgh. The proportion in agreement with both statements is lower for the 550 motorists that drive "most days" (59%), but still represents the majority of frequent car drivers.

Correlation between agreement with these two statements and six socio-economic and travel behaviour segmentation variables was tested. The segmentation variables are age, gender, household income and frequency of driving, cycling and walking. The correlations are shown in Table 8.7.

Table 8.7. The correlation between agreement with statements on pollution and congestion and six segmentation variables, using the West Edinburgh Survey sample

Variable	Values	Agreement with congestion statement – scale from 1 = "Strongly agree" to 5 = "Strongly disagree"			Agreement with air pollution statement – scale from 1 = "Strongly agree" to 5 = "Strongly disagree"		
		Number	**Pearson correlation**	**Significance level**	**Number**	**Pearson correlation**	**Significance level**
Age	Scale from 1 = "18-24" to 8 = "75 and over"	985	-0.045	0.162	981	-0.030	0.353
Gender	1 = "Male", 2 = "Female"	980	-0.044	0.173	976	-0.185**	0.000
Household income p.a.	Scale from 1 = "Less than £6,000" to 7 = "More than £40,000"	875	0.105**	0.002	875	0.180**	0.000
Frequency of travel as a car driver	Scale from 1 = "Most days" to 7 = "Never"	885	-0.069*	0.040	882	-0.157**	0.000
Frequency of travel as a cyclist	Scale from 1 = "Most days" to 7 = "Never"	674	0.031	0.418	673	0.082*	0.032
Frequency of walking	Scale from 1 = "Most days" to 7 = "Never"	831	0.017	0.624	830	0.074*	0.033

Note: * = correlation significant at the 0.05 level (2-tailed), ** = correlation significant at the 0.01 level (2-tailed).

Table 8.7 shows that amongst the population segments, the most disagreement with the statements addressed to motorists is by males, those on higher incomes and those with higher car usage. The correlation between these three variables and the two statements is significant in each of the eight cases, apart from between gender and the congestion statement. The relationships are stronger for the air pollution than the congestion statements. Of interest to this study is that individuals who cycle and walk more frequently are more likely to agree that air pollution is a problem in Edinburgh.

Of the four postcode sector areas, Dalry has the highest proportion of respondents agreeing that congestion and pollution are problems in Edinburgh (89% and 75% respectively). Slateford has the lowest for congestion (83%), Currie has the lowest for air pollution (64%). There appears to be a slight spatial effect, that those living nearer to the centre of Edinburgh are more likely to agree that congestion and air pollution are problems (particularly air pollution).

Of the seven population segments, the highest proportion of respondents agreeing that "congestion and pollution are problems in Edinburgh" is for 'part-timers with children' (96% and 81% respectively) and 'mid earners' (93% and 80% respectively). Those 'retired in a couple' (82% and 55% respectively) and 'high earners without children' (82% and 65% respectively) have the lowest proportions. From these segments it appears that households without children and on higher incomes are more likely to disagree that congestion and air pollution are problems in Edinburgh.

8.3.2 Car driver responses to six transport policy measures

Car drivers were also asked for their response to six current and potential transport policy measures. These six transport policy measures are categorised in the analysis as either sticks or carrots (defined in Section 2.4.2). The sticks are: gradually doubling the cost of petrol; charging drivers a £2 daily charge to enter the city centre; making parking penalties and restrictions much more severe; and making most city routes a 20mph speed limit. The carrots are: improving the frequency of local buses; and improving the local cycle facilities. In response to the six transport policy measures, the five options offered to respondents were "use car even more", "make no difference", "use car a little less", "use car a lot less" and "give up using car".

There were 609 car drivers who provided responses to the six transport policy measures. Of these, most (489, 80%) are known to drive "most days". By postcode sector area, the highest proportion of car drivers is in Currie (the lowest proportion is in Dalry); by population segment it is those classified as 'high earners with children' (the least were 'mid earners').

The proportion of the 609 car drivers that would reduce their motor car use (ticked one of the following three options: "using car a little less", "use car a lot less" or "give up using car"), in response to each of the six transport policy measures, are:

1. Gradually double the cost of petrol	70%
2. Improve the frequency of local buses	61%
3. Charge motorists £2 to enter the city centre during the day	50%
4. Make parking penalties and restrictions much more severe	42%
5. Improve the local cycle facilities	27%
6. Make most city routes a 20mph speed limit	20%

Therefore, the main influencing measures are either sticks affecting the user's costs (either increasing petrol prices or introducing road user charges), or carrots improving the public transport alternatives. In terms of car driver responses to local cycle facilities, only a small group of car driver respondents (27%) would reduce their motor car use if there is an improvement to local cycle facilities.

Further segmentation analysis was undertaken of those prepared to give up using their motor car in response to a transport policy measure i.e. 78 respondents (13%) that stated they would "give up using car" for at least one of the six transport policy measures. Those on lower household incomes are more likely to be in this group, particularly those on less than £15,000 per year (26% of this group). There is no evident link between readiness to give up using the car and either the remaining socio-economic variables (age or gender) or postcode sector area.

For the 78 individuals prepared to give up their car for at least one of the policy measures, there is no spatial effect. The proportion is similar for each area: Dalry (13%), Slateford (15%), Wester Hailes (11%) and Currie (12%). There is a difference amongst the population segments. The highest proportions are for 'mid earners' and 'retired living on own', although the number of car drivers answering this question is small for some population segments (the lowest were 26 'part-timers without children').

At the other end of the travel behaviour change spectrum, an indicator of those reluctant to reduce car use is the proportion of respondents ticking "Make no difference" or "Use car even more" for all of the six transport policy measures. This is 13% (81 respondents) of car drivers.

The proportion within this group is much lower in Dalry (3%) than the other areas of Slateford (8%), Wester Hailes (10%) and Currie (11%). There is, therefore, a small spatial effect, with car drivers near to the centre of Edinburgh more reluctant to change travel behaviour for any policy measure. With small sample sizes and small differences in proportions amongst the seven population segments (between 4% and 10%), it is not possible to make statements concerning these groups.

8.3.3 Car driver responses to price changes in petrol or diesel

Car driver respondents in the West Edinburgh survey were asked to choose from a list the petrol or diesel price levels at which they might "consider what alternatives are available" and "definitely use an alternative" to the motor car (622 respondents). The price changes are based on the price of fuel as at July 2003 (80p a litre). The proposed price level rises in the questionnaire are £1 a litre (25% increase), £2 a litre (250% increase), £5 a litre (625% increase) and £10 a litre (1,150% increase).

As expected, there is an overall reluctance to change travel behaviour in response to a change in petrol or diesel price. This was illustrated by low price elasticities, of between -0.058 and -0.087, for the four price increases. Respondents included in the elasticity calculations are those who stated a definite change in behaviour away from the motor car.

However, a small proportion of car drivers would change travel behaviour at the slightest price increase; 16% would at least consider alternatives for a 25% increase to £1 a litre. These 99 car drivers, eleven of whom would definitely give up driving if petrol prices increased to £1, were tested against the segmentation variables. Income is the only variable that significantly correlates against the change in price, with perhaps predictably respondents in lower income households more likely to change their travel behaviour. This may be reflected in the analysis by spatial area and population segment. The proportion of car drivers who would change at the slightest increase in fuel is highest in Wester Hailes (19%), more than the three areas of Dalry (15%), Slateford (15%) and Currie (16%). By population segment, the highest proportions who would change travel behaviour at the slightest increase in fuel are 'part-timers without children' (28%) and those 'retired in a couple' (21%).

It is of interest to note the price turning points at which respondents would either "consider" or "definitely" change travel behaviour. The most popular trend amongst car drivers (192, 31% of the sample) is to consider what alternatives are available at the £2 level, and then definitely use an alternative at the £5 level. It must be borne in mind that with only five price alternatives provided, the situation in reality would be much more complex.

At the other end of the spectrum, there is a small proportion of car drivers (12%), who would not change their car use even if the petrol or diesel price increased by over ten times current levels (to £10 a litre). Suppressed demand for motoring is also evident amongst some drivers for the one option of a decrease in the petrol or diesel price to 60p a litre (25% reduction). Of the respondents, 52 (8% of 622 car drivers) would "consider using the car more often" at a 25% price reduction in fuel.

8.3.4 Assessment of hypothesis four

In this Section hypothesis four has been tested: "Car drivers acknowledge the problems associated with the motor car but are unwilling to change travel behaviour". From the attitudinal question relating to the problems associated with the motor car, most car drivers agree that congestion and air pollution are problems in Edinburgh. The first part of the hypothesis, that car drivers acknowledge the problems associated with the motor car, can therefore be accepted. Car drivers in the sample typically drive most days, are from higher income households and live towards the edge of the urban area.

The majority of car drivers are reluctant to change travel behaviour away from the motor car. This is shown from their responses to six transport policy measures and proposed fuel price rises. Only a minority of car drivers state a readiness to change travel behaviour, illustrated by just 13% being willing to give up use of their car for at least one of the six transport policy measures presented. The transport policy measures with the largest impact upon car drivers are changes to the user's costs and provision of public transport improvements.

8.3.5 Policy measures to reduce car use

Due to the current level of car dependency and the reluctance of most of the population to change travel behaviour, several policy measures are to be recommended to reduce use of the motor car. Transport policy measures with the largest impact upon car drivers in the West Edinburgh survey are changes to the user's costs and provision of public transport improvements. The most popular measure, of improving public transport should be encouraged, alongside some stick measures to increase the user's costs, due to lack of a willingness amongst car drivers to voluntarily change travel behaviour. Possible stick measures could be increasing petrol costs (national transport policy) or introducing the congestion charging scheme (local transport policy). There are, therefore, fiscal policy measures that could be implemented at a national and local level to force car drivers to change their travel behaviour.

Only a large fuel price rise would result in most car drivers considering a travel behaviour change away from the motor car. The West Edinburgh survey shows that most common experience amongst the population is to consider alternatives to the motor car at a fuel price of £2 a litre and to give up using the motor car at £5 a litre, an price increase of 625% on current levels (as of July 2003). It also shows that the price of fuel should not be reduced, since there is supressed demand amongst some car drivers.

8.4 Propensity to use non-motorised modes from the attitudinal statements

In this Section hypothesis five is tested: "Attitudes towards non-motorised modes vary greatly amongst the population segments". The roles of cycling and walking as alternatives to the motor car are examined in turn, using the non-motorised transport attitudinal statements. The correlation of the cycling and walking statements is tested against eight socio-economic, transport availability and travel behaviour segmentation variables. The segmentation variables are age, gender, household income, bicycle availability, motor car availability and frequency of driving, cycling and walking. Answers to these questions are analysed for the postcode sector areas and the seven population segments.

8.4.1 Responses to cycling statements

The cycling attitudinal statements include the strength of feeling towards cycle lane provision, both on-road and off-road, and safety fears from traffic, often stated as the main barrier to cycling. It is of interest to understand the responses to weather and topography, frequently quoted as deterrents to cycling. The weather variable is that Edinburgh is too wet to cycle; the topography variable that Edinburgh is too hilly for cycling. It is acknowledged that these aspects are difficult to change using transport policy measures. The results are shown in Table 8.8.

Table 8.8. Responses to cycling statements from the West Edinburgh survey sample

Statement	Strongly agree or agree		Neither agree nor disagree		Disagree or strongly disagree		Total
More money should be spent improving on-road cycle lanes in Edinburgh	352	48.6%	270	29.0%	208	22.4%	930
More money should be spent improving off-road cycle lanes in Edinburgh	648	68.8%	209	22.2%	85	9.0%	942
Safety fears of traffic prevent me from cycling more often in Edinburgh	452	52.7%	248	28.9%	158	18.4%	858
Edinburgh is too hilly to cycle	190	21.3%	333	37.4%	368	41.3%	891
Edinburgh is too wet to cycle	199	22.5%	330	37.3%	355	40.1%	884

There is more agreement than disagreement for an increase in spending to improve cycle lanes in Edinburgh, both on-road and off-road, particularly amongst younger respondents (individuals aged 18-24 were 55% agreement for on-road, 78% agreement for off-road). Amongst the whole sample, there is a preference for off-road (69% agreement) over on-road (49% agreement) cycle lanes. Motor car ownership and use correlate with a preference for off-road cycle lanes; those who own and use motor cars are keener for off-road cycle lanes. Motorists may consider that on-road cycle lanes take away valued road space.

The population segment with the highest proportion wanting more money spent improving on-road cycle lanes is 'mid earners' (65%). This population segment and 'high earners with children' both have the greatest desire for an improvement in off-road cycle lanes (80%). The strong preference amongst 'high earners with children' for off-road cycle lanes, follows on from the findings in Chapter Seven, that some individuals on high incomes, with children and with a car available still choose to cycle, or want to cycle. Their preference is for off-road cycle lanes.

Just over half of the respondents (53%) agree that "safety fears of traffic prevent them from cycling more often in Edinburgh". The proportion is higher for those not currently cycling, and reinforces the literature finding that the safety fears of traffic is the main barrier to cycling (Section 3.6.3).

The statements that Edinburgh is too hilly and too wet for cycling produce mixed responses, generating the most ambivalence amongst the eleven statements (more respondents ticked the "neither agree nor disagree" for these two cycling statements). There is significant correlation between the weather and topography variables: 73% of the sample has exactly the same answers to both statements.

There is a significant gender difference from the correlation tests amongst respondents for the cycling attitudinal statements. A higher proportion of women than men agree that more money should be spent on on-road cycle lanes, safety fears are more likely to prevent them from cycling, and that Edinburgh is too hilly and too wet for cycling. The population segment with the highest proportion stating "safety fears of traffic prevent me from cycling more often in Edinburgh" is 'part-timers with children' (75%), almost all of whom are female.

Of the four postcode sector areas, respondents in Dalry are most in favour of cycle lane provision, for both on-road (60%) and off-road (75%) cycle lanes. The reasons for these answers could be linked to safety, since Dalry respondents also represent the highest proportion amongst the four postcode sector areas to state that "safety fears of traffic prevent me from cycling more often in Edinburgh" (57%).

8.4.2 Responses to walking statements

The walking statements in the questionnaire include the strength of feeling towards pavement provision. It is also of interest to ascertain if there are enough convenient or safe pedestrian crossings in Edinburgh. Fears for personal safety, stated in the literature as the main barrier to walking (Section 3.6.3), are also included. Results are shown in Table 8.9.

Table 8.9. Responses to walking statements from the West Edinburgh survey sample

Statement	Strongly agree or agree		Neither agree nor disagree		Disagree or strongly disagree		Total
More money should be spent improving pavements for pedestrians in Edinburgh	683	69.6%	215	21.9%	84	8.5%	982
There are not enough convenient pedestrian road crossings in Edinburgh	281	28.9%	311	32.0%	381	39.2%	973
There are not enough safe pedestrian road crossings in Edinburgh	260	26.9%	318	32.8%	391	40.3%	969
Fears for my personal safety prevent me from walking more often in Edinburgh	218	22.6%	203	21.0%	544	56.4%	965

Most respondents (70%) agree that money should be spent improving pavements for pedestrians in Edinburgh. However, there is less than 30% agreement for either not enough "safe" or "convenient" pedestrian road crossings in Edinburgh. Opinion is similar on the convenience and safety of pedestrian crossings; 84% of respondents provide the same answer to both questions.

There is strong disagreement amongst respondents that fears for their personal safety prevent them from walking more often in Edinburgh (56%). The 23% of the sample that have fears for their personal safety tend to be women, those with lower household incomes and those at each end of the age band spectrum. Over a quarter of those in the age bands 18-24, 65-74 and over 75 agree with the statement.

These characteristics can be linked to the postcode sector area of Wester Hailes, that contain a much higher proportion of individuals with "fears for their personal safety preventing them from walking more often" (35%) than the other three postcode sector areas (between 18% and 22% in each area). Residents in Wester Hailes also want more safe and convenient road crossings than residents in other areas. A higher proportion of Slateford residents reckon "more money should be spent improving pavements" than other areas. This might be linked to the fact that respondents in this area were more likely to be retired, than a factor relating to pedestrian provision in the local area.

In terms of correlating the socio-economic variables against all four walking statements there is more agreement amongst women, older people and those on lower incomes. Of the seven population segments, all four walking statements have markedly higher responses from the population segment 'retired living on their own'. Almost all within this segment (92%) want more money spent on pavement improvements and almost half (43%) state that "safety fears prevented them from walking more often".

With regard to background transport and travel behaviour, akin to the other attitudinal statements, the responses tend to be proportional to the amount a person uses that transport mode, and alternative modes. Naturally, individuals show self-interest in their responses and attitudes, and the amount of walking they undertake.

8.4.3 Assessment of hypothesis five

Hypothesis five, "Attitudes towards non-motorised modes vary greatly amongst the population segments" has been tested using a number of cycling and walking statements. Cycling is a minority activity and local cycling facility improvements are low on the list of favoured transport policy measures amongst respondents. Concerning the attitudinal statements, policy measures that focus on off-road, rather than on-road, cycle lanes are more popular with the public. Safety is confirmed as a major barrier to cycling, with just over half of respondents agreeing that safety fears of traffic prevent them from cycling more often in Edinburgh. Responses to cycling statements are strongly segmented by gender. More men than women currently cycled. Barriers to cycling are greater for women, particularly safety from traffic fears but also topography and weather.

Almost everyone walks, and yet the responses to the walking attitudinal statements vary according to gender, age and income. In terms of pedestrian provision, most respondents in the survey consider that more money should be spent on pavement improvements in Edinburgh. Agreement is much lower for increasing either the convenience or safety of pedestrian road crossings. Personal safety concerns are more acute amongst women, those on low incomes and at the age extremes.

The detailed information gathered in the survey on the population segments for attitudes to cycling and walking statements are sufficient to accept the hypothesis.

8.4.4 Policy measures to encourage non-motorised mode use

The primary responses to cycling statements that can be linked to transport policy measures are the preference for on-road and off-road cycle lanes. The stronger preference for off-road than on-road cycle lanes suggests that, amongst the public, there is a preference for off-road cycle lanes. Cycling provision in Edinburgh could be adapted to this preference; there is currently a relatively even split between on-road and off-road cycle lane provision (approximately 75km of on-road and 75km of off-road cycle lanes, City of Edinburgh Council, 2004b). The greatest preference for off-road cycle lanes is from 'high earners with children'; off-road cycle lanes could be encouraged at new or existing housing estates that are designed for this population segment.

Direct policy measures to encourage more walking can be targeted at particular spatial areas and population segments, from the attitudinal statements within the West Edinburgh survey. Wester Hailes could be particularly targeted with measures to reduce safety fears (e.g. increased CCTV coverage, improved street lighting), and more safe and convenient road crossings. Since the walking responses are also linked to the lower income aspects of respondents, these type of measures could be applied to other lower income and/or Social Inclusion Partnership areas. Those in the older age bands have a strong preference for improvements to the pedestrian environment (pavements, crossings) and walking experience (safety fears). Such improvements could be focused in locations where a higher proportion of older population segments reside (e.g. Slateford).

8.5 Weighting the sample

Some of the relationships shown in this Chapter were tested according to a series of weights, to compensate for non-response bias. The weights used are by street and by postcode sector area. Results from the application of these weights are shown in Table 8.10.

Table 8.10. Results from the application of weights to the West Edinburgh survey data set

Statistics generated from the West Edinburgh survey data set, within Chapter 8	Unweighted sample	Weight by street	Weight by postcode sector area
8.3.1 Percentage agreeing that both air pollution and congestion are problems in Edinburgh	N=982, 66.0%	N=972, 67.5%	N=976, 66.6%
8.3.2 Percentage prepared to give up using the motor car for at least one policy measure	N= 609, 12.8%	N=546, 13.3%	N=586, 12.7%
8.3.3 Percentage that would at least consider alternatives to the motor car with a 25% increase in the fuel price	N=622, 15.9%	N=559, 17.5%	N=596, 16.3%
8.4.1 Percentage that safety fears of traffic prevent them from cycling more often	N=858, 52.7%	N=853, 53.3%	N=855, 53.2%
8.4.2 Percentage that consider more money should be spent improving pavements in Edinburgh	N=982, 69.6%	N=975, 71.2%	N=975, 69.5%

The weights by street and area relate to spatial non-response bias. Streets and areas with a lower representation within the survey data sets had been given a greater weight, setting the mean weight to one. As shown in Section 8.2, response rates are greater in sub-areas containing higher income households and lower density housing, for example Colinton Road, North Meggetland, Corslet Road and Curriehill Castle Drive. The lower income and high-density housing sub-areas with poor response rates are Dumbryden Gardens and Murrayburn Place, both in the postcode sector area of Wester Hailes.

Applying the street and area weights to the West Edinburgh survey data shows an increase in agreement that congestion and air pollution are problems, in the motor car reduction measures and in increasing the money spent on pavements. These represent a percentage increase of up to two per cent in favour of motor car problems and sustainable transport policies. This is to be expected from lower income and higher density streets and areas, under-represented in the survey and more likely to acknowledge the motor car problems and support sustainable transport policies. Results are more pronounced for the street weight than the area weight. These weights also marginally increase the proportion of the sample considering that "safety fears of traffic prevent them from cycling more often".

The series of weights marginally affect the statistical relationships generated in this Chapter, although the general conclusions are just as relevant. For example, it can still be asserted that "a small group of the population are prepared to give up their motor car for at least one policy measures" and "just of half of the sample considered that safety fears of traffic prevent them from cycling more often".

8.6 Summary

An outline of the sample for the West Edinburgh survey is presented in Section 8.2. The large sample size has enabled segmentation to be undertaken and the development of robust discrete choice models. The size is large enough to compensate for spatial and non-response bias within the survey. The scale of the survey has enabled seven of the ten population segments defined in Chapter Seven to be analysed. The 'call and post' methodology could be considered a success, with a response rate of 33%. This has been achieved at a time of increased reluctance amongst the population to partake in surveys. Some respondents were reluctant to complete some of the questions such as income or transport modes they did not consider relevant.

From the West Edinburgh survey data, household income (aside from Wester Hailes), whether children are present in the household, and the amount of driving are greater the further the distance from the centre of Edinburgh. Since households with children have more bicycles available (shown in Chapter Seven) an anomaly exists: more bicycles are available towards the edge of the city, yet the locations with the greatest propensity to cycle are near to the centre of Edinburgh.

Car driver responses to the problems associated with the motor car are examined in Section 8.3. Hypothesis four, "Car drivers acknowledge the problems associated with the motor car but are unwilling to change travel behaviour", has been accepted. From the attitudinal question relating to the problems associated with the motor car, most car drivers agree that congestion and air pollution are problems in Edinburgh. There appears to be a slight spatial effect, with those living nearer to the centre of Edinburgh more likely to agree that congestion and air pollution are problems.

The segmentation analysis shows that most disagreement with the statements addressed to motorists is by males, those on higher incomes, households without children, and those with higher car ownership and use. The literature (Section 3.3.3) and Scottish Household Survey findings (Section 7.6) show that these are all population groups with highest reliance on the motor car, apart from households without children. Perhaps adults in households with children have the most frustration with their car dependence, since of the car dependent population segments, they are more likely to agree that congestion and air pollution are problems associated with the motor car.

Although many car drivers would at least consider using the car at least "a little less" if petrol prices were gradually doubled (70%) or if the frequency of local buses was improved (61%), few are close to the greater step of giving up use of a motor car.
A minority of car drivers state a readiness to change travel behaviour, illustrated by 13% willing to "give up" use of their car for at least one of the six transport policy measures presented. There are, therefore, signs of travel behaviour change at the margins of the population. The transport policy measures with the largest impact upon car drivers are changes to the user's costs and provision of public transport improvements. Of these, improving public transport, as an enticing carrot to encourage less reliance on the motor car, would be more popular amongst the general public. This has also been shown in the literature (Section 2.4 - Pearce, 1999; Stradling et al, 2000).

However, the majority of respondents within the West Edinburgh surey are reluctant to change travel behaviour away from the motor car and the hypothesis has, therefore, been accepted.

Much of the population is car dependent and, when responding to transport policy measures, tend to act with self-interest rather than altruistically, confirming the situation described in the literature (Section 3.4 - Liebling, 1998). Only a large fuel price rise would result in most car drivers considering a travel behaviour change away from the motor car. Furthermore, there is a segment of the population extremely reluctant to change travel behaviour, resisting any transport policy measures and indicating no change in their behaviour for any of the petrol or diesel prices changes offered. Some respondents would increase their car use if the price of fuel fell. The costs of motoring are, therefore, important to alter the travel behaviour of car drivers. Of the segmentation variables, only income has an effect upon the readiness of car drivers to change behaviour.

The propensity to use non-motorised modes is assessed in Section 8.4 using attitudinal statements within the West Edinburgh survey. Hypothesis five, "Attitudes towards non-motorised modes vary greatly amongst the population segments", has been accepted. The detailed information on the population segments for attitudes to cycling and walking statements have resulted in acceptance of the hypothesis. Responses to cycling statements are strongly segmented by gender. Barriers to cycling are greater for women, particularly fears of safety from traffic, but also topography and weather. Dickinson et al (2003), reflecting upon the gender imbalance of cycling, provide evidence that a subgroup of women should be targeted with travel plan measures. Responses to the walking attitudinal statements vary according to gender, age and income. Personal safety concerns are more acute amongst women, those with lower household incomes and at the age extremes.

The responses to non-motorised modes statements provide some implications for policy measures. Off-road rather than on-road cycle lanes would be preferable for the general public (confirming Abraham et al, 2002 – Section 3.7.1), part of a "cyclist-inferiority superstition" whereby roads are too dangerous for cyclists (Forrester, 1994 – Section 3.6.1). Cycle lane provision could be targeted at 'high earners with children'. Findings from the cycling statements correspond with those in the literature. Abraham et al (2002) show a preference for off-road cycling, whilst Stinson and Bhat (2003) found that hilliness is not an issue. However, these surveys were of cyclists; the West Edinburgh survey was broader, considering the population as a whole.

Direct policy measures to encourage more walking can be targeted at areas containing households on lower incomes (e.g. Wester Hailes) and a high proportion of retired individuals (e.g. Slateford). Policy measures in such areas could include increased CCTV coverage, improved street lighting, and the implementation of safe and convenient road crossings.

The relationships developed in this Chapter from the West Edinburgh survey are tested against a series of weights in Section 8.5, to compensate for non-response bias. Applying the weights represents a marginal increase in favour of motor car problems and sustainable transport policies, although the general conclusions can still be applied.

9. DISCRETE CHOICE MODELS FOR THE PROPENSITY TO WALK

9.1 Introduction

Chapter Nine concerns the development of discrete choice models for the propensity to walk. The models use data from the West Edinburgh survey stated preference experiment on the propensity to walk for motorists. Motorists were incorporated into the propensity to walk stated preference experiment because much of the emphasis within transport-related literature and policy is on reducing motor car usage.

This Chapter relates to the second research objective, "to develop a methodology that will model individual travel behaviour and thus the propensity to use non-motorised modes". The modelling focus is on the relative importance that different population segments place on attributes when choosing between the motor car and walking, and the forecasts generated concerning the amount of walking that individuals might undertake for a change in one of the attributes. Practical policy outputs are, therefore, produced.

Propensity to walk discrete choice models for the total sample of motorists are estimated in Section 9.2. The sample is then split by various segments for modelling purposes, namely by individual segmentation variable, by individual postcode sector area and by population segment (identified from the Scottish Household Survey data in Chapter Seven). These segmented models are estimated in Section 9.3, including the testing of hypothesis six: "The most influential attribute affecting mode choice between the motor car and walking for short trips varies amongst population segments". To test this hypothesis the relative importance of the three attributes of journey time, petrol cost and parking cost are examined.

Forecasts from the discrete choices models for the propensity to walk are presented in Section 9.4. These relate to the petrol price and parking cost attributes. This includes forecasts of both attributes for the total motorist sample, of the petrol price attribute split by population segment, and of the parking cost attribute split by population segment within the postcode sector area of Slateford. Section 9.4 includes the testing of hypothesis seven: "Increases in petrol prices and parking costs could induce a modal shift from the motor car to walking for short trips".

9.2 Model estimation

The choices that West Edinburgh survey respondents make between the motor car and walking for short trips are investigated.

The design of the propensity to walk stated preference experiment is outlined in Section 6.5. In the absence of previously published work examining walking trade-offs, a simple stated preference experiment of nine scenarios was designed using three time and cost variables. The three attributes within the experiment are door to door journey time, petrol price and parking cost at the destination. The journey time is 10 minutes for all motor car choices and 15 minutes, 20 minutes and 30 minutes for the walking choices. The petrol prices are 80p (current at time of survey), £1 and £2 for the motor car choices. Parking is either free, costs £2 or costs £5 for the motor car choices. It should be noted that the term 'petrol price' is used for the remainder of this thesis, although the attribute incorporates both petrol and diesel.

9.2.1 The motorist sample

A large sample of 627 respondents completed this stated preference experiment, all of whom are car drivers. As shown in Section 8.3, motorists in the sample typically drive most days, are from higher income households and live towards the edge of the urban area. The 627 respondents made 5,643 stated choices (each respondent was presented with nine scenarios). Of these choices, the walk option was chosen on 4,303 occasions, the motor car option on 1,340 occasions. This represents sufficient trade-offs between the two modes for modelling purposes.

9.2.2 Model estimation for the motorist sample

A model run was undertaken for the sample of 627 motorists. The utility expressions, based on the formula shown in Section 2.7, for the two choices between the motor car and walking, are:

$$U1_{car} = ß1*time_{car} + ß2*petrol_{car} + ß3*park_{car}$$

$$U2_{walk} = MSC_{walk} + ß1*time_{walk} + ß2*petrol_{walk} + ß3*park_{walk}$$

where U = utility, ß = coefficient, MSC = mode specific constant.

The utility of each mode is affected by the three variables in the propensity to walk stated preference experiment. There is also a mode specific constant, attributable to one of the modes. The mode specific constant reveals the level of bias within the models, showing the effect of attributes not within the model. In this example, it would be the impact of everything except for journey time, petrol price and parking cost. Outputs from the model estimation of the total motorist sample are shown in Table 9.1.

Table 9.1. Outputs from the propensity to walk model estimation of the total motorist sample

Number of respondents		627
Number of SP choices		5643
Rho squared – zero		0.3094
Rho squared – constant		0.1267
Attribute	**Coefficient**	**T value**
time	-0.09822	-18.1
petrol	-0.4159	-6.3
parking	-0.3399	-18.5
constant	1.205	10.4

In terms of model robustness, the rho-squared value with respect to zero is 0.3094. Rho-squared values for stated preference experiments that concern cyclist mode or route choice tend to range between 0.13 and 0.16 (Hopkinson and Wardman, 1996; Wardman et al, 1997; Ortuzar et al, 2000). The higher rho-squared value in the propensity to walk experiment could reflect the higher number of cases and the simplicity of the experiment (three variables for journey time, petrol costs and parking costs). Furthermore, the propensity to walk is more straight-forward to model than the propensity to cycle, because unlike cycling almost everyone walks.

Each of the three attributes significantly affects the model, since the T values are greater than 1.96, a 95% confidence level. The T value signs are also negative; a negative sign would be expected for time, petrol costs and parking costs for mode choice, since an individual's relative utility increases with a decrease in any of these three attributes (and vice versa). For example, if petrol costs decrease in price, fuel would become more attractive (an increase in relative utility) in comparison with the other options (in this case journey time and parking costs). The order of influence of the attributes on the model is parking costs, journey time and then petrol costs. Petrol costs have a considerably lower relative influence upon the choice between the motor car and walking.

9.2.3 Model outputs

The value of time, shown by an individual's willingness to pay, is an important output from discrete choice models, using the estimated coefficients. As Louviere et al (2000, p. 61) state, "increasingly discrete-choice models are being used to derive estimates of the amount of money an individual is willing to pay (or willing to accept) to obtain some benefit (or avoid some cost) from a specific action." The ratio of two utility parameters provides a willingness to pay measure, holding all other potential influences constant.

The variables from the model of the motorist sample (and their estimated coefficients) are time (-0.09822), petrol (-0.4159) and parking (-0.3399). Using these coefficients as a ratio of cost per minute, values of time for petrol and parking costs are 23.6p per minute and 28.9p per minute respectively. Respondents put a higher value of time on parking costs than petrol prices. As a comparison, the most recent non-working value of time 'market type' figures from the Department for Transport, calculated from the National Travel Survey, are 8.4p for commuting trips and 7.4p (calculated from £ per hour) for other trips (Department for Transport, 2004c – Table 2). The trip for the propensity to walk stated preference experiment is not specified, although it is more likely to be a non-working journey.

More disaggregate values of time than the Department for Transport (2004c) figures are not available. Although the United Kingdom non-working values of time are much lower than the West Edinburgh survey values, there are three key differences between the two data sources. Firstly, the national data covers all United Kingdom areas, but data from the West Edinburgh survey concerns an urban area where the values of time are expected to the higher. Secondly, the United Kingdom values of time concern all modes, whereas the West Edinburgh survey focuses on motor car choices (trading-off against walking choices). Motorists are expected to have a higher value of time than other transport modes. Thirdly, it is to be expected that values of time associated with parking and petrol costs would be higher than the United Kingdom value of time figures, which concern all travel costs. The reluctance for individuals to change mode away from the motor car in response to an increase in petrol prices has already been shown in the thesis from the review of literature (Section 3.5) and the West Edinburgh survey analysis (Section 8.3.3).

The discrepancies could also be explained by problems associated with global values of time. One study comparing stated preference and revealed preference outputs (Wardman, 1988), has shown discrepancies can exist with global stated preference values of time. The stated preference generated values of time in Wardman (1988) were more realistic when the sample was segmented according to socio-economic factors.

It is acknowledged that the value of time outputs from the propensity to walk discrete choice models are from a specific transport choice situation (i.e. between the motor car and walking), and so some care needs to be taken interpreting the values of time generated. As Ortuzar and Willumsen (2001: p457) state, "subjective values of time are heavily dependent on model specification and data; this is an undesirable property because consistent evaluation of projects is sought over a wide range of models and areas."

Therefore, the values of time generated from model estimation should be treated with caution. There is evidence of potential bias within the discrete choice model estimation, both generic to stated preference modelling and specific to the propensity to walk experiment, which has implications for model forecasting. It is difficult to comment on specific bias, as there is no body of evidence regarding propensity to walk stated preference experiments. Many have commented on generic bias within stated preference experiments, and this is elaborated further in the discrete choice model forecasting (Section 9.4.6).

Cross elasticities have been output from the models. The motor car alternatives for journey time, petrol and parking towards an increase in walking are 0.2002, 0.1044 and 0.1191 respectively. For example, a 1% increase in journey time by motor car, will lead to a 0.2% increase in individuals choosing to walk. These values are comparable with those in other studies. There have been two recent independent reviews of road traffic demand elasticities within the literature, both commissioned by the Department for Transport. Graham and Glaister (2004) state a short-run elasticity of demand for fuel between -0.2 and -0.3; Goodwin et al (2004) state a short-run average elasticity with respect to fuel price in the post-1981 period to be -0.16. The elasticity of demand for fuel in this study is -0.10, towards the lower end of comparable elasticities in the literature; this may be due to the unique set of circumstances within the propensity to walk stated preference experiment (e.g. in an urban context and considering solely the modal shift from the motor car and walking).

9.3 Model segmentation

In this Section, hypothesis six is tested: "The primary reason for choosing between the motor car and travelling on foot for short trips varies amongst population segments". A series of discrete choice models were run using a segmented sample rather than the total motorist sample. The focus is on the relative importance that different population segments place on attributes when choosing between the motor car and walking. Due to the large size of the motorist sample (627 respondents), it has been possible to run many different segmented models. This includes models for individual segmentation variables, for individual postcode sector areas and for population segments identified from the Scottish Household Survey in Chapter Seven.

9.3.1 Model estimation using individual segmentation variables

Some socio-economic segmentation variables are the same as those used in the Chapter Seven and Chapter Eight analysis: age, gender, income and house type. In addition, the key life stages identified from the cluster analysis of the Scottish Household Survey data (i.e. having children, being in employment and being retired) are incorporated as segmentation variables. A further variable is disability of the respondent or a member of the household (if there is a Blue badge holder within the household). The segmented models consist of at least 25 individuals, considered as a minimum for robust discrete choice models. If a variable has many categories, such as income, those at the extremes are the segments used (e.g. £15,000 p.a. or less and more than £40,000 p.a.), enabling variations to be more visible.

Results from the segmented models are shown in Table 9.2. Model estimation outputs for the total motorist sample are also provided as a comparison.

Table 9.2. Results for the propensity to walk stated preference experiment, by individual segmentation variables

Segmentation model, in comparison with the total motorist sample	Number	Rho^2-zero	T value: time	T value: petrol	T value: park
Age – under 35	126	0.3442	-7.4	-2.5	-9.8
Age – 65 and over	135	0.2282	-6.5	-2.9	-7
Gender – male	347	0.3222	-14.9	-5.4	-14.4
Gender – female	277	0.2970	-10.5	-3.4	-11.6
Income – £15,000 pa or less	102	0.2673	-4.9	-3.1	-6.6
Income – more than £40,000 pa	166	0.3210	-10.8	-2.5	-9.8
Children – in household	172	0.3613	-9.9	-3.6	-10.4
Children – not in household	455	0.2915	-15.2	-5.2	-15.4
House type – detached	186	0.2742	-10.4	-3.1	-9.8
House type – flat	169	0.3668	-9.4	-3.6	-10.1
Situation of respondent – employed full-time[1]	306	0.3490	-14.9	-4.5	-14.1
Situation of respondent – retired	159	0.2624	-7.4	-3.5	-7.3
Blue badge – in household	31	0.0722	-2.5	-1.2	-2.9
Blue badge – not in household	596	0.3293	-18.1	-6.1	-18.4
Total motorist sample	**627**	**0.3094**	**-18.1**	**-6.3**	**-18.5**

Note: [1] = not self-employed

As might be expected, the segmented models have lower T values than the total motorist sample models, since they contain choices from fewer individuals. However, almost all of the T values are significant at the 95% level (the petrol cost attribute of the Blue badge in the household model is not significant), and all attributes have signs in the correct (negative) direction.

Hypothesis six states that, "the most influential attribute affecting mode choice between the motor car and walking for short trips varies amongst population segments". This relates to the importance of the relative attributes amongst the segmented models as shown by the T values. As with the model of the total motorist sample, the two attributes with the greatest influence amongst the segmented models (with higher relative T values) are journey time and parking cost. There is, however, a distinct difference between the primary attribute amongst the segmented models.

Parking cost is the most influential attribute for women, those living in flats and those on low incomes (£15,000 per annum or less). The age, Blue Badge and presence of children segments do not affect the relative importance of the attributes; the two contrasting model runs for these segments produce the same result, resulting in parking cost being the most influential attribute.

Journey time is the most influential attribute for men, those on high incomes (over £40,000 per annum), those living in detached houses, those in full-time employment and those in retirement. The results for these segments are generally to be expected, since these population segments tend to have a higher value of time (Wardman, 1998). The exception would perhaps be those in retirement, although this group has the most marginal difference between journey time and parking cost.

Although petrol cost is a much less influential attribute, those on low incomes (less than £15,000 per annum) and those in retirement are the most sensitive to fuel price increases. This is as expected (Black, 2000).

Segmented models were also run using some of the attitudinal variables within the West Edinburgh survey, to validate respondent choices. The responses to the petrol price change (segmenting those that would definitely give up using the motor car at a £2 petrol price) and parking policy (segmenting those that would change motor car usage in response to parking policy) questions provided results as expected: these segments showed greater sensitivity to the petrol price and parking cost variables respectively.

9.3.2 Model estimation using postcode sector area and population segment

This Section is concerned with established spatial and population segment splits amongst the West Edinburgh survey respondents, as described in Chapter Eight. Model runs were conducted for each of the four postcode sector areas within the West Edinburgh survey, to assess if there is a spatial influence upon the relative modal choices between the motor car and walking. Further runs were undertaken for the seven population segments, adapted from those originally developed from the Scottish Household Survey data (Section 7.3). These population segments have been split by postcode sector area and, where more than 25 individuals could be grouped accordingly, combined population segment by postcode sector area model runs were undertaken. There are seven model runs combining population segments with postcode sector areas.

Results from these segmented models are shown in Table 9.3. As with Table 9.2, model estimation outputs for the total motorist sample are also provided as a comparison.

Table 9.3. Results for the propensity to walk stated preference experiment, segmented by postcode sector areas, population segments and combined (population segments within postcode sector areas)

Segmentation model, in comparison with the total motorist sample	Number	Rho^2-zero	T value: time	T value: petrol	T value: park
Area – Dalry	96	0.4349	-6.2	-3.0	-7.8
Area – Slateford	215	0.3599	-11.4	-3.3	-11.1
Area – Wester Hailes	93	0.1989	-7.0	-2.1	-7.6
Area – Currie	219	0.2805	-10.8	-3.9	-10.0
Segment - Mid earner	35	0.4358	-3.5	-3.0	-5.2
Segment - High earner without children	163	0.3539	-11.4	-3.4	-10.7
Segment - Part timer without children	25	0.6937	-2.1	-0.2	-3
Segment - High earner with children	80	0.3697	-7.9	-2.1	-6.7
Segment - Part timer with children	40	0.4082	-3.3	-2.2	-4.8
Segment - Retired in a couple	97	0.3464	-7.2	-3.2	-7.2
Segment - Retired living on own	53	0.1192	-2.8	-1.3	-2.3
Combined - High earner without children, Dalry	48	0.4498	-4.4	-1.5	-5.4
Combined - High earner without children, Slateford	50	0.4264	-7.7	-2.3	-6.9
Combined - High earner without children, Currie	48	0.2587	-6.5	-1.9	-4.8
Combined - High earner with children, Slateford	29	0.4678	-4.8	0.3	-5.1
Combined - High earner with children, Currie	35	0.4417	-5.1	-2.0	-3.6
Combined - Retired in a couple, Slateford	39	0.3978	-4.1	-1.9	-4.1
Combined - Retired in a couple, Currie	42	0.3592	-5.5	-2.1	-4.5
Total motorist sample	**627**	**0.3094**	**-18.1**	**-6.3**	**-18.5**

The segmented models by population segment and postcode sector areas have satisfactory rho-squared values (with respect to zero) and significant T values (at the 95% level), except the petrol cost attribute for six of the segmented models.

There is a distinct difference in the primary attribute for the segmented models listed in Table 9.3. Parking cost is the most influential attribute for those living in Dalry and Wester Hailes. Of the segmented models, parking cost is the primary reason affecting mode choice for 'mid earners' and 'part-timers' (both with and without children). For the combined segment models, those most influenced by parking cost are 'higher earners without children, Dalry' and 'higher earners with children, Slateford'.

Respondents putting more of an emphasis upon journey time in the experiment are those living in Slateford and Currie. Of the population segments, those most influenced by journey time are 'high earners' (both with and without children) and those 'retired living on their own'. As shown in the model estimation for individual segmentation variables, the presence of children does not affect the influence of journey time and parking cost.

It is of note that three of the four combined segment models, with a primary reason of journey time affecting mode choice, concern residents of Currie. Of the segmented models run, the variable of Currie would appear to have the most influence over whether an individual would chose journey time over parking cost, more than income (shown by high earners). The influence of parking cost may be reflected in the location of Currie being further away from the city of Edinburgh than other areas surveyed. Certainly, most residents in Currie would have residential parking available in a garage, a driveway or on-street, compared to more limited parking in Dalry, Slateford and Wester Hailes. This may have affected respondent thinking when completing the propensity to walk stated preference experiment.

As with the individual population segment variables, those on relatively lower incomes (of the population segments) are the most sensitive to petrol price increases. The population segments with the most sensitivity to petrol, albeit to much lesser degree than the other two attributes, are 'mid earners', 'part-timers with children' and those 'retired living on their own'.

9.3.3 Assessment of hypothesis six

Hypothesis six, "The most influential attribute affecting mode choice between the motor car and walking for short trips varies amongst population segments", has been accepted. Segmented models show that for some segments journey time is the most influential attribute, whilst for other segments it is parking cost. From the individual segmentation variable models, respondents putting more of an emphasis upon journey time in the experiment are men, those on high incomes (over £40,000 per annum), those living in detached houses, those in full-time employment, those in retirement and those living in Currie. This can be linked to a higher value of time amongst these segments. Parking cost was the most influential attribute for women, those living in flats and those on low incomes. Although there is an income effect, there could be a link to residential parking availability.

9.4 Forecasts from the model

In this Section, hypothesis seven is tested: "Increases in petrol prices and parking costs could induce a modal shift from the motor car to walking for short trips". Akin to non-motorised mode modelling examples in Chapter Three (Noland and Kunreuther, 1995; Wardman et al, 1997; Ortuzar et al, 2000), this study uses the sample enumeration method for forecasting. The probability of each alternative (motor car, walking) is predicted using the formula stated in Section 2.7. The focus is on the forecasts concerning the amount of walking that individuals might undertake for a change in one of the attributes, in this case petrol prices and parking costs.

For example, the predicted probability of an individual choosing to walk rather than travel by motor car for a given change in attribute X (e.g. an increase in petrol cost of 10%), would induce a change in probability of Y (e.g. an increase in walking of 0.8% - shown in Table 9.4).

9.4.1 Scenario development

Scenarios depicting how the transport situation may change in the future were input to the model. The variables of petrol price and parking cost are considered as policy measures, representing national and local transport policy measures respectively. The propensity of an individual to walk increases as these costs increase, decreasing the utility of the motor car.

The petrol price base scenario has a cost of 80p, the current price at the time of the survey (July 2003). A range of increases upon the base scenarios are used from short-term, feasible increases of 5% and 10%, to more unrealistic longer term increases. It was of interest to assess the level of petrol price increase that would encourage the probability of individuals walking by a reasonable amount, say of 10%.

A base figure for parking cost is not easy to deduce, since parking costs vary across Edinburgh. Parking charges in Edinburgh can be time dependent (e.g. 20p for 20 minutes), linked to the cost of a residential permit cost or free of charge. It is acknowledged that the length of time an individual will stay parking at the destination is not specified in the stated preference experiment. The destination of the trip is also not specified; it could be on-street or in an off-street car park. This would affect modal choice between the motor car and walking.

However, realistic parking levels of no charge, £2 or £5 were set in the stated preference experiment. Model estimation illustrates the reliability of these levels i.e. they have a significant effect (in Section 9.2). The base scenario was set at 50p and future scenarios of subsequent increases of 50p (a likely increase level, since it is a round figure). A comparison with parking free of charge is also included, as the fourth scenario.

9.4.2 Petrol and parking cost forecasts for the total motorist sample

Table 9.4 shows forecasts for the effects of petrol price and parking cost increases upon the probability of individuals choosing to walk.

Table 9.4. Forecasts for the effect of petrol price and parking cost increases upon the probability of individuals choosing to walk

Scenario	Probability motor car	Probability walk (% increase over base)
Petrol price		
Base: petrol = 80p	26.8	73.2
1: petrol = 84p (5% increase)	26.6	73.4 (+0.4%)
2: petrol = 88p (10% increase)	26.3	73.7 (+0.8%)
3: petrol = £1.00 (25% increase)	25.5	74.5 (+1.9%)
4: petrol = £1.20 (50% increase)	24.1	75.9 (+3.7%)
5: petrol = £2.00 (150% increase)	19.2	80.8 (+10.5%)
Parking cost		
Base: parking = 50p	33.4	66.6
1: parking = £1.00 (100% increase)	30.0	70.0 (+5.0%)
2: parking = £1.50 (200% increase)	26.8	73.2 (+9.8%)
3: parking = £2.00 (300% increase)	23.9	76.1 (+14.2%)
4: parking = free	36.9	63.1

As shown in Table 9.4, for a sizeable increase in the walking share (a 10% increase), a three-fold increase in petrol prices, from 80p a litre to £2.00 a litre, is required. However, such a rise appears unlikely in the short-term, particularly in light of the recent fuel tax protests (highlighted in Chapter Four). A more realistic increase in the petrol price would be between 0% and 10%. The model forecasts for this level of price increase represent a marginal increase in the walking modal share, of between 0% and 0.8%.

With all other factors remaining constant, for short trips individuals are more responsive towards a modal shift to walking through parking cost rather than petrol price increases for short trips. This is illustrated by the level of relative attributes for the model estimation of the total motorist sample (in Section 9.2). Parking cost increases could be more effective than petrol price increases because they may be less likely to generate public protest.

For a sizeable increase in the walking share (a 10% increase), a three-fold increase in parking costs, from say 50p to £1.50, is required (shown in Table 9.4). Doubling the parking costs (from 50p to £1), at the upper end of a realistic price rise, would increase by 5% the probability that an individual would walk. This represents a slight rather then a considerable increase in the walking modal share in response to parking costs.

Forecasts have also been generated for the segmented models. Petrol price is considered in Section 9.4.3, parking cost is considered in Section 9.4.4.

9.4.3 Petrol price attribute forecasts split by population segment

Petrol price increases can not be targeted at specific spatial areas (i.e. they could not be applied just to petrol stations in a postcode sector area), rather they are regulated nationally and affect individuals differently. Some individuals may change mode for specific journeys in response to petrol price increases. The focus in this Section is the population segment to which an individual belongs. Petrol price forecasts were generated for the seven population segments within the West Edinburgh survey (plus one for the remainder of the population), using the same scenarios as the forecasts for the total motorist sample (presented in Table 9.4). Forecasts by population segment are shown in Table 9.5.

Table 9.5. Forecasts for the effect of petrol price increases upon the probability of individuals choosing to walk, split by population segment

Segment	Number	Scenario: petrol price (percentage increase)					
		Base: 80p	**1: 84p (5%)**	**2: 88p (10%)**	**3: £1 (25%)**	**4: £1.20 (50%)**	**5: £2 (150%)**
Mid earner	35	74.5	75.1 (0.8%)	75.8 (1.7%)	77.6 (4.1%)	80.4 (7.8%)	89.3 (19.8%)
High earner without children	163	73.1	73.4 (0.4%)	73.6 (0.8%)	74.5 (2.0%)	75.9 (3.9%)	81.0 (10.9%)
Part timer without children	25	92.1	92.1 (0.0%)	92.2 (0.1%)	92.3 (0.2%)	92.4 (0.4%)	93.2 (1.2%)
High earner with children	80	75.5	75.7 (0.3%)	76.0 (0.6%)	76.7 (1.6%)	77.9 (3.1%)	82.2 (8.9%)
Part timer with children	40	77.6	78.0 (0.5%)	78.4 (1.0%)	79.6 (2.6%)	81.4 (5.0%)	87.7 (13.0%)
Retired in a couple	97	74.0	74.4 (0.5%)	74.8 (1.0%)	75.9 (2.5%)	77.6 (4.9%)	83.8 (13.2%)
Retired living on own	53	65.7	66.0 (0.3%)	66.2 (0.6%)	66.8 (1.6%)	67.8 (3.2%)	71.8 (9.2%)
Other	134	69.1	69.3 (0.3%)	69.5 (0.5%)	70.0 (1.2%)	70.8 (2.4%)	74.1 (7.1%)
Total sample	**627**	**73.2**	**73.4 (0.4%)**	**73.7 (0.8%)**	**74.5 (1.9%)**	**75.9 (3.7%)**	**80.8 (10.5%)**

The forecasts presented in Table 9.5 show that response to petrol price change varies by population segment. The model forecasts for the total motorist sample show an increase of 0.8% in the walking modal share at a 10% increase in the petrol price. Using segmented models, this proportion varies from a negligible response amongst 'part-timers without children' (0.1%) to a slight response amongst 'mid earners' (1.7%). As indicated from the estimation of segmented models (in Section 9.3), it is the lower income groups that are affected more by petrol price increases.

9.4.4 Parking cost attribute forecasts split by population segment within the postcode sector area of Slateford

Unlike petrol price rises, parking cost increases can be targeted at specific spatial areas. For example, parking prices for all car parking in Slateford could be increased by the City of Edinburgh Council. Slateford was chosen of the four postcode sector areas within Edinburgh for the parking cost forecasts because the sample from the West Edinburgh survey was large enough within this postcode sector area to model three distinct population segments (see Table 9.3). Slateford represents a mixed neighbourhood in terms of housing and population segments (see Section 8.2). Since Slateford is 4.2km from the centre of Edinburgh (see Section 8.2) and the upper threshold for walking trips is 2km (see Section 2.2), the short trips considered by residents of Slateford would not be to the city centre; but rather within West Edinburgh. Parking forecasts were undertaken for the three population segments within Slateford (plus one for the remainder of the population), using the same parking scenarios as the forecasts for the total motorist sample (shown in Table 9.4). Forecasts by population segment within Slateford are shown in Table 9.6.

Table 9.6. Forecasts for the effect of parking cost increases upon the probability of individuals choosing to walk, split by population segment within Slateford

Segment	Number	Scenario: parking cost (percentage increase)			
		Base: 50p	**1: £1 (100%)**	**2: £1.50 (200%)**	**3: £2 (300%)**
High earner without children	50	62.8	67.6 (7.5%)	72.0 (14.6%)	76.1 (21.1%)
High earner with children	29	68.5	74.1 (8.1%)	79.0 (15.4%)	83.4 (21.7%)
Retired in a couple	39	73.7	76.6 (3.9%)	79.2 (7.5%)	81.7 (10.8%)
Other	97	70.3	72.9 (3.7%)	75.3 (7.2%)	77.7 (10.5%)
Total – Slateford	**215**	**69.0**	**72.4 (5.0%)**	**75.7 (9.7%)**	**78.7 (14.0%)**

Table 9.6 shows that high earners are more sensitive to parking cost increases than other population segments ('retired in a couple', other). The model forecasts for the total motorist sample show an increase of 5.0% in the walking modal share in response to the doubling of parking costs. This value is much higher (7.5% and 8.1%) for the high earner population segments (without children and with children); the value is lower for the other two population segments (3.9% and 3.7% respectively). The difference may be due to high earners starting from a lower walking base level or because others, particularly those retired, might be more reluctant to walk (perhaps because some individuals within the population segment are unable to walk). The presence of children does not appear to have an effect, since the forecasts are similar for 'high earners with children' and 'high earners without children'.

9.4.5 Applying the propensity to walk forecasts to the Edinburgh population

The forecasts for the propensity to walk can be factored up for the Edinburgh population using Scottish Household Survey travel diary data. The stated preference experiment for the propensity to walk considers journeys taking between 10 and 30 minutes on foot. It assumes that the respondent has a motor car available and is able to walk. In the Scottish Household Survey travel diary, 32.2% of trips are of the required distance (taking between 10 and 30 minutes on foot), for 60.8% of trips a motor car is available to the individual, and for 98.7% of trips the individual is fit to walk (not a Blue Badge holder). From these three values, 19% of trips would be relevant for the motor car and walking trade-off stated preference experiment. In reality, the proportion would be less. The data does not enable the other three pre-requisites from the stated preference experiment to be incorporated: the individual has nothing to carry, is travelling on their own and the weather is dry.

Therefore, from the total motorist sample forecasts, the 0.8% and 5.0% increases in the walking modal share from the 10% petrol price increase and doubling of parking costs would represent an approximate maximum of 0.16% and 1.0% of all trips (20% of the forecasts). As with many of the travel behaviour changes the impacts would be small. However, if a series of travel behaviour measures were applied with similar impacts, say these two cost measures and some 'carrot' measures (e.g. improved pavements and crossings for pedestrian), there could be an increase in walking modal share by a few percentage points.

9.4.6 Validation of the forecasts against the attitudinal responses

Internal validation of the forecasts from the discrete choice models presented in this Section was undertaken to assess forecast reliability. Internal validation concerned a comparison of the forecasts against individual responses within the West Edinburgh survey attitudinal data. Within the West Edinburgh survey, motorists were asked their travel behaviour responses to increases in petrol price and parking costs (results are presented in Section 8.3).

Of the six transport policy measures presented to respondents, 'gradually double the cost of petrol' is the measure most likely to encourage individual to reduce car use (70% of respondents would at least 'use their car a little less', Section 8.3). From the forecasts (see Table 9.4) it is estimated that a doubling of petrol prices (to £1.60) would produce a motor car modal share decrease of between 10% (a 50% increase in petrol to £1.20) and 28% (a 150% increase in petrol to £2.00). This appears reasonable given that choosing to walk rather than travelling by motor car for short trips represents a small part of 'using a car a little less'. Instead of walking the individual may not make the trip or choose an alternative mode (e.g. bus or bicycle).

The petrol price forecasts can be compared against the direct response of individuals to petrol price increases (in Section 8.3). One statistic is that 16% of motorists within the West Edinburgh sample would at least consider alternatives for a 25% increase to £1.00 a litre. The percentage increase forecast for walking at a 25% increase in the petrol price to £1.00 a litre is 1.9% (see Table 9.4). Given where choosing walking over the motor car for a short trip fits within all travel behaviour change choices, the petrol price forecast appears to be reasonable.

Although it was possible to successfully validate the forecasts using other data within the West Edinburgh survey, there are reservations regarding the forecasts generated. Forecasts produced from stated preference data can be subject to bias, typically if respondents state something in the experiment but act differently in practice (shown in Section 2.2.2). There are other aspects in which the forecasts should be treated with care, and not misinterpreted in a wider context. As shown in Section 9.2.3, caution needs to be placed on the value of time figures generated for these models, impacting upon the reliability of the forecasts. One remedy in the literature (Polak and Jones, 1997; Ortuzar and Willumsen, 2001; Walker and Ben-Akiva, 2002) is to generate forecasts from joint revealed preference / stated preference discrete choice models, reducing bias and improving the efficiency of parameter estimates.

Despite there being no stated preference examples for the trade-off between the motor car and walking, some general forecasting principles used in other transport applications can provide insights into forecast reliability. Stated preference intentions to use a new transport service can over-predict actual usage, often by a considerable amount. For example, a modelling case study forecasting new local rail services (Fowkes and Preston, 1991) produced forecasts, based on stated preference data, 56% greater than actual usage.

Increasing the number of observations per respondent can be a useful way of improving the sample size on a limited budget, as in this study. However, it is also the case that repeated observations cause autocorrelation of the error terms (Bates, 1988; Ouwersloot and Rietveld, 1996). One way to remedy this situation would be to replicate the propensity to walk stated preference experiment using another case study. In hindsight, external validation could have been undertaken, collecting observed choices of respondents within the propensity to walk stated preference experiment.

Many commentators (Bates, 1988; Wardman, 1988; Wardman, 1991) consider the scaling problem associated with the forecasts generated from discrete choice models. The error in stated preference responses may not be random, and the problem can be compounded when such responses are subsequently used for model forecasting. Another source of possible bias relates to the West Edinburgh sample. Sample enumeration assumes that the sample used to estimate the model is representative of the overall population (Ortuzar and Willumsen, 2001: p311); as shown in Section 8.2.3, one aspect in which the West Edinburgh survey may not be representative is that is contains a greater proportion of higher income households than would be expected.

A recent study has explored stated preference experiment design, in order to minimise bias. Caussade et al (2005) modelled 16 different stated choice experiment designs, using simulated data. The two most critical design dimensions were the number of attributes and number of alternatives. In hindsight, perhaps having only two alternatives in the propensity to walk stated preference experiment (rather than the preferred four in the Caussade et al study) over-simplified the choice context and increased bias in the model forecasting.

It should be re-stressed, though, that the propensity to walk discrete choice modelling represents a tentative approach in a new study area. They models have provided useful insights into an individual's propensity to use non-motorised modes. Further research could develop more advanced model functions for the propensity to use non-motorised modes, in order to reduce bias and improve the forecasting element.

9.4.7 Assessment of hypothesis seven

Scenarios were developed to forecast changes in responses to petrol price and parking cost increases, as national and local policy measures. Hypothesis seven: "Increases in petrol prices and parking costs could induce a modal shift from the motor car to walking for short trips", has been accepted. The model forecasts for the total motorist sample show an increase of 0.8% in the probability that an individual would walk at a 10% increase in the petrol price, and a walking probability increase of 5.0% in response to the doubling of parking costs. These policy measures could therefore induce a slight modal shift from the motor car to walking for short trips. Factoring the forecasts to cover all trips shows the modal shift to be minimal, but the cost policy measures could be implemented with pedestrian facility improvements to increase the walking modal share further.

Forecasts have been generated from the propensity to walk discrete choice models, based on stated preference data, but due to inherent bias associated with such forecasts there is an element of unreliability associated with them.

9.5 Summary

This Chapter relates to the second research objective, "to develop a methodology that models individual travel behaviour and thus the propensity to use non-motorised modes". The objective has been achieved for the propensity to walk, since robust models have been developed for both the total sample of motorists and the segmentation variables. Realistic forecasts have been generated, including an internal validation exercise using revealed preference motorist choices within the West Edinburgh survey.

The propensity to walk model is estimated in Section 9.2. The order of influence on the model for all car drivers is parking costs, journey time and then petrol costs. Petrol costs have a much lower relative influence upon the choice between the motor car and on foot. It can be concluded, therefore, that for short journey in urban areas, when trading-off between the motor car and walking, parking cost and journey time are much more influential than petrol prices. Value of time outputs and elasticities are comparable with those in the literature; any differences are due to the unique nature of the propensity to walk stated preference experiment (i.e. binary mode choice of the motor car versus walking for short trips in an urban area).

Model runs have been undertaken using segmentation variables, documented in Section 9.3. Hypothesis six, "The most influential attribute affecting mode choice between the motor car and walking for short trips varies amongst population segments", has been accepted. Segmented models show that for some segments journey time is the most influential attribute, whilst for other segments it is parking cost. Parking cost is the most influential attribute for women, those living in flats and those on low incomes (£15,000 per annum or less). These are the type of individuals with a lower value of time and are least car dependent. Respondents putting more of an emphasis upon journey time in the experiment are men, those on high incomes (over £40,000 per annum), those living in detached houses, those in full-time employment, those in retirement and those living in Currie.

Model forecasts have been generated, for the total motorist sample and for population segments, documented in Section 9.4. Scenarios have been developed to forecast increase in walking levels in response to petrol price and parking cost increases, as national and local policy measures. Hypothesis seven: "Increases in petrol prices and parking costs could induce a modal shift from the motor car to walking for short trips", was accepted, although there is an element of unreliability associated with the model forecasts. The model forecasts for the total motorist sample show an increase of 0.8% in the probability that an individual would walk at a 10% increase in the petrol price, and a walking probability increase of 5.0% in response to the doubling of parking costs. These policy measures could, therefore, induce a slight modal shift from the motor car to walking for short trips.

Factoring the forecasts to cover all trips shows the modal shift to be slight, but the cost policy measures could be implemented with 'carrot' policy measures, as identified from the motorist responses to transport policy measures, documented in Chapter Eight. Rather than public transport improvements, policy measures in this case could encourage walking, such as an improvement of the pedestrian environment.

Of the petrol and parking policy measures, the local transport policy measure of increasing the cost to park would have more impact. Not only are individuals more responsive to the parking cost increases in the discrete choice models, but parking policy measures are less likely to receive a public protest and can be varied spatially. This would enable the targeting of specific areas or population segments. The forecasts for those living in Slateford in response to parking cost increases showed a variation amongst population segments; higher earning households are more likely to increase the amount they walk than those retired (in a couple).

Current parking policies, outlined in Chapter Four, are to be commended. These include the PPG13 / NPPG17 policies of maximum parking standards for new development and using parking policies to promote alternatives to the car (Section 4.2.4), and extension of the Edinburgh Controlled Parking Zone (Section 4.3.4). As shown in Table 4.3 (as W4 within the Edinburgh Local Transport Strategy), designing and reviewing controlled parking zones also represents an opportunity to improve the pedestrian environment. Parking policy should be reinforced and extended to reduce motor car usage. Parking policy could have more emphasis on the level of charge, in addition to the control of supply and the enforcement of regulations. For instance, minimum parking charges could be set within national and/or local transport policy.

Given the importance of parking in the discrete choice models presented in this Chapter, it would be of interest to consider the parking attribute further. In addition to cost, other parking related variables could be incorporated to stated preference experiments such as parking availability, walking time from the parking space and time searching for a parking space.

As shown in Chapter Eight, only a large petrol price rise would result in car drivers considering a travel behaviour change away from the motor car. Of the Scottish Household Survey variables, income is the only one to have an effect upon the readiness of car drivers to change behaviour. The segmented model forecasts in response to petrol price increases (Section 9.4.4) appear to confirm this, since the population segment with the greatest modal share increase for walking is 'mid earners' (in comparison with high earners).

Aside from journey time, the propensity to walk stated preference experiment considers the motor car variables of petrol price and parking costs. The propensity to walk modelling effort could be developed further to include walking-related attributes such as footway provision and (safe and convenient) road crossings. There could be links to the walking policy measures of CCTV coverage and improved street lighting, as highlighted in Chapter Eight. These are target policy measures for those identified from the West Edinburgh survey attitudinal data with personal safety concerns, namely women, those with lower household incomes and at the age extremes.

The discrete choice modelling approach for the propensity to cycle models presented in Chapter Ten is the same as for the propensity to walk in Chapter Nine.

10. DISCRETE CHOICE MODELS FOR THE PROPENSITY TO CYCLE

10.1 Introduction

Chapter Ten concerns the development of discrete choice models for the propensity to cycle. The models use data from the West Edinburgh survey stated preference experiment on the propensity to cycle for the journey to work or study. The modelling approach is the same as for Chapter Nine.

This Chapter relates to the second research objective, "to develop a methodology that will model individual travel behaviour and thus the propensity to use non-motorised modes". The modelling focus is on the relative importance that different population segments place on different attributes when choosing between their current mode and cycling, and the forecasts generated concerning the amount of cycling that individuals might undertake for a given change in one of the attributes. Practical policy outputs are thereby produced.

Propensity to cycle discrete choice models for those travelling to work or study are estimated in Section 10.2. The sample is then split by various segments for modelling purposes, namely by individual segmentation variable, by individual postcode sector area, by population segment and by transport indicator. These segmented models are estimated in Section 10.3, including the testing of hypothesis eight: "The most influential attribute affecting mode choice between the motor car and cycling for the journey to work varies amongst population segments". To test this hypothesis the relative importance of the four attributes of journey time, a cost incentive to cycle, cyclist facilities at the destination and cyclist facilities on route are examined.

Forecasts from the discrete choice models for the propensity to cycle are presented in Section 10.4. These relate to the cyclist facility attributes, both at the destination and on route. Hypothesis nine is tested: "An improvement in cyclist facilities could induce a modal shift from the motor car to cycling for the journey to work or study".

10.2 Model estimation

The choices presented to the West Edinburgh survey respondents investigate the decision-making process in choosing between their current mode and cycling to work or study.

The design of the propensity to cycle stated preference experiment is outlined in Section 6.5. A stated preference experiment of nine scenarios was designed using four attributes: door to door journey time, a cost incentive to cycle, cyclist facilities at the destination and cyclist facilities on route. The journey time is 'same as current' for all bicycle choices and 'same as current', 10 minutes longer and 20 minutes longer than the current mode choices. The cost incentive to cycling alternatives presented are a daily payment of nothing, 50p and £2. Cycling facilities at the place of work or study concern no cycle parking facilities, cycle parking facilities only, and cycle parking, shower and changing facilities. For the bicycle choices there is also the route choice of cycling on-road with no cycle lanes, on-road with cycle lanes and off-road with cycle lanes.

10.2.1 Classifying the journey to work or study

Respondents making a journey to work or study are classified in this Section according to their appropriateness for the propensity to cycle stated preference experiment. Since the models concern the journey to work or study, only those in employment or education are considered. As shown in the summary of the socio-economic variables in Section 8.2, there are 654 respondents who work or study, within the West Edinburgh survey sample. Just under half of these respondents in work or study classify themselves as Professional (45%); the next most frequent employment status is Clerical / administrative (22%). The mode of travel of those travelling to work or study (625 respondents provided an answer) is shown in Table 10.1.

Table 10.1. Mode of travel for the journey to work or study in the West Edinburgh survey

	Frequency	Percentage
Car (driver)	316	50.6
Car (passenger)	17	2.7
Bus	168	26.9
Walk	78	12.5
Bicycle	31	5.0
Motorcycle	6	1.0
Train	9	1.4
Total	625	100.0

Table 10.1 shows that approximately half of the respondents drive and approximately a quarter travel by bus for the journey to work or study. The proportion driving to work or study is higher in the West Edinburgh survey than the Edinburgh data available in both the 2001 Census for Edinburgh (Table 8.1 – 36%) and the Scottish Household Survey (Table 7.6 - 40%). Conversely, the proportion walking to work or study in the West Edinburgh survey is lower than the Edinburgh data for both the 2001 Census for Edinburgh (Table 8.1 – 21%) and the Scottish Household Survey (Table 7.6 - 21%). The higher proportion travelling to work by motor car within the West Edinburgh survey sample may be due to a number of reasons. Firstly, higher income areas generated higher response rates in the survey (Section 8.2.2). Secondly, most of the City of Edinburgh Council area is within the city bypass, apart from those areas in West Edinburgh. Therefore, respondents within the Currie postcode sector area (high earners, car drivers) are over-represented at an Edinburgh-wide level.

Many of the sample work in Edinburgh city centre (17.8%); the majority work within the City of Edinburgh Council area but outside either the area where they live or the centre (59.7%). Of the remainder, 7.8% work in the four postcode sector areas in which they live and 14.8% work outside the City of Edinburgh Council area. The journey time estimates (622 respondents) within the West Edinburgh survey population travelling to work or study produce a mean of 26.6 minutes, comparable with the United Kingdom mean journey to work time of 25.4 minutes (Department for Transport, 2003a - Table

1.7). Most respondents do not work at home, but a distinct subset (a quarter of the sample) work from home at least occasionally.

There are 31 individuals cycling to work or study in the sample; primary reasons for cycling to work or study relate to the speed of the journey (20 cyclists) and to individual fitness or health (15 cyclists). Those cycling to work (30 provide socio-economic information) tend to be male (19 cyclists), live towards the centre of Edinburgh (12 Dalry, 10 Slateford), are aged between 25 and 44 (28 cyclists) and have a Professional job status (18 cyclists). The mean cycling journey time to work or study is 19.4 minutes, shorter than for those walking (78 respondents, mean = 22.3 minutes) or driving (303 respondents, mean = 24.2 minutes). The cyclists' workplace or study locations are typically in the centre of Edinburgh (13 cyclists), or within Edinburgh but outside the four postcode sector areas (12 cyclists).

10.2.2 Reasons for not cycling

Within the questionnaire, an open-ended question asked respondents to provide reasons why they do not cycle to work or study; 474 respondents answered this question. A coding framework was applied to reasons why individuals did not travel by bicycle to work or study, and the results are shown in Table 10.2. The analysis of this question aims to investigate further the reasons why individuals do not cycle, and to validate the stated preference experiment (by checking these answers against the screening question and the attributes).

Table 10.2. Codes for reasons individuals did not travel by bicycle to work or study in the West Edinburgh survey

Code	Results	Percentage
Too far	115	24.3%
Bike ownership	99	20.9%
Safety	92	19.4%
Traffic (too much)	68	14.3%
Not confident / able to ride bike	66	13.9%
Weather	57	12.0%
Facilities at work	53	11.2%
Another mode	40	8.4%
Carry equipment	36	7.6%
Clothing for work	34	7.2%
Facilities on route	29	6.1%
Unwilling	28	5.9%
Children	22	4.6%
Convenience	17	3.6%
Hilliness	14	3.0%
Facilities at home	12	2.5%
Other	75	15.8%

As shown in Table 10.2, there are a variety of reasons individuals do not cycle to work or study. The reasons can be compared with factors presented in the propensity to cycle stated preference experiment. The two most popular reasons are practical, that the journey is too far (24%) and that an individual does not have a bicycle available (21%). These reasons are accounted for in the stated preference experiment: respondents are excluded if their journey is too far to cycle, and it is assumed that a bicycle is available to respondents for the journey.

Safety is acknowledged as an important factor, stated by just under a fifth of the sample (19%). It may not be the principal reason (the literature highlights "safety fears from traffic" as the principal reason, Section 3.6) in Table 10.2 because "traffic (too much)" covers similar issues. Safety is not included directly in the propensity to cycle stated preference experiment, but the route choice attribute would assist those for whom safety fears from traffic is a problem. Cycle lanes, whether on-road or off-road, provide cyclists with a degree of separation from the road traffic. The analysis of the attitudinal questions within the West Edinburgh survey (Section 8.4.1) shows that women and the population segment 'part-timers with children' are the most likely within the population to cite "safety fears of traffic" preventing them from cycling.

Of the attributes within the propensity to cycle stated preference experiment, three are stated as reasons for not cycling by respondents (shown in Table 10.2). The variables of journey time (24% - too far), facilities at work (11%) and facilities on route (6%) are stated by respondents. Interestingly, cost is not stated as a reason; a payment to cycle is the fourth attribute within the stated preference experiment.

Other reasons of interest include the "weather" (12%), "unwillingness to cycle" (6%) and "children" (5%). The weather response tallies with the attitudinal statement answers (Section 8.4.1), suggesting that it can represent a barrier to cycling, but only for a small group of respondents. A small proportion (6%) state unwillingness to cycle; no reason is given, but they seem determined not to cycle whatever the circumstances. This echoes the car driver responses to petrol price changes, whereby 12% of respondents would not change the driving habits even if fuel costs increased by over ten times (Section 8.3.2). A minority of the population are extremely reluctant to follow sustainable transport measures, determined to continue their car usage.

It is of interest that for a small proportion of respondents "children" is the reason for not cycling (5%, 16% of respondents working or studying and in households with children). Perhaps the barrier to cycling is that the adult has to do the school run and, therefore, is not able to cycle to work. Therefore, the presence of children in a household has a mixed impact upon whether an adult in the household cycles: analysis in Chapters Seven and Eight has shown that households with children are more likely to have a bicycle, and for some adults, encourage them to cycle.

10.2.3 Participation in the propensity to cycle stated preference experiment

The propensity to cycle stated preference experiment is applicable for respondents who travel to work or study by motor car, bus or walk. From Table 10.1, this applies to 579 respondents that travelled to work as a car driver (316), as a car passenger (17), by bus (168) or on foot (78). There are valid stated preference answers for 195 respondents. The modal split for these individuals is: 100 travel by motor car (6 of these were car passenger), 58 take the bus and 37 walk. Overall this represents 34% of those able to take part in the stated preference experiment. Those not completing the experiment gave a reason why they could not cycle to work or study. When split by mode of travel, and in order, the proportion of those able to take part is 30% of those travelling by motor car, 35% of those taking the bus and 47%, the highest, of those who walk to work or study. This is to be expected, since the modes over shorter distance are more likely to be appropriate for cycling journeys.

The number of those not able to complete the propensity to cycle stated preference experiment for the journey to work in this study (66%) is comparable with participation levels elsewhere, whereby less than half of the original sample are able to complete the propensity to cycle stated preference experiment (Wardman et al, 1997; Ortuzar et al, 2000).

Of those eligible but not completing the propensity to cycle stated preference experiment, 358 respondents provide a reason for non-participation via a qualifying question. The question enables respondents to state if no measures would encourage them to cycle to work or study. Such respondents may "never consider cycling, whatever their circumstances", or the nature of the respondent's work or study may ensure they would not cycle (the "journey may be too far" or the nature of their work or study may make cycling inappropriate"). Responses are shown in Table 10.3.

Table 10.3. Reasons given by respondents for non-participation in the propensity to cycle stated preference experiment

	Frequency	Percentage
Never consider cycling whatever the circumstances	235	65.6
Consider cycling, current journey too far	70	19.6
Consider cycling, nature of work or study means cannot cycle	53	14.8
Total	358	100.0

In terms of the propensity to cycle, the first answer represents a population segment that would "never" consider cycling whatever measures are implemented to encourage it (66% of non-participants, 44% of those in work or study). The second and third answers may represent suppressed demand (34% of non-participants, 23% of those in work or study). These two groups of respondents would "consider" cycling to work but their current circumstances prevent them. If their work or study situations and/or location changes, they may consider cycling.

Respondents estimate their journey time by bicycle; a mean of 34.7 minutes was generated, ten minutes longer than the overall mean journey to work time, calculated on the method of transport to work or study they currently used.

10.2.4 Model estimation for those travelling to work or study

There are 195 respondents who completed the propensity to cycle stated preference experiment. This constitutes 1,755 stated choices. Of these choices, the current mode option is chosen on 1,208 occasions, the bicycle option on 547 occasions. The modal split for these respondents is 100 usually travelling by motor car (6 of these were car passenger), 58 by bus and 37 walking.

A model run was estimated for the total sample of 195 respondents travelling to work or study. Further runs were undertaken by current mode of transport. The utility expressions, based on the formula shown in Section 2.7, for the two choices between current mode (cm) and bicycle (bike) are:

$$U1_{cm} = \beta 1*time_{cm} + \beta 2*pay_{cm} + \beta 3*facil_{cm} + \beta 4*route_{cm}$$

$$U2_{bike} = MSC_{bike} + \beta 1*time_{bike} + \beta 2*pay_{bike} + \beta 3*facil_{bike} + \beta 4*route_{bike}$$

where U = utility, ß = coefficient, MSC = mode specific constant.

The utility of each mode is affected by the four variables in the propensity to cycle stated preference experiment. The mode specific constant reveals the level of bias within the models, showing the effect of attributes not within the model (in this example, the impact of everything except for journey time, a cost incentive to cycle, facilities at the destination and facilities on route). Outputs from the model estimation are shown in Table 10.4.

Table 10.4. Outputs from the propensity to cycle model estimation for those travelling to work or study

Run	All modes	Current mode		
		Car	Bus	Walk
Number	195	100	58	37
SP choices	1755	900	522	333
Rsq-zero	0.2149	0.229	0.2381	0.1869
Rsq-const	0.1229	0.1125	0.1863	0.0853
Coefficient (T values)				
journey time	-0.3910 (-5.3)	-0.3547 (-3.4)	-0.3435 (-2.4)	-0.5680 (-3.5)
payment to cycle	0.1077 (1.6)	0.0987 (1.0)	0.1601 (1.2)	0.0550 (0.4)
facilities at destination	0.9447 (11.9)	0.9248 (8.3)	1.255 (8.0)	0.5768 (3.4)
facilities on route	0.7435 (9.9)	0.6807 (6.4)	0.9606 (6.6)	0.6224 (3.8)
Constant	3.163 (13.7)	3.136 (9.7)	3.564 (7.7)	2.768 (5.9)

The rho-squared value (with respect to zero) for the standard model is 0.2149. Although lower than the propensity to walk total motorist sample model, it compares favourably against other stated preference experiments that concern cyclist mode or route choice; rho-squared values in such studies tend to lie between 0.13 and 0.16 (Hopkinson and Wardman, 1996; Wardman et al, 1997; Ortuzar et al, 2000). The constant contributed 0.1229 of this, suggesting the attributes in the utility expressions do have an important role in explaining mode choice. The mode specific constant (at 3.163, T value of 13.7) shows that other attributes have a significant effect upon the mode choice between current mode choice and cycling, representing a higher level of bias than the propensity to walk models. However, the rho-squared values and coefficients (three attributes are significant and the signs are in the expected direction) indicate model robustness.

There are three significant attributes of journey time, cycling facilities and nature of the cycle route. Cycling facilities, firstly at the destination and secondly on route, are the most influential. Time taken for a journey is not as important to respondents. Of additional interest is the insignificance of the cost inducement. In addition to cost not being a barrier to cycling (as shown in Section 10.2.2), payments to individuals do not appear an effective method to induce cycling.

Unlike the propensity to walk model estimation (Section 9.2.3), model outputs for values of time and cross elasticities have not been included. This is because the propensity to cycle modelling focus concerns facility provision rather than cost values (the propensity to walk modelling focus concerns parking and petrol costs).

Model estimation by current mode produces similar results to the model run for all three current modes. The remainder of the Chapter concentrates on the trade-offs between the motor car and the bicycle choices. This is because the focus of the thesis has been on reducing motor car usage (rather than walking or bus usage) and encouraging individuals to cycle (as well as walk), so this trade-off has the most relevance. Furthermore, the sample size, of 100 individuals currently taking the motor car to work or study, is larger than the other two current modes.

Examining the composition of the motorist sample, the 100 motorists completing the propensity to cycle stated preference experiment are more likely to have children, have a bicycle available, be younger and work in Edinburgh than the 216 motorists not taking part in the experiment.

10.3 Model segmentation

In this Section, hypothesis eight is tested: "The most influential attribute affecting mode choice between the motor car and cycling for the journey to work varies amongst population segments". The focus is on the relative importance that different population segments place on attributes when choosing between the motor car and cycling.

10.3.1 Estimation of the segmented models

Although the motorist sample (100 respondents) is smaller than for the propensity to walk segmented models, presented in Chapter Nine, propensity to cycle model runs can be undertaken using different segments. Models are segmented by individual segmentation variables, postcode sector area, population segment (developed using Scottish Household Survey data in Chapter Seven) and cycling variables. The sample size did not permit combined models of population segments within postcode sector areas to be modelled. Table 10.5 shows results of the segmented model estimation using individual segmentation variables; Table 10.6 shows results of the segmented estimation using postcode sector area, population segment and cycling variables.

Table 10.5. Results for the propensity to cycle stated preference experiment, segmented by individual segmentation variables

Segmentation model, in comparison with the model for the total sample	Number	Rho^2-zero	T value: time	T value: payment	T value: facilities at destination	T value: facilities on route
Age – under 35	33	0.2135	-1.2	1.3	5.6	3.7
Age – 35 or over	67	0.2438	-3.3	0.3	6.2	5.2
Gender – male	52	0.1779	-2.4	0.8	5.8	4.1
Gender – female	48	0.2990	-2.5	0.8	5.9	5.0
Income – £40,000 per annum or less	64	0.2004	-2.6	1.4	6.4	4.4
Income – more than £40,000 per annum	36	0.2931	-2.3	0.0	5.2	4.7
Children – in household	49	0.2176	-2.5	1.4	5.4	4.0
Children – not in household	51	0.2442	-2.3	0.1	6.3	5.0
House type – detached	25	0.1801	-1.5	-0.7	3.5	2.1
House type – flat	32	0.2559	-1.0	0.2	5.6	3.7
Situation of respondent – employed full-time	75	0.2444	-2.5	1.1	8.1	6.2
Situation of respondent – not employed full-time[1]	25	0.2183	-2.6	0.2	2.4	2.0
Total sample	**100**	**0.229**	**-3.4**	**1.0**	**8.3**	**6.4**

Note: [1] = this group consisted primarily of part-timers (13) and the self-employed (6)

Table 10.6. Results for the propensity to cycle stated preference experiment, segmented by postcode sector area, population segment and cycling variables

Segmentation model, in comparison with the model for the total sample	Number	Rho^2-zero	T value: time	T value: payment	T value: facilities at destination	T value: facilities on route
Area - Slateford	25	0.2651	-0.7	-0.7	4.8	3.9
Area - Currie	43	0.2281	-3.6	2.1	4.9	4.1
Segment - High earner without children	32	0.2655	-2.5	0.4	4.5	4.0
Segment - High earner with children	27	0.2309	-0.9	0.5	4.8	3.6
Cycling - Cycled in previous month	33	0.2092	-3.1	1.0	5.0	4.1
Cycling - Did not cycle in previous month	67	0.2445	-1.9	0.5	6.7	5.0
Cycling - Adult bicycle available to household	72	0.2254	-3.0	1.0	7.1	5.7
Cycling - Adult bicycle not available to household	28	0.2404	-1.7	0.2	4.3	3.0
Cycling - Consider cycling to be unsafe	73	0.2280	-2.5	-0.5	6.5	7.0
Cycling - Do not consider cycling to be unsafe	27	0.3096	-2.4	2.6	5.1	1.0
Total sample	**100**	**0.229**	**-3.4**	**1.0**	**8.3**	**6.4**

The segmented model results shown in Tables 10.5 and 10.6 have satisfactory rho-squared values (with respect to zero) and significant T values (at the 95% level) for the two cyclist facilities attributes. Payment to cycle is only significant in two of the models (Currie, those considering cycling unsafe). Journey time has a significant effect for fifteen of the twenty-two segmented models.

Apart from two segmented model runs, cyclist facilities at the destination is the most influential variable. The exceptions are respondents not employed full-time (for whom journey time is more influential) and respondents considering cycling to be unsafe (for whom facilities on route are more influential). Those not employed full-time are part-timers and the self-employed, so for many within this group the workplace will not be a regular destination and such facilities would have little impact. For those considering cycling to be unsafe, this fear stems from traffic on the roads and so facilities on route would be more influential for these individuals than facilities at the destination.

Since almost all of the model runs have cyclist facilities at the destination as the most influential variable, it is of interest to gauge the difference in emphasis between the two cyclist facility attributes (at the destination, on route) for the various segmented models. For all respondents except those considering cycling to be unsafe, facilities at the destination have more influence. The segments with a particular emphasis on cyclist facilities at the workplace (compared to on route) are male individuals, the young (under 35), those living in flats and those on lower incomes. These socio-economic characteristics are similar to the characteristics of those currently cycling to work or study (Section 10.2.1).

There is little difference between the segmented models with and without children in the household, by area and by bicycle availability.

10.3.2 Assessment of hypothesis eight

Hypothesis eight, "The most influential attribute affecting mode choice between the motor car and cycling for the journey to work varies amongst population segments", has been accepted. For almost all of the segmented models, cyclist facilities at the destination is the most influential variable. It is particularly influential amongst those who could be most likely to cycle to work, since they share similar characteristics to those currently cycling to work or study.

However, there are two models without cyclist facilities at the destination as the most influential variables, showing differences amongst population segments. Journey time is more influential for respondents not employed full-time who would not have a regular work destination. Facilities on route are more influential for those considering cycling to be unsafe, having a strong preference for safe, off-road cycle routes.

10.4 Forecasts from the model

In this Section, hypothesis nine is tested: "An improvement in cyclist facilities could induce a modal shift from the motor car to cycling for the journey to work or study". Akin to non-motorised mode modelling examples in Chapter Three (Noland and Kunreuther, 1995; Wardman et al, 1997; Ortuzar et al, 2000), this study uses the sample enumeration method for forecasting. The probability of each alternative (motor car, cycling) is predicted using the formula stated in Section 2.7. The focus is on the forecasts concerning the amount of cycling that individuals might undertake for a change in one attribute, in this case cyclist facilities at the destination and cyclist facilities on route.

For example, the predicted probability of an individual choosing to cycle rather than travel by motor car for a given change in attribute X (e.g. the provision of on-road cycle lanes), would induce a change in probability of Y (e.g. an increase in cycling of 61.4% - shown in Table 10.7).

10.4.1 Scenario development

Of the four attributes, cyclist facilities at the destination and on route are used for forecasting, since they are measures promoted within transport policy. There are two levels of improvement for facilities at the destination and on route, from a base level of no current facilities. For cyclist facilities at the destination, the first level is to install cycle parking and the second level to install shower and changing facilities. For cyclist facilities on route, the first level is to travel on-road with cycle lanes, and the second level to travel off-road with cycle lanes. As stated in Section 10.2.2, the cyclist facilities on route attribute provides increased separation from traffic to indicate increased safety from the fears of sharing road-space with motorised transport.

10.4.2 Cyclist facility forecasts for the motorist sample

Table 10.7 shows forecasts for the effects of destination and on route cyclist facilities upon the probability of individuals choosing to cycle.

Table 10.7. Forecasts for the effect of cyclist facilities at the destination and on-route upon the probability of individuals choosing to cycle

Scenario	**Probability motor car**	**Probability cycle (% increase over base)**
Base: no facilities at destination	0.87	0.13
1: cycle parking facilities	0.73	0.27 (101.6%)
2: cycle parking, shower and changing facilities	0.54	0.46 (247.2%)
Base: on-road with no cycle lanes	0.83	0.17
1: on-road with cycle lanes	0.72	0.28 (61.4%)
2: off-road with cycle lanes	0.59	0.41 (139.2%)

The forecasts in Table 10.7 show that implementing facilities can induce a modal shift to cycling in the journey to work or study. Installing cycle parking facilities increases projected cycling levels by 102%, and combined with shower and changing facilities by

247%. Providing cyclist facilities on route has a lesser effect upon projected cycling levels. The provision of cycle lanes on-road increases the levels by 61%; off-road cycle lanes increases levels by 139% upon the base level. The reasons provided for not cycling (Section 10.2.2) and the model estimation (Section 10.2.4) show that cyclist facilities at the destination are more influential than cyclist facilities on route.

A forecasting sample size of 100 motorists has been considered too be small to generate forecasts of segmented models.

10.4.3 Applying the propensity to cycle forecasts to those in work or study

The forecasts for the propensity to cycle can be factored up for those in work or study, in a similar manner to the propensity to walk forecasts (Section 9.4.5) and in the literature (Davies et al, 2001 – Section 3.6.2). This is undertaken using other data within the West Edinburgh survey.

As stated in Section 10.2.3, of those currently travelling by motor car to work or study, 30% took part in the propensity to cycle stated preference experiment. Factoring the forecasts to take account for this (multiplying them by 0.3), produces the following values for both cyclist facilities:

- Base: no cyclist facilities at destination = 0.039
- Scenario 1: cycle parking facilities = 0.081
- Scenario 2: cycle parking, shower and changing facilities = 0.138

- Base: on-road with no cycle lanes = 0.051
- Scenario 1: on-road with cycle lanes = 0.084
- Scenario 2: off-road with cycle lanes = 0.123

Implementation of cyclist facilities could, therefore, increase the cycling modal share of motorists to a maximum of approximately 14% for cyclist facilities at the destination and approximately 12% for cyclist facilities on route (plus the 5% of the population currently cycling to work). These could be considered maximum values because the forecasting relates to a complete coverage of facilities. For the facilities on route, it would be virtually impossible to implement off-road cycle lanes for all respondents travelling to work or study. Not only is there the cost to consider, but there may not be the space to implement cycle lanes, whether on-road or off-road.

The forecasts indicate that there are some individuals with a propensity to cycle for the journey to work or study if cyclist facilities are installed. These percentage increases appear to represent a major effect upon cycling levels for this journey, greater than the propensity to walk forecasts. However, it is recognised that the cycling forecasts are from a lower base level and have less reliability due to a small sample size. In addition, as stated at the outset (Section 2.2.2 – Polak and Jones, 1997) and in Section 9.4.6, stated preference studies typically over-estimate forecasts and require validation. Unlike the propensity to walk discrete choice models, internal validation could not be undertaken using attitudinal data within the West Edinburgh survey, because there are not any appropriate questions (about cyclist facilities).

The propensity to cycle forecasts concern motorists. Within the West Edinburgh survey they constitute 51% of the journey to work sample (Table 10.1), a higher proportion than those typically travelling to work motor car. The sample is acknowledged to be over-represented with high earners and motor car drivers; as stated in Section 9.4.6, the sample enumeration forecasting technique assumes that the sample used to estimate the model is representative.

A limited number of studies have generated cycling forecasts, as documented in Section 3.7.2. The forecasts generated by Wardman et al (1997) are acknowledged as over-estimates and unrealistic (24% amongst current car users, 25% amongst current bus users). Wardman et al (1997: p130) state that this could be due to the scale of the utilities being wrong and individuals stating a preference for cycling but not changing their actual behaviour. Noland and Kunreuther (1995) also over-estimated forecast shares for cycling, in the short-run to be a percentage change of 196%.

As stated in Section 9.4.6, generating forecasts from joint revealed preference / stated preference discrete choice models can reduce bias and improve the efficiency of parameter estimates. Such forecasting could be recommended as an outcome of this study. As Wardman et al (1997: p133) state, it would be "sensible to develop joint revealed preference / stated preference models which provide a firm basis in actual behaviour yet exploit the ability of stated preference methods to examine a wide range of cycle attributes in detail."

Of the propensity to cycle modelling research, it is the Wardman et al (2000a) study, using joint revealed preference / stated preference discrete choice models, which has generated the most reliable cycling forecasts. Forecasts within Wardman et al (2000a) have a base market share of 4.5% cycling to work, up to a maximum market share of 7.3% for cycle lanes, 19.3% for daily payments to cycle and 6.3% for facilities at the workplace. These forecast levels are comparable to those generated in this study: a base market share of 5% cycling to work, up to maximum market share of 17% for cyclist facilities on route and 19% for facilities at the destination. The forecast levels may be comparable, but the order of influence of the attributes is different between the two studies. Wardman et al (2000a) establish a daily payment to cycle as the most influential variables; in this study it has an insignificant effect.

The forecasts for the propensity to cycle have been put into context as part of the journey to work or study, but there are concerns about the reliability, given the small sample size and possible bias within the motorist sample. It is a question of providing a balance between promoting forecasts that appear realistic and recognising possible bias within the forecasts. Rather than emphasise the forecast levels, it is preferable, therefore, to assert that cyclist facilities have a 'slight' effect upon cycling levels, accounting for over-estimation by respondents.

There would need to be further factoring up to take account of the full modal choice set for the journey to work or study and the proportion of trips that account for the journey to work or study. As an example, within the Scottish Household survey travel diary sample for Edinburgh, for all modes the journey to work constitutes 20% of all trip purposes (for motorist trips the journey to work constitutes 23% of all trip purposes).

10.4.4 Assessment of hypothesis nine

Hypothesis nine: "An improvement in cyclist facilities could induce a modal shift from the motor car to cycling for the journey to work or study", has been accepted. Model forecasts were produced for cyclist facilities both at the destination and on route. They have been factored up to account for motorists not taking part in the propensity to cycle stated preference experiment. The resultant forecasts are at similar levels to the most comparable study, Wardman et al (2000a), but the attributes have different influences. The validation process has shown some elements of unreliability within the forecasts, so rather than emphasising the increased levels of cycling, it can simply be stated that cyclist facilities have a 'slight' affect upon cycling levels for motorists travelling to work or study.

10.5 Summary

This Chapter relates to the second research objective, "to develop a methodology that models individual travel behaviour and thus the propensity to use non-motorised modes". The objective has been achieved for the propensity to cycle, since robust models have been developed for both the total sample of motorists and segmented discrete choice models. Forecasts have also been generated, for cyclist facilities at the destination and on route.

This study has a novel approach of considering the population as a whole through a household survey rather than concentrate on cyclists. Most stated preference experiments on cycling consider the latter rather the former (Section 3.7).

Section 10.2 provides a breakdown of the journey to work or study sample. Most work within Edinburgh, in a range of locations. The minority cycling to work or study do so for reasons of exercise and speed. Indeed, those who choose to cycle have, on average, a quicker journey to work or study than those driving or walking. Respondents making a journey to work or study are classified according to their appropriateness for participation in the propensity to cycle stated preference experiment. The journey to work or study sample within the West Edinburgh survey is acknowledged to be over-represented with high earners and motor car drivers (particularly within the postcode sector area of Currie).

A variety of reasons are provided by respondents for not cycling to work or study. The most popular relate to practical issues (journey too far or do not have a bicycle available) and safety fears from too much traffic. Some of these responses validate the attitudinal findings of Chapter Eight: a small proportion state the weather as a barrier to cycling and small minority is extremely reluctant to follow sustainable transport policies (cycling in this case). For some respondents, children act as a barrier to cycling, perhaps if they also have to do the school run (for utility trips). As shown in the analysis in Chapters Seven and Eight, adults may be encouraged to purchase bicycles when their children are learning to cycle (for leisure trips). The life stage of having children has, therefore, been shown to have a mixed impact upon the propensity of an adult to cycle.

Of the three modes within the model estimation, unsurprisingly it is the motorists who are least willing to cycle to work or study; 30% of motorists took part in the stated preference experiment. Model estimation produces three significant variables for each of the three current modes of travel - by motor car, by bus and on foot. Cycling facilities, firstly at the workplace and secondly on route, are the most influential. Journey time is not as important, but still significant, to most individuals in the propensity to cycle stated preference experiment. Of interest is the insignificance of the cost inducement to cycle.

The propensity to cycle stated preference experiment was designed to consider cycling components of 'Green Travel plans' (Section 6.5.2). Findings from model estimation show that cyclist facilities, both at the destination and on route, should be core cycling components within Green Travel plans. The cost element, an inducement to cycle, has been shown to be ineffective.

Model runs have been undertaken using segmentation variables for those currently travelling by motor car to work or study. These are documented in Section 10.3. Hypothesis eight states, "The most influential attribute affecting mode choice between the motor car and cycling for the journey to work varies amongst population segments". For almost all of the segmented models, the cyclist facility at the destination is the most influential variable. However, the hypothesis has been accepted due to two exceptions. Firstly, for respondents not employed full-time, journey time is more influential. This shows that some respondents don not have a fixed, regular work or study destination; for these individuals it is difficult to provide cyclist facilities for the journey to work or study. Secondly, for those considering cycling to be unsafe, facilities on route are more influential than those at the destination. Facilities at the destination may, therefore, have a greater impact overall, but facilities on-route can help to overcome the main barrier to cycling, "safety fears from traffic".

Cyclist facilities at the destination are particularly influential amongst those motorists most likely to cycle to work, since they share similar characteristics to those currently cycling to work or study.

Forecasts from the discrete choice models for the propensity to cycle, of those currently travelling to work or study by motor car, are documented in Section 10.4. Hypothesis nine: "An improvement in cyclist facilities could induce a modal shift from the motor car to cycling for the journey to work or study", has been accepted. Model forecasts are produced for both cyclist facilities both at the destination and on route. The forecasts have been factored up to account for motorists not taking part in the propensity to cycle stated preference experiment. The validation process has shown some elements of unreliability within the forecasts, so rather than emphasising the increased levels of cycling, it can simply be stated that cyclist facilities have a 'slight' affect upon cycling levels for motorists travelling to work or study.

This study has developed research concerning the factors affecting non-motorised mode usage, as recommended by Porter et al (1999) in Section 3.6.3, by modelling the design of cyclist facilities on route (e.g. cycle lanes, off-road) and at the destination (e.g. bicycle parking and showers). Cyclist route choice models have shown that, for cyclists, safety and time are considered to be more important than facilities (Section 3.7.1). However, this experiment is for mode choice and considers those not currently cycling. Similar forecasts have been produced in this study, as Wardman et al (2000a), in a journey to work context. Although the attribute influences vary between the two studies, both show that cyclist facilities, at the destination and on route, affect the propensity to cycle to work.

Chapter Eleven is the final Chapter, discussing and concluding the findings of the thesis.

11. DISCUSSION AND CONCLUSIONS

11.1 Introduction

Chapter Eleven concerns discussion and conclusions of the thesis findings. The thesis has assessed the propensity of individuals to use non-motorised modes in Edinburgh. The first research objective has been to identify segments of the population with the greatest propensity to use non-motorised modes. The second research objective has been to model individual travel behaviour and thus the propensity to use non-motorised modes. Findings are presented according to the two research objectives, in Section 11.2 and Section 11.3 respectively.

The policy implications of the research are summarised in Section 11.4. Section 11.5 presents suggestions for further research; overall conclusions to the thesis are provided in Section 11.6.

11.2 Identifying population segments with the greatest propensity to use non-motorised modes

All nine behavioural hypotheses relate to the first research objective, "to identify segments of the population with the greatest propensity to use non-motorised modes". The approach has used population segments deduced from the Scottish Household Survey analysis and individual segmentation variables. The size of the two household survey data sets has enabled detailed segmentation to be undertaken. This Section considers the development of population segments from the Scottish Household Survey data (Section 11.2.1); survey data analysis using these population segments (Section 11.2.2) and individual segmentation variables (Section 11.2.3); and the identification of segments with the greatest propensity to use non-motorised modes from the discrete choice models (Section 11.2.4).

11.2.1 Developing population segments from the Scottish Household Survey data

Cluster analysis was performed on six socio-economic variables within the Scottish Household Survey data, showing that the population could be split into segments according to socio-economic characteristics (Section 7.3). The most influential variables upon the composition of the population segments are the life stages of gaining employment, having children and entering retirement; income and house type also affect the nature of the population segments. A novel aspect of this study has been the consideration of cluster analysis separately as a prelude to travel behaviour analysis.

11.2.2 Identifying segments with the greatest propensity to use non-motorised modes: survey analysis using the ten population segments

Headline results from the Scottish Household Survey and West Edinburgh survey analysis of the ten population segments are shown in Table 11.1.

Table 11.1. Headline segmentation results from the Scottish Household Survey and West Edinburgh survey analysis

Population segment	Scottish Household Survey analysis	West Edinburgh survey analysis
Group 1 – Student	Primary segment with adult bicycles available & no motor car (45% of students). High proportion of utility walkers (86%).	-
Group 2 – In-between jobs	Low motor car availability (38% had car available), suited for non-motorised modes and public transport.	-
Group 3 - Mid earner	Many motor car available but no bicycle available (40%). Particularly suited to non-motorised mode travel since all live in flats.	High proportion agree congestion / pollution are problems, & want improved cycle lanes (on-road & off-road).
Group 4 - High earner without children	Almost all motor car available (91%); highest proportion driving to work (65%) & lowest proportion walking to work (10%).	-
Group 5 – Part-timer without children	Relatively high proportion bicycle available but not motor car (11%); high proportion of utility walkers (88%); highest proportion walking to work (31%).	High proportion change travel behaviour at slightest increase in fuel.
Group 6 - Child minder	Almost no cyclists in sample (1%); high proportion of utility walkers (77%).	-
Group 7 - High earner with children	Almost all motor car available (94%) – most car dependent group; also most bicycles available (66%).	High proportion want improved on-road cycle lanes.
Group 8 – Part-timer with children	High bicycle availability (59%).	High proportion agree congestion / pollution are problems; highest proportion safety fears of traffic prevent cycling.
Group 9 - Retired in a couple	Least propensity to cycle (car available, no bicycle available). Almost no cyclists in sample (1%); low proportion of walkers (69%).	Low proportion agree congestion / pollution are problems; high proportion change travel behaviour at slightest increase in fuel.
Group 10 - Retired living on own	Lowest motor car availability (38% had car available); particularly suited to walking & public transport; almost no cyclists in sample (1%); low proportion of walkers (62%).	Low proportion agree congestion / pollution are problems; highest proportion for all walking statements: more pavements & road crossings, fears for personal safety.

Of the ten population segments in Table 11.1, a lack of motor car availability ensures that 'students' and those 'in-between' jobs have the greatest opportunity to use non-motorised modes and this is reflected in relatively high usage compared to other population segments. 'Part-timers without children' have a high propensity to use non-motorised modes; they have high bicycle availability, they make more utility walking trips than other segments and many would change travel behaviour at a slight increase in fuel.

Conversely, the high earning households have high motor car availability and usage. 'High earning households without children' could be considered the most car dependent of the ten population segments. 'High earning households with children' at least have most adult bicycles available of the segments; the difficulty is converting bicycle ownership to bicycle usage.

Hardly any individual within the two retired population segments travels by bicycle. Of the two segments, those 'retired on their own' would tend to be older, reflecting a lower likelihood of being able to drive and walk. Those 'retired on their own' are most likely to desire improved pedestrian facilities and have fears for their personal safety.

The remaining three population segments have mixed propensity to use non-motorised modes. 'Mid earners', who live in flats, would be particularly suited to non-motorised travel, but many do not have a bicycle available. 'Part timers with children', who tend to be female, have potential as they have bicycles available, but safety fears from traffic deter them from cycling. Hardly any individual within the 'child minder' population segment cycles, but a high proportion of them make utility walking trips.

Figure 11.1 illustrates these findings, placing the ten population segments on a spectrum of high, medium and low propensity to use non-motorised modes. Since non-motorised mode propensity can be distinguished between the ten population segments, it can be asserted that the first objective has been achieved: population segments have been identified with the greatest propensity to use non-motorised modes.

Figure 11.1. The ten population segments on a spectrum of propensity to use non-motorised modes

LOW PROPENSITY ⇒	**MEDIUM PROPENSITY** ⇒	**HIGH PROPENSITY**
High earner without children (most car dependent)	Mid earner (live in flats, but many do not have bicycle available)	Student (high non-motorised mode usage)
Retired in a couple (low non-motorised mode usage)	Child minder (low cycling usage, high utility walking usage)	In-between jobs (high non-motorised mode usage)
Retired living on own (low non-motorised mode usage)	High earner with children (many have bicycles available, high car dependency)	Part-timer without children (high bicycle availability, most utility walking trips)
	Part-timer with children (many have bicycles available, deterred by safety fears from traffic)	

Figure 11.1 confirms the importance of life stage, particularly children within the household, affecting the propensity to use non-motorised modes. Of interest, children increase the propensity of high earners to use non-motorised modes, but decrease the propensity for part-timers. 'High earners with children' may have more adult bicycles available in the household because they want to teach their children to ride a bicycle (Section 7.6). 'Part-timers without children' may walk more because they tend to be flat dwellers (living near to the centre of Edinburgh, easier to make walking trips) and on lower incomes (Table 7.4). Housing for families tends to be low-density and on the outskirts of Edinburgh; in the West Edinburgh survey a higher proportion of children were present in households on the outskirts of Edinburgh than towards the city centre (Section 8.2.5).

The links between propensity to use non-motorised modes and having children also illustrate that the propensity to walk and the propensity to cycle can be very different.

11.2.3 Identifying segments with the greatest propensity to use non-motorised modes: survey analysis using individual segmentation variables

Survey analysis using individual segmentation variables has produced some interesting findings relating to the propensity to use non-motorised modes.

The study has a premise that the least car dependent individuals have a greater propensity to use non-motorised modes. Empirical analysis of the two data sets within this thesis has shown that individuals in Edinburgh particularly reliant on the motor car (Section 7.4), and with strong disagreement the congestion and air pollution are problems in Edinburgh (Section 8.3.1), are those of working age, male, with higher incomes, in households with children and those that reside further from the city centre. This confirms the motorist market segments deduced in the literature (Section 3.3.3) and indicates those with a greater propensity to use non-motorised modes: those not working, female, on lower incomes, in households without children and those living near to the city centre.

Responses to cycling statements within the West Edinburgh survey data set are strongly segmented by gender (Section 8.4.1). Males have the greatest propensity to cycle; barriers to cycling are greater for women, particularly safety from traffic fears but also topography and weather. Almost everyone walks, yet the responses to attitudinal statements within the West Edinburgh survey data, show that walking opinions vary according to gender, age and income (Section 8.4.2). For example, personal safety concerns are more acute amongst women, those living in low income areas and at the age extremes. Such concerns can act as a barrier, resulting in individuals having a lower propensity to walk.

11.2.4 Identifying segments with the greatest propensity to use non-motorised modes using discrete choice models

Discrete choice models were run using population segments, individual segmentation variables, and variants of these, such as population segments within a postcode sector area. Many segment combinations have been used; this Section highlights the findings of most interest. These segmentation modelling findings represent a novel aspect, highlighting the differences amongst motorists within the non-motorised mode choice contexts of the stated preference experiments.

Segmented models for the propensity to walk show that for some population segments journey time is the most influential attribute, whilst for other segments it is parking cost. Parking cost is the most influential attribute for those with a lower value of time and the least car dependent: women, those living in flats and those on low incomes (£15,000 per annum or less). Respondents putting more of an emphasis upon journey time in the experiment are men, those on high incomes (over £40,000 per annum), those living in detached houses, those in full-time employment, those in retirement and those living in Currie (i.e. those living further from the city centre in the sample population).

Forecasting for the propensity to walk stated preference experiment was undertaken for those segments with a sufficient sample size. Segmented response to petrol price increases is varied: from a negligible response amongst 'part-timers without children' (0.1%) to a slight response amongst 'mid earners' (1.7%). This illustrates that lower income groups are affected more by petrol price increases. Segmented response to parking cost increases, in Slateford, shows that higher earning households are more likely to increase the amount they walk than those retired (in a couple).

For almost all of the models for the propensity to cycle, cyclist facilities at the destination is the most influential attribute. Cyclist facilities at the destination are particularly influential amongst those motorists most likely to consider cycling to work, since they share similar characteristics to those currently cycling to work or study. For those considering cycling to be unsafe, facilities on route are more influential that those at the destination. Facilities at the destination may, therefore, have a greater impact overall, but facilities on-route can help to overcome the main barrier to cycling, "safety fears from traffic".

11.3 Modelling individual travel behaviour and the propensity to use non-motorised modes

Discrete choice models were developed to test the second research objective, "to develop a methodology that will model individual travel behaviour and thus the propensity to use non-motorised modes". The models use data from the two stated preference experiments within the West Edinburgh survey. The West Edinburgh survey sample, of 997 households, enabled the development of robust discrete choice models, including segmented model runs and non-motorised mode forecasts; all four modelling hypotheses have been accepted. The size of the West Edinburgh survey was sufficient to cover any spatial and non-response bias within the survey; the 'call and post' methodology achieved a credible response rate of 33%. As stated in Section 3.8.1, collecting data on non-motorised modes, particularly for walking, makes this research an important contribution.

This study has concerned the application of discrete choice models, based on random utility theory, rather than an examination of the theoretical aspects (Section 2.6). Much of the originality of the study concerns the model application into the area of non-motorised modes. The emphasis on choice within the Integrated Transport White Paper (Section 4.2.1) makes discrete choice modelling an appropriate methodology for analysing the trade-offs between the motor car and non-motorised modes.

Non-motorised mode discrete choice models tend to concern either cyclist route choice or a mode choice that includes cycling (Section 3.7). The examples in this study concern a novel trade-off, between walking and the motor car for a general trip, and an extension of the studies modelling the propensity to cycle for the journey to work (Section 3.7.2).

The propensity to walk experiment concerns a general trip, and includes national (petrol prices) and local (parking costs) transport policy measures amongst the attributes to reduce car use. Model estimation (Section 9.2.2), applying to short journey in urban areas, has shown that parking cost and journey time are more influential upon the propensity to walk than petrol prices.

The propensity to cycle experiment focuses on the journey to work or study. From the model estimation (Section 10.2.4) cycling facilities, firstly at the workplace and secondly on route, are the most influential upon the propensity to cycle of those currently travelling to work or study by car, by bus or on foot. Journey time is not as important, but still significant; a cost inducement to cycle to work or study is insignificant.

As shown in Section 11.2.4, results from the segmented models have provided detailed information on how various population segments respond to non-motorised mode choices.

Forecasts have been generated from the discrete choice models for both the propensity to walk and the propensity to cycle models; in both experiments the transport policy measures show a slight increase in the levels of cycling and walking, when factoring is taken into account. Validation of the models has been possible using attitudinal, revealed preference data within the West Edinburgh survey for the propensity to walk experiment (Section 9.4.6) and travel behaviour data within the Scottish Household Survey for both experiments (Section 9.4.5; Section 10.4.3).

Since robust models have been developed, with practical outputs, the second research objective has been achieved: a methodology has been advanced that will model individual travel behaviour and thus the propensity to use non-motorised modes.

11.4 Policy implications of the research

The increase in non-motorised mode emphasis within transport policy represented the starting point to this study. As outlined in Chapter Four, the United Kingdom Integrated Transport Strategy and the Edinburgh Local Transport Strategy have promoted sustainable transport alternatives to the motor car. It has yet to be seen whether the policy rhetoric will be translated into increased levels of cycling and walking.

This Section outlines the policy implications of the research. It considers transport policy measures that could be implemented to reduce motor car usage (Section 11.4.1) and to encourage non-motorised modes (Section 11.4.2). A package of possible transport measures that could be implemented are listed in Section 11.4.3.

11.4.1 Reducing motor car usage

Since most of the population are car dependent (Section 3.3), there is unlikely to be a large-scale change in travel behaviour away from the motor car. The West Edinburgh survey analysis (Section 8.3) confirms findings from the literature (Section 3.4) that car drivers acknowledge the problems associated with the motor car but are unwilling to change travel behaviour. Most car drivers in the survey agree that congestion and air pollution are a problem in Edinburgh (68%), but only 13% of them are willing to give up use of their car in response to transport policy measures.

There are signs that there is a willingness to change travel behaviour away from the motor car at the margins of the West Edinburgh survey sample (Section 8.3). However, there would appear to be a similar-sized proportion of the population (say between 10% and 20%) at the other end of a 'willingness to change' travel behaviour spectrum (as suggested by the literature – Section 3.4). This is illustrated by 12% of the motorist sample not willing to change their car use even if the fuel price increased by over ten times current levels (Section 8.3.3). Furthermore, evidence has been provided of suppressed demand: some motorists would drive more in response to lower petrol prices (Section 8.3.3).

A concerted policy effort would, therefore, be required to reduce motor car usage. A package of transport policy measures is to be recommended, in order for there to be a sufficient reduction in motor car usage. There is evidence to suggest that a range of 'soft' transport policy measures could reduce traffic levels (Section 2.4.2 - Cairns et al, 2004).

The most popular of such measures amongst West Edinburgh survey residents (Section 8.3.2), improving public transport, should be encouraged. A package should also include some 'stick' policy measures, increasing the user's costs, due to lack of willingness amongst car drivers to voluntarily change travel behaviour. Both stick measures within the propensity to walk discrete choice models have a significant effect on reducing motor car usage and warrant inclusion in a package of transport policy measures. The measures concern petrol prices (national transport policy) and parking costs (local transport policy).

The propensity to walk discrete choice modelling shows that local transport policy measures increasing parking costs could have more of an impact than a national increase in petrol prices (Section 9.2.2). Not only are individuals more responsive to the parking cost changes, but parking policy measures are less likely to receive a public protest and can be varied spatially, enabling certain population segments to be targeted if required. Current parking policy, as outlined in Chapter Four (e.g. PPG13 / NPPG17, extending Controlled Parking Zones), should be extended.

A package of transport policy measures to reduce motor car useage could also include measures not tested in this thesis, to complement increases in parking and petrol costs and improvements in public transport. Of the five categories listed in Table 2.1 (Section 2.4.2 - Banister, 2000), the study has focused on the infrastructure and financial travel reduction measures that particularly relate to non-motorised mode travel; perhaps such measures could be complemented by organisation and operational, land use, and technological changes.

11.4.2 Encouraging non-motorised modes

Within the package of transport measures to reduce car use, suggested in Section 11.4.1, there should be some to encourage non-motorised modes. This study has contended (originally in Section 3.5) that non-motorised modes should continue to be promoted, particularly for certain population segments and certainly in urban areas such as Edinburgh.

Most of the emphasis of the non-motorised mode measures within the City of Edinburgh Council's Local Transport Strategy is on the provision of facilities, which are relatively easy to implement (Section 4.3.3). A stronger preference is evident amongst West Edinburgh survey respondents for off-road cycle lanes (Section 8.4.1). Cycling provision in Edinburgh could be adapted to this preference; there is currently an even split between on-road and off-road cycle lane provision (Section 8.4.4).

The Scottish Household Survey analysis provides an insight into the spatial implications of cyclist facilities needed to encourage cycling (Section 7.6). For Edinburgh tenements located near to the city centre, bicycle storage schemes could be developed. Space for bicycle parking could be taken up from the footway, the shared green available at many tenements or car parking spaces. For lower density housing areas further from the centre, further off-road cycle lanes could be developed, encouraging households with bicycles to use them more frequently. The West Edinburgh survey shows off-road cycle lanes to be particularly favoured by residents of lower density areas (Section 8.4.1).

Cyclist facilities, both at the destination and on route, were directly tested within the propensity to cycle stated preference experiment. Both facility types have a significant effect upon the propensity to cycle (Section 10.2.4) and should be included in a package of transport measures to encourage non-motorised modes. The Travel Plan policies within the Edinburgh Local Transport Strategy are, therefore, to be commended (Section 4.3.3). The daily inducement to cycle did not affect the propensity to cycle and should, therefore, not be included in a package of measures.

Cyclist facilities could be targeted at certain population segments identified in this study. Facilities could be targeted at those with the greatest propensity to cycle, 'students' and those 'in-between jobs', for example by developing routes to university and routes within socially excluded areas. The extent to which this is possible depends on the distribution of the population segments; some population segments are evenly dispersed around the city and may be difficult to target.

Walking policy measures can also be linked to the recent social inclusion policy strand (Section 4.2), since walking responses within the West Edinburgh survey relate to the lower income respondents (Section 8.4.2). For example, Wester Hailes could be targeted with measures to reduce safety fears (e.g. increased CCTV coverage, improved street lighting), and to provide more safe and convenient road crossings. Those in the older age bands (retired population segments) also have a strong preference for improvements to the pedestrian environment (pavements, crossings) and walking experience (safety fears). Such improvements could be focused in locations where a higher proportion of older segments of the population reside (e.g. Slateford). Although not directly tested in the propensity to walk discrete choice models, improvements to the pedestrian environment warrant inclusion as a transport policy measure.

The study has examined non-motorised mode policy. As shown in Chapter Four, national and local transport policy has focused on cycling more than walking. Although both should be promoted, perhaps a greater emphasis should be on walking policy measures. Tolley (2003) rightly states that there has been mixed picture in the recent United Kingdom sustainable transport agenda impacts upon non-motorised modes (Section 4.2.2). Non-motorised mode policy could go in one of two directions, either continuing on an ad-hoc basis with a variable impact, or producing travel behaviour gains from a concerted transport policy effort. The former is more likely, although non-motorised modes remain on the transport policy agenda, and small walking and cycling gains could be achieved in certain locations and amongst certain population segments.

As illustrated in Chapter Four, sometimes walking and cycling are considered together in policy documents (e.g. Department for Transport, 2004a); at other times they are considered separately (e.g. Department of Transport, 1996a; Department of Transport, 1996b).

This study has confirmed some of the similarities between the two modes. Exercise has been shown to be a particular advantage of non-motorised modes (Section 7.5.2 – from the Scottish Household Survey travel to work information; Section 9.3.2 – reasons for cycling to work or study). Given the topicality of health promotion within transport policy (Section 4.2.1), the exercise aspects of non-motorised modes should be strongly promoted. Another similarity, constant throughout the study, is that non-motorised modes are particularly suited to local neighbourhood trips; if possible non-motorised neighbourhood level policy measures should be encouraged.

The primary distinction between the two modes is that the bicycle is a form of transport whilst walking requires no equipment, as stated at the outset of the study (Section 1.4). Provision has typically differed: cyclist facilities on the carriageway, pedestrian facilities on the footway. With a preference amongst the population for off-road cycle lanes (confirmed in this study in Section 8.4.1), together with an increase in the implementation of shared-use routes (helping to easy the safety fears from traffic of cyclists), this distinction is becoming blurred.

11.4.3 A package of transport measures

To summarise Section 11.4.1 and Section 11.4.2, the following package of transport policy measures is to be recommended from the research findings, to reduce motor car usage and encourage non-motorised mode usage:

- Increase parking costs within local transport policy
- Increase petrol prices within national transport policy
- Improve public transport
- Implement cyclist facilities at key trip end destinations, in the form of cycle parking and shower / changing facilities
- Implement safe cycle routes to key trip end destinations
- Improve the pedestrian environment
- Promote the exercise benefits of non-motorised modes

These measures could be accompanied by transport policy measures not considered within this study, adapted to target certain population segments and focused at a neighbourhood level.

11.5 Suggestions for further research

This Section provides suggestions for further research, primarily to develop upon the findings presented in this Chapter, but also to counteract some of the study's limitations.

The findings from this Edinburgh-based study could be applied to other United Kingdom cities, particularly those with similar demographics, urban form and modal split. This is often the case in travel behaviour research using urban case studies (Section 3.2.2). Edinburgh is a city with relatively high-density accommodation (typified by four-storey tenement flats), relatively low levels of car ownership and use, and high public transport and walking levels, in comparison with other United Kingdom cities (Section 1.4). A further study could examine urban areas either similar (to compare and justify results) or dissimilar (to contrast findings) in nature to Edinburgh.

Perhaps the applicability of the findings from this study would be more appropriate at a sub-city rather than a city-wide level. Many of the findings relate to ten population segments and/or four postcode sector areas within West Edinburgh. The research outcomes could be compared against other population segments (e.g. students, high earners with children) or spatial areas (e.g. a Social Inclusion Partnership area similar to Wester Hailes, a village on the urban fringe similar to Currie), either within Edinburgh or in another urban area.

It is recommended that the population segment focus be on those with the greatest propensity to cycle, 'students' and those 'in-between jobs', who could not be modelled from the West Edinburgh survey data set due to a small sample size. Alternatively, segmentation within this study could be extended further by examining some of the intra-segment variations. For instance, this study shows that 'high income households with children' are a mixed group (Section 7.6) with a medium propensity to use non-motorised modes (Figure 11.1). There are some individuals on high incomes, with children and a car available that still choose to cycle. It would be of interest to understand some of the reasons why these individuals cycle, while (most of the) others within the same population segment choose not to.

The cluster analysis of the Scottish Household Survey data has identified life stage as the primary variable affecting the nature of the population segments. It would be of interest to explore further the impacts of life stage upon travel behaviour. The impact of children upon travel behaviour choices has been particularly highlighted in this study. For instance, it would be interesting to test the hypothesis whether 'high earners with children' have more adult bicycles available in the household because they want to teach their children to cycle (Section 7.6).

The discrete choice modelling aspects of the study could be extended. Further modelling work for the propensity to walk could include the testing of walking-related attributes such as pedestrian facilities (e.g. footway provision, safe and convenient road crossings). The propensity to cycle experiment could be extended to trips other than the journey to work or study (such as leisure trips, recommended by Wardman et al, 1997 - Section 3.7.2), to include an improved safety variable, and to develop more reliable forecasts of cycling levels. Joint revealed preference and stated preference based discrete choice models could be also be developed using the West Edinburgh survey data.

Due to the complex nature of travel behaviour choices, the focus has been narrow, i.e. on the choice between the motor car and non-motorised modes, with many assumptions. The research could be extended to cover a wider choice context. This study has considered modal shift towards non-motorised modes; other changes could concern an individual's route, time of the journey, destination or journey frequency (Section 2.4.1).

11.6 Conclusions

The thesis has assessed the propensity of individuals to use non-motorised modes in Edinburgh. Propensity to use non-motorised modes has been put in a context of car dependency, and there is unlikely to be a major change in travel behaviour away from the motor car. However, there are signs of a change in travel behaviour away from the motor car at the margins from this study population.

The two household surveys within this study have enabled non-motorised mode data to be examined in detail. The originality of the thesis stems from the data segmentation and the model application concerning non-motorised modes. This has provided some interesting outcomes, confirming and adding to research findings elsewhere.

Population segments, defined through cluster analysis of the Scottish Household Survey data, have been identified with differing propensities to use non-motorised modes (Section 11.2), achieving the first research objective. Of the ten segments, 'students', those 'in-between jobs' and 'part-timers without children' have the greatest propensity to use non-motorised modes; 'high earners without children' and the two segments in retirement have the least propensity. The population segments have been largely determined by the life stage events of gaining employment, having children and entering retirement. Segmentation using individual variables has also developed research outcomes of interest. For instance, attitudes towards non-motorised modes are strongly segmented by gender; in addition, walking attitudes vary according to age and income.

The second research objective has been achieved through the development of discrete choice models for the propensity to walk and the propensity to cycle (Section 11.3). The West Edinburgh survey sample, of 997 households, has enabled the development of robust discrete choice models, including segmented model runs and non-motorised mode forecasts. The impact of parking costs is the most influential upon walking probability for motorists making short trips in urban areas, although journey time and petrol costs also had an effect. Cyclist facilities, primarily at the workplace but also on route, have been established as the primary factor affecting the propensity to cycle to work for motorists. The forecasts indicate that walking and cycling policy measures could have a slight impact upon non-motorised mode levels.

Given the reluctance of motorists to change travel behaviour, a concerted policy effort (Section 11.4) is required to reduce motor car usage. A package of transport policy measures is to be recommended, in order for there to be a sufficient reduction in motor car usage. Measures suggested in this thesis to reduce car usage are increased parking and petrol costs and improved public transport. From the research findings the following non-motorised mode measures should also be included: the implemenetation of cyclist facilities (at key destinations and on key routes); improvements to the pedestrian environment; and promotion of the exercise benefits. If possible, the package of measures should be targeted at certain population segments or neighbourhoods.

The research effort could be extended by developing upon the segmentation and modelling aspects of the thesis (Section 11.5).

BIBLIOGRAPHY

Abercrombie, P. and Plumstead D. (1949) *A civic survey & plan for the City & Royal Burgh of Edinburgh.* Edinburgh Town Council.

Abraham, J.E., McMillan, S., Brownlee, A.T. and Hunt J.D. (2002) Investigation of cycling sensitivities. *Paper presented at the Transportation Research Board 81st Annual Meeting,* January 2002. Washington DC.

Anable, J. (2002) Segmenting the leisure travel market using attitudinal theory. *Universities' Transport Study Group, 34th Annual Conference, 3-5 January 2002.* City Chambers, Edinburgh.

Anderson, S. and Stradling, S. (2004) *Attitudes to car use and modal shift in Scotland.* Transport Research Series report. Scottish Executive Social Research, Scottish Executive.

Armstrong, P., Garrido, R. and Ortuzar, J.D. (2001) Confidence intervals to bound the values of time. *Transportation Research Part E*, 37, pp. 143-161.

Automobile Association. (1993) *Cycling Motorists. How to encourage them.* AA Group Public Policy, Basingstoke.

Bailey, N., Tuck, I. and Docherty, I. (1999) *Edinburgh and Glasgow. Contrasts in competitiveness and cohesion.* Interim Report of the Central Scotland Integrative Case Study.

Banister, D. (2000) Sustainable mobility in the EU. *Built Environment*, 26 (3), pp. 175-186.

Banister, D. and Bowling, A. (2004) Quality of life for the elderly: the transport dimension. *Transport Policy*, 11 (2), pp. 105-115.

Bates, J. (1988) Econometric Issues in stated preference analysis. *Journal of Transport Economics and Policy*, 22 (1), pp. 59-70.

Begg, D. and Gray, D. (2004) Transport policy and vehicle emission objectives in the UK: is the marriage between transport and environmental policy over?, *Environmental Science & Policy* 7, pp. 155-163.

Ben-Akiva, M. and Lerman, S. (1985) *Discrete Choice Analysis: Theory and Application to Travel Demand.* MIT press, Cambridge.

Bendixson, T. (1977) *Instead of Cars.* Penguin Books.

Bergström, A. and Magnusson, R. (2003) Potential of transferring car trips to bicycle during Winter. *Transportation Research Part A*, 37, pp. 649-666.

Bhatt, K. (1993) Implementing Congestion Pricing: Winners and Losers. *Institute of Transportation Engineers Journal*, 63 (12), pp. 33-37.

Black, W.R. (2000) Socio-economic barriers to sustainable transport. *Journal of Transport Geography,* 8, pp. 141-147.

Bonsall, P.W. and O'Flaherty C. A. (1997) *Participatory transport surveys,* Chapter 14 in O'Flaherty C A (eds) Transport Planning and Traffic Engineering, Arnold, London pp. 252-260.

Bovy, P.L. and Bradley, M.A. (1985) Route choice analyzed with stated-preference approaches. *Transportation Research Record,* 1037, pp. 11-20.

Bradley, M.A. and Bovy, P.L. (1984) A stated preference analysis of bicyclist route choice. *Proceedings for the 12th PTRC Summer Annual Meeting.* University of Sussex, England.

Brown, P. J. B. (1991) Exploring geodemographics, in Masser, I. and Blakemore, M. (eds.) *Handling Geographical Information: Methodology and Potential Applications.* Longman, London, pp. 221-258.

Cairns, S., Sloman, L., Newson, C., Anable, J., Kirkbride, A. and Goodwin P. (2004) *Smarter Choices – Changing the Way We Travel.* Department for Transport, London.

Cameron, I., Kenworthy J.R. and Lyons T.J. (2003) Understanding and predicting private motorised urban mobility, *Transportation Research Part D*, 34, pp267-283.

Causssade, S., Ortuzar, J.D., Rizzi, L.I. and Hensher, D.A. (2005) Assessing the influence of design dimensions on stated choice experiment estimates. *Transportation Research Part B*, 39, pp. 621-640.

Chisholm, M. (1997) The Road Traffic Reduction Act 1997 lacks teeth. *Traffic Engineering and Control*, September 1997, pp. 454-456.

City and Royal Burgh of Edinburgh. (1965) *Development Plan. 1965 Review. Written statement.* City and Royal Burgh of Edinburgh.

City of Edinburgh Council. (1998) *Edinburgh Facts and Figures. Household Structure.* City of Edinburgh Council. http://www.edinburgh.gov.uk/CEC/City_Development/Economic_Development_and_Estates/Edinburgh_Facts_and_Figures/Household_Structure/household.html [accessed 10.8.2004]

City of Edinburgh Council. (2000) *The City of Edinburgh Local Transport Strategy. On route.* The City of Edinburgh Council.

City of Edinburgh Council. (2003) *Edinburgh's Census 2001 City Comparisons.* City Development Department Research Section, the City of Edinburgh Council.

City of Edinburgh Council. (2004a) *The Integrated Transport Initiative for Edinburgh and South East Scotland proposed congestion charging scheme.* Statement of Case. Transport Initiatives Edinburgh Ltd and the City of Edinburgh Council (Download T163 from ITI website: iti.tiedinburgh.co.uk).

City of Edinburgh Council. (2004b) *Local Transport Strategy 2004-2007.* The City of Edinburgh Council, March 2004 (Download T7 from ITI website: iti.tiedinburgh.co.uk).

City of Edinburgh Council. (2004c) *The Draft Edinburgh Congestion Charging Order. The City of Edinburgh Council*, 18 February 2004 (Download from ITI website: iti.tiedinburgh.co.uk).

City Of Edinburgh Council, East Lothian Council, Midlothian Council and West Lothian Council. (2004) *Edinburgh and the Lothians Structure Plan 2015*. June 2004.

Clarke, A. (2000). Bicycling. Pathway to the future. *Paper presented at the Transportation Research Board 79th Annual Meeting from the A3B07 Committee on Bicycling*, January 9-13, 2000, Washington DC.

Cole, S. (1998) *Applied Transport Economics*. Second edition. Koran Page Ltd, London.

Commission of the European Communities. (2001) *Transport White Paper. European transport policy: time to decide*. Brussels.

Cooper, J., Ryley, T. and Smyth, A. (2001) Contemporary lifestyles and the implications for sustainable development policy. Lessons from the UK's most car dependent city, Belfast. *Cities*, 18 (2), pp. 103-113.

Costley, T. (2002) Survey of cycling in Scotland. Scottish Executive Social Research. Scottish Executive, Edinburgh.

Cullinane, S. (1992) Attitudes towards the car in the UK: Some implications for policies on congestion and the environment. *Transportation Research Part A*, 26A, pp. 291-301.

Cyclists' Touring Club. (1993) *Costing the Benefits: the value of cycling*. Cyclists' Touring Club, Godalming, Surrey.

Cyclists' Touring Club, Cyclists' Public Affairs Group and Southampton City Council. (1997) *Barriers to cycling. Perspectives from existing and potential cyclists*. Cyclists' Public Affairs Group, Godalming, Surrey.

Davies, D.G., Emmerson, P. and Gardner, G. (1998) *Achieving the aims of the National Cycling Strategy: Summary of TRL research*. TRL Report 365. Crowthorne, Berkshire.

Davies, D.G., Gray, S., Gardner, G. and Harland G. (2001) *A quantitative study of the attitudes of individuals to cycling*. TRL Report 481, Crowthorne, Berkshire.

Davies, D.G., Halliday, M.E., Mayes, M. and Pocock, R.L. (1997) *Attitudes to cycling - A qualitative study and conceptual framework.* TRL Report 266, Crowthorne, Berkshire.

Department for Environment, Food and Rural Affairs (DEFRA). (2004) *Achieving a better quality of life. Review of progress towards sustainable development. Government annual report 2003.* Defra Publications, London.

Department for Transport. (2003a) *Transport Statistics Great Britain 2003.* 29th Edition. HMSO, London.

Department for Transport. (2003b) *Transport statistics. Cycling in Great Britain. Personal Travel Factsheet 5a.* HMSO, London.

Department for Transport. (2003c) *Transport statistics. Walking in Great Britain. Personal Travel Factsheet 4.* HMSO, London.

Department for Transport. (2004a) *Walking and cycling: an action plan.* June 2004. HMSO, London.

Department for Transport. (2004b) *The future of transport: a network for 2030.* July 2004. HMSO, London.

Department for Transport (2004c). *Values of time and operating costs.* Transport Analysis Guidance (TAG) Unit 3.5.6, Department for Transport. December 2004. HMSO, London.

Department of the Environment. (1994) *Sustainable Development, The UK Strategy.* HMSO, London.

Department of the Environment and Department of Transport. (1995) *PPG13. A Guide to Better Practice.* HMSO, London.

Department of the Environment, Transport and the Regions. (1998) *A New Deal for Transport: Better for Everyone, The Government's White Paper on the Future of Transport.* HMSO, London.

Department of the Environment, Transport and the Regions. (1999) *The UK strategy for sustainable development. A better quality of life. A strategy for sustainable development for the United Kingdom.* HMSO, London.

Department of the Environment, Transport and the Regions. (2000a) *Encouraging walking: advice to local authorities.* HMSO, London.

Department of the Environment, Transport and the Regions. (2000b) *Transport 2010. The 10 Year Plan.* HMSO, London.

Department of the Environment, Transport and the Regions. (2000c) *Guidance on the Methodology for Multi-Modal Studies.* HMSO, London.

Department of the Environment, Transport and the Regions. (2000d) *A measure of road traffic congestion in England: method and 2000 baseline figures.* HMSO, London.

Department of the Environment, Transport and the Regions. (2000e) *Journey Times Survey 1999: Inner and Central London.* HMSO, London.

Department of the Environment, Transport and the Regions. (2001) *PPG13. Transport.* HMSO, London.

Department of Transport. (1996a) *National Cycling Strategy.* HMSO, London.

Department of Transport. (1996b) *Developing a Strategy for Walking.* HMSO, London.

Dickinson, J.E., Kingham, S., Copsey, S. and Peralman Hougie D.J. (2003) Employer travel plans, cycling and gender: will travel plan measures improve the outlook for cycling to work in the UK? *Transportation Research Part D*, 8, pp. 53-67.

Dill, J. and Carr, T. (2003) Bicycle commuting and facilities in major US cities: if you build them, commuters will use them. *Transportation Research Record,* 1828, pp. 116-123.

Docherty, I. and Shaw, J. (eds) (2003) *A new deal for transport?* RGS-IBG Book Series. Blackwell.

Donegan, K., Smyth, A., Ryley, T. and McEldowney, M. (2003) Sustainable transport and land use policy links to economic development: theory and evidence from two UK medium sized cities. *Proceedings of Association of European Transport (AET) European Transport Conference.* Strasbourg, France, October, 2003.

Eash, R. (1999) Destination and mode choice models for non-motorized travel. *Transportation Research Record,* 1674, pp. 1-8.

ECOTEC. (1993) *Reducing Transport Emissions through Planning.* HMSO, London.

Elster, J. (2000) *Cycling and social inclusion.* Centre for Analysis of Social Exclusion (CASE) Report 8, London School of Economics and Political Science.

Enoch, M., Trevelyan, B. and Titheridge, H. (2002) Identifying the key geo-demographic variables affecting bus service provision in rural areas. *Paper presented at the Universities Transport Studies Group Conference,* Edinburgh, 3rd-5th January, 2002.

European Commission. (1999) *Cycling: the way ahead for towns and cities.* Office for Official Publications of the European Communities, Luxembourg.

Field, A. (2000) *Discovering Statistics using SPSS for Windows.* SAGE Publications.

Forrester, J. (1994) *Bicycle Transportation: A handbook for cycling transportation engineers.* MIT Press, London.

Fowkes, T. and Preston, J. (1991) Novel approaches to forecasting the demand for new local rail services. *Transportation Research Part A,* 4, pp. 209-218.

Freeman, Fox & Associates and Colin Buchanan & Partners. (1972) *Edinburgh: The Recommend Plan.* City of Edinburgh Planning and Transport Study.

Gaffron, P. (2000) Walking and cycling - does common neglect equal common interests. *World Transport Policy and Practice,* 6 (3), pp. 9-14.

Gardner, G. (1998) *Transport implications of leisure cycling.* TRL Report 347, Crowthorne, Berkshire.

Gardner, G. (1999) Identifying potential cyclists. *Proceedings of Association of European Transport (AET) European Transport Conference, Seminar B. Transport Planning, Policy and Practice,* pp405-414. Cambridge University, September 1999.

Gardner, G. and Ryley, T. (1997) *Trip end facilities for cyclists.* TRL Report 309. Crowthorne, Berkshire.

General Register Office for Scotland. (2003) *Scotland's Census 2001. Key statistics of Council Areas and Health Board Area Scotland.* General Register Office for Scotland, Edinburgh.

Giuliano, G. and Narayan, D. (2003) Another look at travel patterns and urban form: the US and Great Britain, *Urban Studies*, 40 (11), pp. 2295-2312.

Goodwin, P. (1997) Mobility and car dependence, Chapter 47 in Rothengatter, T. and Carbonell Vaya, E. (1997) *Traffic and Transport Psychology. Theory and Application.* Pergamon.

Goodwin, P. (1999) Transformation of transport policy in Great Britain. *Transportation Research, Part A*, 33, pp. 655-669.

Goodwin, P. (2003) *Towards a genuinely sustainable transport agenda for the United Kingdom*, Chapter 10 in Docherty, I. and Shaw, J. (eds) (2003) A new deal for transport? RGS-IBG Book Series. Blackwell.

Goodwin, P., Dargay, J. and Hanly, M. (2004) Elasticities of road traffic and fuel consumption with respect to price and income: A review. *Transport Reviews*, 24 (3), pp. 275-292.

Goudie, D. (2002) Zonal method for urban travel surveys. *Journal of Transport Geography*, 10, pp. 287-301.

Graham, D.J. and Glaister, S. (2004) Road traffic demand elasticity estimates: A review. *Transport Reviews*, 24 (3), pp. 261-274.

Hague Consulting Group. (1995) *ALOGIT Users' Guide. Version 3.8: August 1995.* Hague Consulting Group, The Hague, Netherlands.

Hague, P.N. (1993) *Questionnaire Design.* Kogan Page, London.

Hair, J.F., Anderson, R.E., Tatham, R.L. and Black, W.C. (1998) *Multivariate Data Analysis. Fifth Edition.* Pearson, US.

Handy, S. (1996a) Methodologies for exploring the link between urban form and travel behaviour. *Transportation Research, Part D: Transport and Environment*, 1 (2), pp. 151-165.

Handy, S. (1996b) Urban Form and Pedestrian Choices: Study of Austin Neighbourhoods. *Transportation Research Record* 1552, pp. 135-144.

Harrison, J. (2001) Planning for more cycling: the York experience bucks the trend. *World Transport Policy and Practice*, 7 (3), pp. 21-27.

Hass-Klau, C. (1990) *The Pedestrian and City Traffic.* Belhaven, London.

Hazel, G. (1998) Sustainable transport: Edinburgh's approach. *World Transport Policy and Practice*, 4 (4), pp. 16-23.

Headicar, P. and Curtis, C. (1994) Residential development and car-based travel: does location make a difference? *Proceedings of PTRC Summer meeting, Seminar C. Environmental Issues.* Warwick University, September 1994.

Hensher, D.A. (1994) Stated preference analysis of travel choices: The state of practice. *Transportation*, 21, pp. 107-133.

Hensher, D.A. and Button, K.J. (2000) *Handbook of transport modelling. Volume 1.* Pergamon.

Higgitt, M. (1999) Prioritising the pedestrian: a framework for the development of a walking strategy. *Proceedings of Association of European Transport (AET) European Transport Conference, Seminar B. Transport Planning, Policy and Practice,* p391-p403. Cambridge University, September 1999.

Higgins, P.A.T. and Higgins, M. (2003) Viewpoint. A healthy reduction in oil consumption and carbon emissions. *Energy Policy*, 33, pp. 1-4.

Hine, J., Forster, E. and Hutton, B. (1998) *Review of Scottish Travel Data Sources.* Transport Research Institute, Napier University.

Hole, A. R. (2004) Forecasting the demand for an employee Park and Ride service using commuters' stated choices. *Transport Policy*, 11, pp. 241-249.

Hopkinson, P. and Wardman, M. (1996) Evaluating the demand for new cycling facilities. *Transport Policy*, 3 (4), pp. 241-249.

House of Commons Environment, Transport and Regional Affairs Committee. (2000) *Departmental Seventeenth Annual Report 2000 and Expenditure Plans 2000-2001.* HMSO, London.

House of Commons Health Affairs Committee. (2004) *Obesity. Third Report of Session 2003-2004, Volume 1.* HMSO, London.

Hoyle, B.S. and Knowles, R.D. (1992) *Modern Transport Geography.* Belhaven Press, London and New York.

Huby, M. and Burkitt, N. (2000) Is the New Deal for Transport really better for everyone? The social policy implications of the UK 1998 White Paper on transport. *Environment and Planning C: Government and Policy*, 18, pp. 379-392.

Institute of Highways and Transportation (1997). *Transport in the Urban Environment.* Institute of Highways and Transportation, London.

Ison, S., Peake, S. and Wall, S. (2002) *Environmental issues and policies.* Pearson Education.

James, A. (1998) Exploding myths about the cost of car transport. *World Transport Policy and Practice*, 4 (4), pp. 10-15.

Johnston, R.J. (ed) (1986) *The Dictionary of Human Geography.* Second Edition. Blackwell.

Katz, R. (1995) Modeling Bicycle Demand as a Mainstream Transportation Planning Function. *Transportation Research Record*, 1502, pp. 22-28.

Kinnear, P.R. and Gray, C.D. (2000) *SPSS for Windows made simple. Release 10.* Psychology Press Ltd, Hove.

Kocur, G., Adler, T., Hyman, W. and Aunet, B. (1982) *Guide to forecasting travel demand with direct utility assessment.* United States Department of Transportation, Report UMTA-NH-11-0001-82-1, Washington DC.

Kroes, E.P. and Sheldon, R.J. (1988) Stated preference methods. An introduction. *Journal of Transport Economics and Policy*, 22 (1), pp. 11-26.

Lawson, S.D. and Morris, B. (1999) Out of cars and onto bikes - what chance? *Traffic Engineering & Control,* 40 (5), pp. 272-276.

Liebling, D. (1998) *Ten years of measuring motorists' attitudes*, from Department of the Environment Transport and the Regions, Transport Trends 1998 Edition. HMSO, London.

Litman, T. (2001) *Quantifying the benefits of non-motorized transport for achieving TDM objectives.* Victoria Transport Policy Institute, Victoria, Canada

Lothian Regional Council Department of Physical Planning. (1978) *Lothian Region Structure Plan.* May 1978.

Lothian Regional Council. (1985) *Transport Policies and Programme.* No. 8 1985-90. April 1985. Lothian Regional Council.

Lothian Regional Council Department of Planning. (1993) *Lothian Region Structure Plan* 1993. *Written Statement. Draft for Consultation.* Lothian Regional Council.

Loukopoulos, P., Jakobsson, C., Gärling, T., Schneider, C.M. and Fujii, S. (2004) Car-user responses to travel demand management measures: goal setting and choice of adaptation alternatives, *Transportation Research Part D*, 9, pp. 263-280.

Louviere, J.J., Hensher, D.A. and Swait, J.D. (2000) *Stated choice methods. Analysis and application.* Cambridge University Press.

Lumsdon, L. and Tolley, R. (1999) Techniques for planning local networks: developing a walking strategy. *World Transport Policy and Practice*, 5 (1), pp. 17-23.

Lumsdon, L. and Tolley, R. (2001) The National Cycle Strategy in the UK: to what extent have local authorities adopted its model strategy approach? *Journal of Transport Geography* 9, pp. 293-301.

Lyons, G. (2003) *Transport and Society.* Inaugural Lecture, Arup, Bristol, 1 May, University of the West of England.

Lyons, G. and Chatterjee, K. (eds) (2002) *Transport lessons from the fuel tax protests of 2000.* Ashgate.

MacIver, A. (1999) Transportation impact assessment and trip-chaining behaviour. *Traffic Engineering & Control*, 40 (3), pp.129-134.

Mackett, R.L. and Ahern, A. (2000) *Potential for mode transfer of short trips: Report on the analysis of the survey results.* Centre for Transport Studies, University College, London. September 2000.

Mackett, R.L. and Robertson, S.A. (2000) *Potential for mode transfer of short trips: Review of existing data and literature sources.* Centre for Transport Studies, University College, London. September 2000.

Martens, K. (2004) The bicycle as a feedering mode: experience from three European countries. *Transportation Research Part A*, 9, pp. 281-294.

McClintock, H. (1992) *The Bicycle and City Traffic: Principles and Practice.* Belhaven Press, London.

McDonald, C.H. and Burns, E.K. (2001) Cycling to work in Phoenix: Route Choice, Travel Behaviour, and Commuter Characteristics. *Paper presented at the Transportation Research Board 80th Annual Meeting*, January 7-11, 2001, Washington DC.

McKenzie, C. (1999) Car-free cities - myth or possibility? Exploring the boundaries of sustainable urban transport. *World Transport Policy and Practice*, 5 (1), pp.4-10.

Metz, D. (2002) Limitations of transport policy. *Transport Reviews*, 22, pp. 134-145.

Ministry of Transport. (1963) *Traffic in Towns: A study of the long term problems of traffic in urban areas.* Reports of the Steering Group and Working Group appointed by the Minister of Transport. HMSO, London.

Moser, C. and Kalton, G. (1979) *Survey methods in social investigation.* Second Edition. Dartmouth.

Mowen, J.C. and Minor, M. (1998) *Consumer behaviour, 5th edition.* Prentice Hall, New Jersey.

Nelson, A.C. and Allen, D. (1997) If you build them, commuters will use them: association between bicycle facilities and bicycle commuting. *Transportation Research Record,* 1578, pp. 79-83.

Newman, P. and Kenworthy, J. (1989) *Cities And Automobile Dependency.* An International Sourcebook. Gower Technical, Aldershot.

Nijkamp, P., Rietveld, P. and Spierdijk, L. (2000) A meta-analytic comparison of determinants of public transport use: methodology and application. *Environment and Planning B, Planning and Design*, 27, pp. 893-903.

Noland, R.B. and Kunreuther, H. (1995) Short-run and long-run policies for increasing bicycle transportation for daily commuter trips. *Transport Policy*, 2 (1), pp. 67-79.

Ogilvie, D., Egan, M., Hamilton, V. and Petticrew, M. (2004) Promoting walking and cycling as an alternative to using cars: systematic review. *British Medical Journal,* 329, pp. 763-766.

Oppenheim, A.N. (1992) *Questionnaire Design, Interviewing and Attitude Measurement.* Pinter, London.

Ortuzar, J. and Willumsen, L.G. (2001) *Modelling Transport. Third edition.* Wiley, Chichester.

Ortuzar, J.D., Iacobelli, I. and Valeze, C. (2000) Estimating demand for a cycle network. *Transportation Research Part A*, 34, pp. 353-373.

Ouwersloot, H. and Rietveld, P. (1996) Stated choice experiments with repeated observations. *Journal of Transport Economics and Policy*, 30 (2), pp. 203-212.

Owen, W. (1972) *The Accessible City.* Washington D.C., Brooklings Institution.

Pallant, J. (2001) *SPSS Survival Manual. A step by step guide to data analysis using SPSS for Windows.* Open University Press, Buckingham.

Pearce, L. (1999) Promoting cycling for health. In *TRL Annual Research Review 1998*, pp. 10-17. Crowthorne, Berkshire.

Pikora, T., Giles-Corti, B., Bull, F., Jamrozik, K. and Donovan, R. (2003) Developing a framework for assessment of the environmental determinants of walking and cycling. *Social Science & Medicine*, 56, pp. 1693-1703.

Polak, J. and Jones, P. (1997) Using stated-preference methods to examine traveller preferences and responses, in *Understanding Travel Behaviour in an Era of Change* (ed. P Stopher and M Lee-Gosselin).

Polk, M. (2004) The influence of gender on daily car use and on willingness to reduce car use in Sweden. *Journal of Transport Geography*, 12, pp. 185-195.

Porter, C., Suhrbier, J. and Schwartz, W.L. (1999) Forecasting Bicycle and Pedestrian Travel. State of the Practice and Research Needs. *Transportation Research Record*, 1674, pp. 94-101.

Potter, S. (1997) *Vital Travel Statistics - A compendium of data and analysis about transport activity in Britain.* Landor Publishing Limited.

Rethati, A. and Rekai, G. (2001) Marketing research as a tool for surveying the attitude towards cycling. *Velo-city Conference, Edinburgh & Glasgow*, 17-21 September 2001.

Rietveld, P. and Daniel, V. (2004) Determinants of bicycle use: do municipal policies matter? *Transportation Research Part A*, 38, pp. 531-550.

Rodríguez, D.A. and Joo, J. (2004) The relationship between non-motorized mode choice and the local physical environment. *Transportation Research Part D*, 9, pp. 151-173.

Rose, G. and Ampt, E. (2001) Travel blending: an Australian travel awareness initiative. *Transportation Research Part D*, 6, pp. 95-110.

Rossi, T.F. (2000) Modelling non-motorised travel. *Paper presented as a poster at the Transportation Research Board 79th Annual Meeting*, January 9-13, 2000, Washington DC.

Royles, M. (1995) *Literature Review of Short Trips.* TRL Report 104. Crowthorne, Berkshire.

Rye, T. and McGuigan, D. (2000) *Green Commuter Plans - Do They Work?* Final report to the Scottish Executive Central Research Unit, Scottish Executive, Edinburgh.

Rye, T., Saunders, J., Celikel, N. and Saleh, W. (1999) Edinburgh City Car Club Goes Live. *World Transport Policy and Practice*, 5 (3), pp. 139-155.

Ryley, T. (1996) *Advanced stop lines for cyclists: The role of central cycle lane approaches and signal timings.* TRL Report 181. Crowthorne, Berkshire.

Ryley, T. (2001) Translating cycling policy into cycling practice. *World Transport Policy and Practice*, 7 (3), pp. 38-43.

Ryley, T., Smyth, A. and Scott, M. (2002) A comparative analysis of travel behaviour in Belfast and Edinburgh. *Paper presented at Universities Transport Studies Group 34th Annual Conference*, Edinburgh, 3rd-5th January 2002.

Sælensminde, K. (2003) Cost-benefit analyses of walking and cycling track networks taking into account insecurity, health effects and external costs of motorized traffic. *Transportation Research, Part A*, 38, pp. 593-606.

Sanches, S.P. and Arruda, F.S. (2002) Incorporating the non-motorized modes in a mode choice model. *Paper presented at the 81st Transportation Research Board Annual Meeting,* January 2002. Washington DC.

Schiller, P. and Kenworthy, J. (1999) Prospects for sustainable transportation in the Pacific Northwest: a comparison of Vancouver, Seattle and Portland. *World Transport Policy & Practice*, 5 (1), pp. 30-38.

Schimek, P. (1996) Household motor vehicle ownership and use: how much does residential density matter? *Transportation Research Record* 1552, pp.120-125.

Schwanen, T., Dijst, M and Dieleman, F.M. (2004) Policies for urban form and their impact on travel: the Netherlands experience, *Urban Studies*, 41 (3), pp. 579-603.

Scottish Cycling Development Project. (2002) *Monitoring the National Cycling Strategy in Scotland.* Final report to the Scottish Executive Central Research Unit, Scottish Executive, Edinburgh.

Scottish Executive. (2000a) *Comparative Evaluation of Greenways and Conventional Bus Lanes,* report by Colin Buchanan and Partners, Development Department Research Programme Research Findings Number 83. Scottish Executive, Edinburgh.

Scottish Executive. (2000b) *Scotland's people. Results from the 1999 Scottish Household Survey. Volume 1. Annual Report.* Scottish Executive, Edinburgh.

Scottish Executive. (2001) *Scotland's people. Results from the 1999/2000 Scottish Household Survey. Volume 4. Technical Report.* Scottish Executive, Edinburgh.

Scottish Executive. (2003) *A Walking Strategy for Scotland. Consultation document.* February 2003. Scottish Executive, Edinburgh.

Scottish Homes and City of Edinburgh Council. (2000) *Housing Needs Assessment.* Report for Scottish Homes and City of Edinburgh Council by System Three Social Research and DTZ Pieda Consulting.

Scottish Office. (1998) *Travel Choices for Scotland. The Scottish Integrated Transport White Paper.* The Stationery Office, Edinburgh.

Scottish Office. (1999) *National Planning Policy Guideline: NPPG17.* April 1999. The Scottish Office, Edinburgh.

Scottish Parliament. (2001) *Transport (Scotland) Act 2001.* The Stationery Office Ltd.

Sharma, S. (1996) *Applied multivariate techniques.* John Wiley & Sons, Inc.

Sharples, R. (1995a) A framework for the evaluation of facilities for cyclists – Part 1. *Traffic Engineering and Control*, March 1995.

Sharples, R. (1995b) A framework for the evaluation of facilities for cyclists – Part 2. *Traffic Engineering and Control*, April 1995.

Social Exclusion Unit. (2003) *Making the Connections - Final Report on Transport and Social Exclusion*. HMSO, London.

Solomon, M.R. (1999) *Consumer behaviour. Buying, having, and being. 4th Edition.* Prentice Hall, New Jersey.

Standing Advisory Committee on Trunk Road Assessment (SACTRA). (1994) *Trunk Roads and the Generation of Traffic*. Department of the Environment, Transport and the Regions. HMSO, London.

Stead, D. (2001) Relationships between land use, socioeconomic factors and travel patterns in Britain. *Environment and Planning B: Planning and Design*, 28 (4), pp. 499-528.

Stinson, M.A. and Bhat, C.R. (2003) An analysis of commuter bicyclist route choice using a stated preference survey. *Paper presented at the 82nd Transportation Research Board Annual Meeting*, January 2003. Washington DC.

Stradling, S.G. (2002) *Persuading people out of their cars*. Napier University Professorial Lecture. Napier University.

Stradling, S.G., Meadows, M.L. and Beatty, S. (2000) Helping drivers out of their cars. Integrating transport policy and social psychology for sustainable change. *Transport Policy*, 7, pp. 207-215.

Sustainable Development Commission. (2004) *Shows promise. But must try harder.* An assessment of the Government's reported progress on sustainable development over the last five years. April 2004. Sustainable Development Commission.

Swift, S. (2001) The new approach to transport appraisal, *British Economy Survey*, Vol. 30 (2) [download from http://www.ac777.dial.pipex.com/bes/ 19 December 2004]

Tertoolen, G., Van Kreveld, D. and Verstraten, B. (1998) Psychological resistance against attempts to reduce private car use. *Transportation Research Part A*, 32 (3), pp. 171-181.

Thomson, M.J. (1978) *Great cities and their traffic.* Penguin, Harmondsworth.

Thorpe, N., Hills, P. and Jaensirisak S. (2000) Public attitudes to TDM measures: a comparative study. *Transport Policy*, 7, pp. 243-257.

Titheridge, H., Hall, S. and Hall, P. (1999) A study of commuting pattern using small-zone data. *Paper presented at the Universities Transport Studies Group Conference, York, 4th-6th January, 1999.*

Tolley, R. (1997) *The Greening of Urban Transport. Planning for Walking and Cycling in Western Cities.* 2nd edition. Belhaven Press, London.

Tolley, R.S. and Turton, B.J. (1995) *Transport Systems, Policy and Planning.* Longman, Scientific & Technical.

Tolley, R. (2003) Ubiquitous, everyday walking and cycling: the acid test of sustainable transport policy, Chapter 8 in Docherty, I. and Shaw, J. (eds) *A new deal for transport?* RGS-IBG Book Series, Blackwell.

Transport Research Laboratory, Transportation Research Group (Southampton University) and University of Portsmouth (1999). *Monitoring and evaluation of the Bikeabout scheme in Portsmouth.* TRL Report 412. Crowthorne, Berkshire.

Transport Visions Network. (2001) *Land Use Planning.* Number Three in a series of Eight Reports. By K Chatterjee, M Beecroft, G Lyons and G Marsden, Transport Research Group, University of Southampton.

Turner, S., Hottenstein, A. and Shunk, G. (1997) *Bicycle and pedestrian travel demand forecasting. A literature review.* Texas Transportation Institute.

Urban Task Force. (1999) *Towards an Urban Renaissance.* The Report of the Urban Task Force, chaired by Lord Rogers of Riverside.

U.S. Department of Transportation. (2003) *Transport Statistics Annual Report.* Bureau of Transportation Statistics, October 2003.

Van Wee, B. (2002) Land use and transport: research and policy challenges. *Journal of Transport Geography*, 10, pp. 259-271.

Walker, J. and Ben-Akiva, M. (2002) Generalized random utility model. *Mathematical Social Sciences*, 43, pp. 303-343.

Wardman, M. (1988) A comparison of revealed preference and stated preference models of travel behaviour. *Journal of Transport Economics and Policy*, 32 (3), pp. 285-315.

Wardman, M. (1991) Stated preference methods and travel demand forecasting: an examination of the scale factor problem. *Transportation Research A*, 25, pp. 79-89.

Wardman, M. (1998) The Value of Travel Time: A Review of British Evidence. *Journal of Transport Economics and Policy*, 32 (3), pp. 285-315.

Wardman, M., Hatfield, R. and Page, M. (1997) The UK national cycling strategy: can improved facilities meet the targets? *Transport Policy*, 4 (2), pp. 123-133.

Wardman, M., Nash C.A., Tight M.R. and Page M.W. (2000a) *Cycling and urban mode choice,* Final report of ESRC project R000237103.

Wardman, M., Page, M., Tight, M. and Siu Y.L. (2000b) Cycling and urban commuting: results of behavioural mode and route choice models. *Working Paper 548*, Institute for Transport Studies, University of Leeds.

World Commission on Environment and Development. (1987) *Our Common Future* The Bruntland Commission, United Nations. Oxford University Press.

Wootton, J. (1999) "Replacing the private car", *Transport Reviews*, 19 (2), pp. 157-175.

Wright, C. and Egan, J. (2000) De-marketing the car. *Transport Policy*, 7, pp. 287-294.

Appendix 1. A copy of the West Edinburgh survey questionnaire

TRANSPORT SURVEY

Summer 2003

Dear Resident

The Transport Research Institute, Napier University is conducting a transport survey of households in Edinburgh. The aim of the questionnaire is to collect information on how and why people travel the way they do. The survey will help us to understand more fully travel behaviour in Edinburgh. Your response will make a valuable contribution.

Please would an adult member of your household (over 18) fill in the questionnaire. A household is one person or a group of people (not necessarily related) living at the same address. **It should take about twenty minutes of your time.**

Please would you return the questionnaire to us at Napier University in the envelope provided. If you have any questions about the survey, feel free to contact me, during daytime hours, on t.ryley@napier.ac.uk or on 0131 455-5154. The responses you provide will be treated in the strictest confidence and your identity will remain anonymous. **Thank you for your help.**

Yours sincerely

Tim Ryley

Transport Research Institute
Napier University

TRANSPORT SURVEY QUESTIONNAIRE

SECTION A. GENERAL HOUSEHOLD AND TRANSPORT

1. How many adults are there in your household? ________

2. How many children are there in your household? ________

3. How often do you use the following method of travel for **any** kind of journey?
*Please tick one box for **each** method of travel*

	Most days	Once or twice a week	About once a fortnight	About once a month	Several times a year	About once a year or less	Never
Car (driver)	☐	☐	☐	☐	☐	☐	☐
Car (passenger)	☐	☐	☐	☐	☐	☐	☐
Walk	☐	☐	☐	☐	☐	☐	☐
Bicycle	☐	☐	☐	☐	☐	☐	☐
Motorcycle	☐	☐	☐	☐	☐	☐	☐
Bus	☐	☐	☐	☐	☐	☐	☐
Train	☐	☐	☐	☐	☐	☐	☐

4. Which of the following best describes your current situation and the current situation of other adults (up to 3 others) in the household? *Please tick one box for each adult in the household*

	YOU	ADULT 2	ADULT 3	ADULT 4
Self-employed	☐	☐	☐	☐
Employed full time	☐	☐	☐	☐
Employed part time	☐	☐	☐	☐
Looking after home or family	☐	☐	☐	☐
Permanently retired from work	☐	☐	☐	☐
Unemployed and seeking work	☐	☐	☐	☐
In education	☐	☐	☐	☐
Government work or training scheme	☐	☐	☐	☐
Unable to work: short-term illness or injury	☐	☐	☐	☐
Permanently sick or disabled	☐	☐	☐	☐

Other (please state for any adult)____

5. How many people in your household (including you) have valid driving licences? ________

6. What is **your** driving licence status? *Please tick one box*

Currently hold a full driving licence	☐	Licence suspended on medical grounds	☐
Currently hold a provisional licence	☐	Never held a UK driving licence	☐
Currently disqualified from driving	☐	Did not reapply for licence at age 70	☐

7. How many cars (including vans) are owned, or available to use, by members of your household? ________

8. **If there are cars available to your household**, of how many of them are **you** the main driver? ________

SECTION B. JOURNEYS TO THE CITY CENTRE

In this study, Edinburgh city centre is defined as the Old Town and New Town. The city centre includes Royal Mile, Princes Street and Queen Street.

9. How often do you travel to or through Edinburgh city centre? *Please tick one box*

Most days	☐	Several times a year	☐
Once or twice a week	☐	About once a year or less	☐
About once a fortnight	☐	Never	☐
About once a month	☐		

10. How do you usually travel to or through Edinburgh city centre?
Please tick one box for the main method of travel, the part of the journey that covers the greatest distance

Car (driver)	☐	Walk	☐	Motorcycle	☐
Car (passenger)	☐	Bicycle	☐	Train	☐
Bus	☐				

Other (please specify)________________________________

SECTION C. CYCLING AND WALKING JOURNEYS

11. **On how many out of the last 7 days** did you make a trip of more than a quarter of a mile (400 metres) on foot?
This would typically be a walk taking over 5 minutes.

Going somewhere (such as work, to see friends) ________

For the pleasure of walking (such as walking dog, jogging) ________

12. **On how many out of the last 7 days** did you make a trip of more than a quarter of a mile (400 metres) by bicycle?

Going somewhere (such as work, to see friends) ________

For the pleasure of cycling or to keep fit ________

13. How many bicycles are owned, or available for use, by one or more members of your household?

________ adult's bicycles ________ children's bicycles

14. **If you have any bicycles in your household**, where are they parked or stored?

____

SECTION D. JOURNEY TO WORK / STUDY

If you do not work or study please go to Question 27

15. Please could you categorise your employment status into one of the following groups?
Please tick one box

Professional	☐	Clerical / Administrative	☐	Skilled manual	☐
Senior management	☐	Student	☐	Other manual	☐
Middle management	☐				

Other (please state)______________________

16. **If you work**, do you ever work from home? *Please tick one box*

No, I do not work from home ☐
Yes, I work from home every day ☐
Yes, I work from home often (at least once a week) ☐
Yes, I work from home occasionally (less than once a week) ☐

If you work from home every day please go to Question 27

17. Where is your main work or study location?
Please put in a location that is not your home and state full postcode if known

____

____

Postcode _ _ _ _ _ _ _

18. How do you usually travel to work or place of study?
Please tick one box for the main method of travel (the part of the journey that covers the greatest distance)

Car (driver) ☐ Walk ☐ Motorcycle ☐
Car (passenger) ☐ Bicycle ☐ Train ☐
Bus ☐

Other (please specify)________________________________

19. What are the main reasons you use this method of travel to work or place of study?

____

____

20. How long does it normally take you to get from home to work or place of study? ________ minutes (door to door)

21. What are the typical hours of your shift pattern (or student timetable)?

____

____

22. **If you usually travel to work / study by car**, do you travel by company car? Yes ☐ No ☐

23. **If you usually travel to work / study by car,** where do you tend to park your car?
Please tick one box

On site, free parking space ☐
On site, pay £________ per day / month / year for a parking space ☐
(*please delete as appropriate*)
On street around the site, free parking ☐
On street around the site, pay £________ per day / month / year for a parking space ☐
(*please delete as appropriate*)

Off-street public car park, pay £________ per day / month / year for a parking space ☐
(*please delete as appropriate*)

24. **If you usually travel to work / study by bus,** please enter in the following details about your typical bus journey from home to work / study.

Time taken to travel to your nearest bus stop from home ________ minutes

Time taken waiting at the bus stop ________ minutes

Time taken on the bus ________ minutes
(if you travel on more than one bus, include waiting time between buses)

Time taken to travel from the bus stop to your place of work / study ________ minutes

Bus journey ticket cost £________
per day / month / year
(*please delete as appropriate*)

25. **If you do not usually travel to work / study by bicycle**, what are the main reasons you do not travel by bicycle?

____

____

26. **This question looks at your current journey to work / study and the incentives that might encourage you to travel to work / study by bicycle in the future.**

Only answer this question if you usually travel to work / study by car, bus or walk
If you do not usually travel to work / study by any of these methods go to Question 27

In this question, assume you have a bicycle in your household available to you for cycling to work / study.

Firstly, there may not be anything that would encourage you to cycle to work / study. If any of the following statements are true, please tick the statement and move onto the next question:

You would never consider cycling whatever the circumstances	☐	**Go to Question 27**
You would consider cycling, but your current journey to work / study is too far to cycle	☐	**Go to Question 27**
You would consider cycling, but the nature of your work / study means you cannot cycle	☐	**Go to Question 27**

Secondly, please estimate how long your journey to work / study would take by bicycle ________ minutes
This value will be used in the next part of the question.

Thirdly, 9 future travel scenarios are presented below. They compare your current method of transport to work / study (car, bus or walk) against travel by bicycle. Each scenario lists door to door journey time, cost (you would get a daily payment for cycling to work / study), the cycling facilities at your place of work / study and the nature of the cycle route.

Please tick one box in each scenario for your preferred choice between cycling and your current method

a

	Bicycle		**Current method**
Journey time (door to door)	Your estimated time	Journey time (door to door)	Same as now
Payment to cycle	No payment to cycle		
Facilities at destination	No bicycle parking or shower / changing facilities		
Route	On road, no cycle lanes		

My preferred choice would be

Bicycle ☐ or **Current method** ☐

b

	Current method		**Bicycle**
Journey time (door to door)	20 minutes longer than current	Journey time (door to door)	Your estimated time
		Payment to cycle	50p per day
		Facilities at destination	Bicycle parking provided, no shower / changing facilities
		Route	On road, no cycle lanes

My preferred choice would be

Current method ☐ or **Bicycle** ☐

c

	Bicycle		**Current method**
Journey time (door to door)	Your estimated time	Journey time (door to door)	10 minutes longer than current
Payment to cycle	£2 per day		
Facilities at destination	Bicycle parking and shower / changing facilities		
Route	On road, no cycle lanes		

My preferred choice would be

Bicycle ☐ or **Current method** ☐

d

	Current method		Bicycle
Journey time (door to door)	10 minutes longer than current	Journey time (door to door)	Your estimated time
		Payment to cycle	50p per day
		Facilities at destination	No bicycle parking or shower shower / changing facilities
		Route	On road, cycle lanes provided

My preferred choice would be

Current method ☐ or **Bicycle** ☐

e

	Bicycle		Current method
Journey time (door to door)	Your estimated time	Journey time (door to door)	Same as now
Payment to cycle	£2 per day		
Facilities at destination	Bicycle parking provided, no shower / changing facilities		
Route	On road, cycle lanes provided		

My preferred choice would be

Bicycle ☐ or **Current method** ☐

f

	Current method		Bicycle
Journey time (door to door)	20 minutes longer than current	Journey time (door to door)	Your estimated time
		Payment to cycle	No payment to cycle
		Facilities at destination	Bicycle parking and shower shower / changing facilities
		Route	On road, cycle lanes provided

My preferred choice would be

Current method ☐ or **Bicycle** ☐

g

	Current method		Bicycle
Journey time (door to door)	20 minutes longer than current	Journey time (door to door)	Your estimated time
		Payment to cycle	£2 to cycle
		Facilities at destination	No bicycle parking or shower / changing facilities
		Route	Off road, cycle lanes provided

My preferred choice would be

Current method ☐ or **Bicycle** ☐

h

	Bicycle		Current method
Journey time (door to door)	Your estimated time	Journey time (door to door)	10 minutes longer than current
Payment to cycle	No payment to cycle		
Facilities at destination	Bicycle parking provided, no shower / changing facilities		
Route	Off road, cycle lanes provided		

My preferred choice would be

Bicycle ☐ or **Current method** ☐

i

	Bicycle		Current method
Journey time (door to door)	Your estimated time	Journey time (door to door)	Same as now
Payment to cycle	50p per day		
Facilities at destination	Bicycle parking and shower / changing facilities		
Route	Off road, cycle lanes provided		

My preferred choice would be

Bicycle ☐ or **Current method** ☐

SECTION E. ATTITUDES TO TRANSPORT

27. To what extent do you agree with the following statements?
Please tick one box for each statement

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
General transport					
Congestion is a problem in Edinburgh	☐	☐	☐	☐	☐
Air pollution is a problem in Edinburgh	☐	☐	☐	☐	☐
Cycling					
More money should be spent improving on-road cycle lanes in Edinburgh	☐	☐	☐	☐	☐
More money should be spent improving off-road cycle lanes in Edinburgh	☐	☐	☐	☐	☐
Safety fears of traffic prevent me from cycling more often in Edinburgh	☐	☐	☐	☐	☐
Edinburgh is too hilly to cycle	☐	☐	☐	☐	☐
Edinburgh is too wet to cycle	☐	☐	☐	☐	☐
Walking					
More money should be spent improving pavements for pedestrians in Edinburgh	☐	☐	☐	☐	☐
Fears for my personal safety prevent me from walking more often in Edinburgh	☐	☐	☐	☐	☐
There are not enough convenient pedestrian road crossings in Edinburgh	☐	☐	☐	☐	☐
There are not enough safe pedestrian road crossings in Edinburgh	☐	☐	☐	☐	☐

SECTION F. TRAVEL CHOICES

This section is for current car drivers
If you are not the main driver of a car owned or available to your household go to Question 31

28. Assuming that the current price for petrol / diesel is approximately 80p a litre, please state how you would react to a change in the price of petrol / diesel. *Please tick one box for each price change*

Petrol / diesel price	Consider using car more often	No change	Consider what alternatives are available	Definitely use an alternative
60p a litre	☐	☐	☐	☐
£1 a litre	☐	☐	☐	☐
£2 a litre	☐	☐	☐	☐
£5 a litre	☐	☐	☐	☐
£10 a litre	☐	☐	☐	☐

29. The following statements are some of the measures that affect car use. For each one, please state how it might change **your car use.** *Please tick one box for each statement*

	Give up using car	Use car a lot less	Use car a little less	Make no difference	Use car even more
Gradually double the cost of petrol	☐	☐	☐	☐	☐
Charge motorists £2 to enter the city centre during the day	☐	☐	☐	☐	☐
Make parking penalties and restrictions much more severe	☐	☐	☐	☐	☐
Make most city routes a 20mph speed limit	☐	☐	☐	☐	☐
Improve the frequency of local buses	☐	☐	☐	☐	☐
Improve the local cycle facilities	☐	☐	☐	☐	☐

30. This question examines the travel choices you make when choosing between your car and walking for a journey.

Imagine you are making a journey from your home to a destination in and around Edinburgh. The only two methods of transport available to you are to take the car and to walk. Assume that you are travelling on your own, have nothing to carry, and the weather is dry.

Nine travel choice scenarios are presented below. They compare taking the car with walking to your destination. Each scenario lists journey time, petrol / diesel price and the cost of parking at your destination. Assume that the current price for petrol / diesel is approximately 80p a litre.

Please tick one box in each scenario for your preferred choice between taking the car and walking

a

	Walk		**Car**
Journey time (door to door)	30 minutes	Journey time (door to door)	10 minutes
		Petrol / diesel price	80p a litre
		Parking cost	Free
My preferred choice would be **Walk** ☐ or **Car** ☐			

b

Car		Walk	
Journey time (door to door)	10 minutes	Journey time (door to door)	30 minutes
Petrol / diesel price	£1 a litre		
Parking cost	£5		

My preferred choice would be

Car ☐ or **Walk** ☐

c

Walk		Car	
Journey time (door to door)	30 minutes	Journey time (door to door)	10 minutes
		Petrol / diesel price	£2 a litre
		Parking cost	£2

My preferred choice would be

Walk ☐ or **Car** ☐

d

Walk		Car	
Journey time (door to door)	20 minutes	Journey time (door to door)	10 minutes
		Petrol / diesel price	80p a litre
		Parking cost	£2

My preferred choice would be

Walk ☐ or **Car** ☐

e

Car		Walk	
Journey time (door to door)	10 minutes	Journey time (door to door)	20 minutes
Petrol / diesel price	£1 a litre		
Parking cost	Free		

My preferred choice would be

Car ☐ or **Walk** ☐

f

Car		Walk	
Journey time (door to door)	10 minutes	Journey time (door to door)	20 minutes
Petrol / diesel price	£2 a litre		
Parking cost	£5		

My preferred choice would be

Car ☐ or **Walk** ☐

g

Walk		Car	
Journey time (door to door)	15 minutes	Journey time (door to door)	10 minutes
		Petrol / diesel price	80p a litre
		Parking cost	£5

My preferred choice would be

Walk ☐ or **Car** ☐

h

Car		Walk	
Journey time (door to door)	10 minutes	Journey time (door to door)	15 minutes
Petrol / diesel price	£1 a litre		
Parking cost	£2		

My preferred choice would be

Car ☐ or **Walk** ☐

i

	Car		Walk
Journey time (door to door)	10 minutes	Journey time (door to door)	15 minutes
Petrol / diesel price	£2 a litre		
Parking cost	Free		

My preferred choice would be

Car ☐ or **Walk** ☐

SECTION G. PERSONAL INFORMATION

31. Are you? Male ☐ Female ☐

32. Please state your age band. *Please tick one box*

18-24	☐	35-44	☐	55-59	☐	65-74	☐
25-34	☐	45-54	☐	60-64	☐	75 and over	☐

33. Do you or anybody in your household have a blue badge issued by the local authority to provide parking concessions to disabled people who travel either as car drivers or passengers?

No ☐
Yes - You have a blue badge ☐
Yes - Someone else in the household has a blue badge ☐

34. How much is your household income (before tax and other deductions)? *Please tick one box*

Weekly	Monthly	Yearly	
Less than £120	Less than £500	Less than £6,000	☐
£120-£190	£500-£830	£6,000-£10,000	☐
£191-£290	£831-£1,250	£10,001 - £15,000	☐
£291-£380	£1,251-£1,670	£15,001 - £20,000	☐
£381-£580	£1,671-£2,500	£20,001-£30,000	☐
£581-£770	£2,501-£3,300	£30,001-£40,000	☐
More than £770	More than £3,300	More than £40,000	☐

35. Do you have internet access at home? Yes ☐ No ☐

36. Which of the following best describes your property? *Please tick one box*

Terraced house	☐	Detached house	☐
Semi-detached house	☐	Apartment or flat	☐

37. Which of the following types of parking are available at or outside your property?
Please tick one box for each type of parking

	Yes	No
Garage	☐	☐
Driveway	☐	☐
Free on street parking	☐	☐

38. We are interested in your comments on the questionnaire. Please feel free to write in the space below any comments you may have, including difficulties or problems with any of the questions.

____

____

THANK YOU FOR FILLING IN THE QUESTIONNAIRE

PLEASE RETURN THE QUESTIONNAIRE IN THE PRE-PAID ENVELOPE

Appendix 2. Published paper from the thesis

The following academic paper was published over the timescale of the thesis:

Ryley, T. (2001) Translating cycling policy into cycling practice. *World Transport Policy and Practice*, 7 (3), pp. 38-43.

PUBLISHED PAPER
NOT INCLUDED